Production and Domestic Use of Fuelwood on the Island of Tongatapu: A Holistic Approach to Describing Fuelwood Systems and to Developing Strategies to Ensure Future Sustainability

by

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Dip. Higher Education, B.Sc.(Hons)

in the Centre for Environmental Studies

submitted in fulfilment of the requirements for the degree of

Doctor of Philosophy

University of Tasmania

May 1991

conferred 1993

STATEMENT

This thesis contains no material which has been accepted for the award of any other higher degree or graduate diploma in any tertiary institution. To the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except when due reference is made in the text of the thesis.

Signed

L.R. King

ABSTRACT

Fuelwood is the most significant traditional fuel in developing countries, but serious shortages already exist and are expected to worsen. To achieve an adequate understanding of fuelwood problems it is necessary to be aware of the human and non-human environmental contexts. This study has developed a methodology to facilitate the comprehensive description of fuelwood systems.

A major feature of the conceptual foundation for the methodology is the aim to minimise anthropocentric bias. A holistic environmental model based on the identification of physical, biological, and cultural factors has been adopted as the basis for a thematic approach to guide the development of a research programme. The research theme, describing fuelwood systems on the island of Tongatapu in the Polynesian Kingdom of Tonga, has provided a focus for a range of information collection activities.

To assist the attainment of a realistic understanding of the significance of fuelwood to domestic activities, a series of detailed structured interviews was conducted with ninety randomly selected households in six study areas. Surveys of representative agricultural allotments yielded data on relationships between tree cover and land management systems. Valuable information was also obtained from the Tongan government, research organisations, and from the literature. Profiles of the six study areas have been based on natural, domestic, cultivated, commercial, and social systems. Various interactions of elements within these systems were examined to provide a broad comprehension of the fuelwood situation.

Fieldwork results indicate that fuelwood is used by almost all Tongatapu households. Fuelwood collection has contributed to significant detrimental impacts on natural ecosystems on common land. As quantities of wood available from such sources have declined, the proportion of households dependent on coconut wastes as fuel has grown. The households with least control over land, and thus with least secure access to fuelwood supplies, were those in peri-urban Nuku'alofa. Programmes of change are needed to regain a sustainable balance between supply and demand. To succeed, they must be well suited to local

environmental conditions. A strategy to identify and implement appropriate action should be based on decisions made by those most affected by fuelwood problems.

The holistic approach taken to the Tongatapu research could provide the foundation for studies of fuelwood systems in other developing countries. The strategy suggested for initiating improvements requires local communities to be empowered to make decisions about the management of their environments. A review of approaches to development indicates that conventional centralised and market-driven mechanisms of economic development would often impede such a strategy. Locally designed and implemented programmes of change are considered to offer the best route to gaining sustainable benefits.

DEDICATION

This thesis is dedicated to the memory of two people whose support and assistance made it possible: Richard Jones, founding Director of the Centre for Environmental Studies at the University of Tasmania, and Greg Stutzman, Tonga's first National Energy Planner.

ACKNOWLEDGEMENTS

I extend my thanks to all those who have contributed in a great variety of ways to my Ph.D. research programme.

Special recognition is due to Dr John Todd, my supervisor at the Centre for Environmental Studies, who has patiently provided such valuable advice and support despite the pressures of an extraordinary workload.

The research programme was funded by a University of Tasmania postgraduate award and University research grants. Funds from the South Pacific Bureau for Economic Cooperation (SPEC) covered the salary and travel costs of a fieldwork assistant. This financial support is gratefully acknowledged.

I am grateful to His Majesty's Government of Tonga for permission to conduct my field research. Special thanks go to the staff of the Ministry of Lands, Survey and Natural Resources, in particular to Mr Sione Tongilava, Superintendent of Lands, Survey and Natural Resources. The encouragement I received from the late Greg Stutzman, National Energy Planner, was invigorating. Others in the Ministry who made significant contributions to the research programme include Taniela Tukia, Solomone Fifita, Uilou Samani, and Tevita Amanaki Puniani. Dennis Tu'inukuafe deserves special mention not only for fulfilling the sometimes onerous tasks required of him as fieldwork assistant, but also for providing me with such valuable insights into the Tongan way of life. I also thank Paula Taufa, Te'uila Tuakoi, Toni Holani, and Kalolo Mahe for their assistance with the field research.

Contributions made by officers in other government Ministries and Departments, particularly the Ministry of Agriculture, Fisheries and Forests, the Central Planning Department, and the Statistics Department, are gratefully acknowledged. Thanks are due to all Governors, town officers, and district officers responsible for the villages in which fieldwork was conducted.

My very special gratitude is extended to all householders and others who participated in, or otherwise contributed to, the interview surveys, and to the landholders and farmers who allowed surveys of their bush allotments. The tolerance and cooperation of woodsellers at the Talamahu market in Nuku'alofa deserve special acknowledgement.

Valuable advice was given by staff of the University of the South Pacific, in particular, Dr Randy Thaman, Dr Bob Lloyd, and Professor John Morrison, all at the Laucala Bay campus in Suva, and Mr George Moengangongo and Dr Tony Marjoram at the Institute of Rural Development, 'Atele, Tongatapu.

I thank all the staff and students who have made the Centre for Environmental Studies such a special place; their support has been invaluable. David Sommerville's guidance in the use of computers, and Airlie Alam's assistance with the preparation of maps and diagrams are particularly appreciated.

TABLE OF CONTENTS

APPENDICES:

GLOSSARY

This glossary contains Tongan words and abbreviations commonly used in the text, and English terms to which particular meanings have been attached.

coconut fuels	are those coconut residues that have a fibrous, woody structure which are used as fuel in air-fed fires; they include husks, shells, frond spines, and stemwood.
crop residue fuels	consist of plant material generated as by-products of agricultural crop production; for example, cassava stems.
DBH	diameter at breast height.
fale	house or building; particularly in fale Tonga, traditional Tongan style house.
felei	dead tree branches used as a trellis to support yam vines; commonly cut from koka trees.
firewood	refers to stem and branch wood which has been prepared by drying and size reduction to a state suited to combustion in an air-fed fire; it does not include coconut fuels, unprepared wood such as living trees, or derivative fuels such as charcoal. Firewood mostly occurs as logs or split billets, but also includes wood mechanically reduced to chunks or chips.
fono	village meeting, generally called by the town officer, which all adult residents are obliged to attend.

fuelwood	includes all woody biomass whose natural structure has not been violated and which is intended to be used as fuel; it includes wood in forms ranging from living trees to split and dried billets, and coconut fuels such as husks and frond spines, but excludes crop residues and derived fuels such as charcoal.
haka	common Tongan cooking technique, boiling food in water to which coconut cream has been added.
helepelu	cane knife, or bush knife.
kili	handsaw.
m.c.w.b.	moisture content, wet basis; weight of moisture expressed as a percentage of the total weight of the wet wood.
na	not applicable.
nr	not recorded.
saliote	horse-drawn cart.
sp.	species (singular).
spp.	species (plural).
TOE	tonnes of oil equivalent.
toki	axe.
umu	earth oven; either the traditional oven dug in the ground, or the modified version which utilises a metal drum.

UNDP	United Nations Development Programme.
UNESCO	United Nations Educational, Scientific and Cultural Organization.
wood	is used specifically to refer to solid, unprocessed material from tree stems, roots, and branches, and does not include residues such as leaf stalks and nut shells.
woodfuel	means woody biomass and its derivatives in forms which are appropriate for use as fuel without further processing. This includes split and dried billets, coconut fuels, and charcoal, but excludes living plant material.
woody biomass	is a composite term to cover wood and other plant material with a fibrous, woody structure which, when dried but otherwise unprocessed, can satisfactorily be used as fuel in an air-fed fire. It includes all woody coconut fuels but excludes crop residues.

1. AN INTRODUCTION TO THE THEORETICAL APPROACH ADOPTED FOR THIS RESEARCH PROGRAMME

This thesis attempts to contribute at two levels to the solution of fuelwood[1] problems in developing countries. First, it provides information about the fuelwood situation on Tongatapu, and suggests a strategy for avoiding serious fuelwood shortages on that island. Second, the theoretical framework and methodology developed for the study of Tongatapu are proposed as appropriate for addressing fuelwood problems in other developing countries.

1.1 Introduction

> By the year 2000, some 2.4 billion rural people will be using fuelwood faster than it is being replenished (Eckholm and others 1984, p.5).

> The woodfuel supplies of hundreds of millions of people will be exhausted long before the oilfields on which the industrialised world relies have run dry (Foley and others, Undated, p.5).

> Considering all the factors, population growth, rate of deforestation, rate of establishment of new plantations it is forecast that by the year 2000 there will still be several zones in the region where fuelwood scarcities will persist or even increase (Ghosh R.C. 1984, p.14).

If predictions of this sort are valid, their fulfilment could have frightening repercussions. The wood energy crisis in the least industrialised areas was not widely recognised until the mid-1970s, and even today its significance is often not fully appreciated. The crisis exists because of a great number of inseparable factors. The scales at which these factors operate range from the household to the global, and they interact in varied and complex ways. As information about fuelwood problems has been collected, researchers have become increasingly aware that characteristics of the factors influencing fuelwood supply and use vary

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1. Three terms (fuelwood, woodfuel, and firewood) are in common usage to refer to woody biomass utilised as fuel. They are not used consistently, but rather the meanings attached to them vary between authors and according to context. The ways these terms are used in this thesis are explained in the glossary.

greatly from locality to locality. While generalisations can be made for similar societies in similar environmental conditions, site-specific factors can greatly influence the nature of the problem in a particular area. The perspective of the observer also influences the understanding gained; there are many ways of viewing the wood energy crisis, and many ways of seeking solutions to particular problems. Dire forecasts such as those quoted above tend to have been made by analysts viewing fuelwood production solely as an energy issue.

The fundamental premise behind the research programme reported in this thesis is that the fuelwood situation in any community cannot be properly assessed if only the value of the wood as an energy source is investigated. Factors essential to sustainable fuelwood production have many roles within social and environmental systems. Only when a comprehensive understanding of these roles has been gained can meaningful progress towards solutions to fuelwood problems be made. As Leach and Mearns explained in their assessment of changing attitudes to fuelwood supplies in Africa:

> The more comprehensive and objective view of woodfuels which is now emerging recognizes that there are no single, simple answers and that the problems surrounding them are inseparably linked to the complex, diverse, extremely dynamic and multi-sectoral issues underlying Africa's broader crisis of population, food, poverty, land and natural resource management. Equally, successful remedies for woodfuel problems must be firmly rooted in these broader contexts (Leach and Mearns 1988, p.3).

Attitudes towards fuelwood and its role in development vary between communities and individuals, and change over time. To provide more information on the global background to this research programme, brief reviews of approaches to development and fuelwood issues are presented in Chapter 3.

The focus of this thesis is an attempt to understand the fuelwood situation on the island of Tongatapu in the Polynesian Kingdom of Tonga. Because no research programme can collect all the data required to construct a fully comprehensive description of any situation, and because any system involving humans is constantly changing, decisions have to be made about what information is to be used to build a descriptive model. This preliminary phase in the design of research procedures needs to be based on clear aims and objectives, and also on an appreciation of the ideological stance of the researcher. Too often a Cartesian, reductionist approach is taken without consideration of how this affects decisions determining which data will be collected and how they will be collated and interpreted. The first chapter of this thesis therefore includes an exposition of the theoretical approach developed for this research programme. The conceptual framework built on the philosophical base is the central structure to which research techniques and methods of data processing are related.

1.2 Aims and objectives

The aim which initiated this research programme was:

> to make a contribution to the understanding of problems of fuel shortage in small communities in less developed countries
> (General Research Aim 1).

At an early stage it was decided that the research undertaken should not attempt to scrutinise problems in a large number of varied communities, but should focus on a few communities experiencing readily comparable environmental conditions. This decision was made for a number of reasons, chiefly:

1. in the time available, studies of a large number of communities would at best be incomplete, and at worst inaccurate or entirely inadequate;
2. because the majority of fuel used by small communities in less developed countries has traditionally been supplied from local sources, detailed knowledge of local environmental conditions would be of paramount importance to the adequate description of fuel supply problems;
3. because local solutions to fuel supply problems are considered preferable, a thorough understanding of the local situation would be required before valid attempts to overcome the problems could be made.

The importance of local factors is seen as a characteristic common to all small communities in less developed countries. It is, therefore, suggested that the experience of studying local factors in detail in a given society will yield lessons to assist similar studies in different societies. A second aim of this research programme was therefore determined:

to develop a methodology that, when suitably adapted to local conditions, could be used to guide the study of fuelwood supply and consumption systems in small communities in less developed countries (General Research Aim 2).

It was decided that while the methodology would be tailored to the needs of the current research programme, it should be constructed and described in such a way as to permit its application and testing in other locations.

In order to make comprehensive studies of communities to satisfy these general research aims, the fieldwork location had to meet a number of requirements. The island of Tongatapu in the Polynesian Kingdom of Tonga was chosen for the following reasons:

1. reports from previous energy studies on the island had predicted that serious fuelwood supply problems were likely occur in the near future;
2. its location in the south-west Pacific was convenient for travel, and gave it special relevance to Australia;
3. the Centre for Environmental Studies had an established relationship with the University of the South Pacific;
4. his Majesty's government of Tonga was prepared to support the study;
5. the island's coastline could provide a convenient definition of boundaries for some aspects of research activities;
6. from preliminary studies current socio-economic changes on Tongatapu appeared to be reasonably representative of developments in Pacific island communities in general, given that Tonga displays some unique characteristics, particularly with regard to its political regime.

Aims and objectives for the field research were established. The aims were designed to guide a field research programme which would produce results valid and useful with specific regard to Tonga while complementing the General Research Aims given above. The twin aims of the fieldwork were:

to describe systems of fuelwood supply and consumption in selected Tongatapu communities in relation to social, economic, and environmental characteristics of those communities and of the whole island (Field Research Aim 1); and

to suggest methods of improving existing fuelwood production systems, or of designing new ones, to provide sustainable supplies adequate to meet likely future fuelwood requirements (Field Research Aim 2).

Objectives to be met in order to satisfy the above aims of the field research programme were set out as follows:

1. to collate and assess information, from literature and other sources, relevant to the study of the fuelwood situation in Tonga and the design of suitable sustainable fuelwood production systems;
2. to devise suitable methods of integrative study;
3. to describe current methods of fuelwood production and supply in the study areas;
4. to obtain quantitative data on current fuelwood resources available in the study areas;
5. to evaluate current fuelwood requirements in the study areas;
6. to collate an adequate amount of information to characterise the study areas on social, economic, and environmental criteria;
7. to relate current fuelwood supply and consumption systems to social, economic, and environmental criteria;
8. to identify factors which are most likely to affect fuelwood supplies and consumption;
9. to assess the likely short-term and long-term implications of changes to the amount of fuelwood available;
10. to develop guidelines to assist in the design and selection of techniques to achieve a sustainable balance between fuelwood supply and consumption; and
11. to utilise these guidelines to suggest ways of improving the supply/consumption balance in the areas studied.

1.3 Philosophical base

Humanity is part of nature; people, and all aspects of their behaviour, are subject to natural processes. Human activities which appear to be 'unnatural' result from rearrangements of combinations of natural materials and processes in ways which have not occurred without human interference. The main difference between human-influenced ecosystems and uninfluenced ecosystems is that without the effects of human behaviour ecosystems tend towards being self-sustaining. The complex interactivity of component organisms responds to environmental changes in ways which promote the well-being of the ecosystem; negative feedback mechanisms initiate responses which tend to return the ecosystem to a state of equilibrium. However, the ability of an ecosystem to self-regulate in this way is limited; severe, naturally incurred modifications to the environment to which the ecosystem has adapted will result in significant alteration to the ecosystem. Local and short-term perturbations can result in permanent modification to the whole ecosystem through the dislocation of ecological processes. The direct impact of the initial perturbation can be compounded and extended by the results of positive feedback mechanisms. Similarly, human interference which exceeds the limits of an ecosystem's self-regulating capabilities will fundamentally alter the nature of the system. Such alteration will affect the availability of components of the ecosystem which humans perceive as resources for the production of goods and services. For this reason arguments have been presented, mainly within rich, industrialised societies, in favour of protecting natural areas from human impacts.

It is not possible to include here a detailed examination of the development and philosophies of the conservation movement, but a fundamental point regarding the perception of the natural environment must be made. To view components of natural ecosystems solely as actual or potential resources for human consumption, is both dualistic and anthropocentric. Matter is regarded to be of value only in so far as it can contribute to the satisfaction of desires of human beings. While logical arguments can be constructed on this basis to support the need for humanity to show greater respect for the natural environment, the adoption of this viewpoint is not conducive to achieving a comprehensive understanding of the environment and man's role within it. More satisfactory progress is being made in the field of deep ecology. Deep ecologists accept that convincing arguments can be made for nature conservation on the basis of future benefits to humankind, but see strongly anthropocentric values as detrimental to gaining a true understanding of the natural world. In his characterisation of levels of environmental awareness Miller (1986) recognises five conditions as being fundamental to deep ecology:

> 1. everyone and every living species is interconnected;
> 2. the role of humans is not to rule and control nature but to work with nature and selectively control relatively small parts of nature on the basis of ecological understanding;
> 3. because the living organisms on earth and their interactions are so diverse and complex that we will never fully understand them, attempts at excessive control will sooner or later backfire;
> 4. our major goal should be to preserve the ecological integrity, stability, and diversity of the life-support systems for all living organisms; and
> 5. since all living species by virtue of their existence have an inalienable right to life in their natural environments, the forces of biological evolution, not human technological control, should determine which species live or die; (Miller 1986, p.362).

These five conditions characterise an ecological view of life, but they do not offer any solution to the fundamental problem of how humans should relate to non-human species. Miller's fifth point, that the future of species should be determined by biological evolution, begs a number of important questions:

- is the development of human ability to change the environment part of biological evolution?
- are changes in human attitudes part of biological evolution?
- where humans have, in the past, used their technological control to alter natural environments do they have a duty to use technology to return those environments to a state in which biological evolutionary processes can proceed in a natural way?
- does humanity have a right to control other species in order to ensure its own continued existence?

While Miller is right to indicate that a serious ethical dilemma exists, the wording of his statement is not particularly helpful in clarifying or over-coming that dilemma, nor does it truly reflect the deep ecology approach to the dilemma. If all living species have an inalienable right to life, then the maintenance of ecosystems and the process of biological evolution depend on the infringement of rights. If this is so, then arguments for the total cessation of human impacts on other species because such interference is not 'natural' have no basis. Such an extreme could never be achieved, and is irrelevant to attempts to gain an ecological balance between humans and their environment. What is relevant is finding ways of developing sustainable relationships in which humans can follow a satisfying existence while minimising damage to non-human species and the natural processes and systems which are essential for the future of humans and non-humans alike. In exploring how such a satisfactory situation can be brought about, deep ecologists are pursuing a better understanding of how individual humans relate to their environments.

A basic premise of deep ecology holds that the natural world with which a human-being identifies becomes part of that person; that an individual's experiences contribute to the formation and development of the Self. While the extent and intensity to which the natural environment is assimilated into the Self depends on the individual's degree of identification with nature, it follows that not only is every human part of nature, but that nature is part of every human.

A more concrete illustration of how humans and their natural environment are inseparable, is to attempt to define the physical boundaries of a human body. At what stage does food become part of the body? When it passes the lips? When it is swallowed? When it is absorbed into the blood stream? And when does atmospheric oxygen qualify as contributing to the maintenance of an individual's life? When it is taken up by haemoglobin in the blood? When it enters the nostrils? Or when it is 'created' by a photosynthesizing plant? If the human body is actually a self-regulating and self-sustaining system which depends entirely on specific forms of interaction with its environment, then surely it would be meaningless to consider it in isolation. All living human-beings are integral parts of the natural environment and cannot be separate from it.

While the idea that humanity is separate from nature is nonsensical, it is valid and useful to describe the results of many human activities as artificial. This artificiality exists not because the products are constructed of unnatural materials, but because natural components have been extracted from natural systems and reorganised in ways which could not occur in nature. The production of goods and services for consumption by humans is often referred to as efficient. This illustrates the strongly anthropocentric attitude which humanity has towards natural systems. The assessment of efficiency is based on human values which ignore the roles played by resources in the natural systems from which they are extracted. If prime value were placed on the maintenance of ecosystems, then the exploitation of resources would have negative efficiency. Obviously a balance must be struck. If humanity is an integral part of nature then people are components of ecosystems which should be sustained. In situations where human exploitation of natural resources has been severely limited, or not accepted, societies have developed strategies to satisfy their needs with minimum disruption to natural processes. Most societies which have been able to exploit natural resources on a large scale, have not attempted to minimise the disruption caused. The assumption that severe impacts on the natural environment are inevitable, has been widespread. However, throughout history some, perhaps most, individuals have regretted the disturbances caused to natural phenomena. Today, it seems that most human-beings would prefer the natural environment to be unspoilt, but the majority are not prepared to sacrifice their 'modern conveniences' for the sake of maintaining natural systems which are not perceived as highly valuable.

In recent years more and more people have come to reject the anthropocentric world-view and are seeking a new ethic on which to base their relationships with the natural environment. Fenton (1987) summarises the 'new' view in the following statement:

> Every species, and individual of that species, has an <u>equal</u> right to existence as man; and a right to a natural life. (Fenton 1987, p.28).

This non-anthropocentric view is promoted not just as an ideal, but as the foundation for a more objective perception of the world. As Fenton puts it:

> If the world is viewed through the eyes of a dog, frog, scorpion, badger, seagull, buttercup, etc., as well as the eyes of man, then a more objective, more humble, less arrogant and more balanced view of the world is achieved; and habitats will be appreciated (Fenton 1987, p.28).

Adopting this non-anthropocentric stance does not mean that humans have to reject all the non-natural phenomena which make human life 'comfortable'. It does mean that a new perspective on their relationships with other components of the biosphere will lead to a new respect for nature which will allow a more comprehensive and meaningful understanding of interactions between human and non-human components of ecological systems.

The ecological approach to the search for knowledge and understanding is supported by the work of scientists such as Fritjof Capra, who, having experienced the impossibility of explaining physical phenomena in isolation, are calling for the development of a new kind of science. Capra (1983) argues that the old paradigm of reductionism, upon which physical sciences have been founded, should be replaced by a paradigm of holism. In relating this proposal to environmental science and environmentalism, O'Sullivan (1986) reiterates Capra's assertion that the paradigm shift will combine with similar trends in the arts, humanities, and social sciences. O'Sullivan goes on to claim that:

> ... this paradigm shift would then give birth to a new kind of society, in which environmental 'problems' are not so much solved, as systematically avoided, owing to the development of a new consciousness (O'Sullivan 1986, p.97).

No satisfactory philosophical basis for this '... development of a new consciousness' has been presented by any of the conventional schools of conservationist or environmental thinking. In 1981 O'Riordan was able to analyse environmentalism in terms of: ecocentrism, followed by self-reliance soft technologists, and deep environmentalists; and technocentrism, advocated by accommodators and cornucopians. While he characterised deep environmentalists by attributes which could now be applied to deep ecologists, he found that attempts to explain the ecological paradigm of the new society were comprised solely of: 'abstract writing of a fairly tedious kind'. He also claimed that:

> ... none of the authors disposes satisfactorily of the current paradigms, which preach man-dominance and hence man-exemption from ecological restrictions, which still permeate all social science disciplines. More to the point, they do not provide either a coherent or a convincing picture of what an ecological paradigm would be like and what kind of 'Utopia' it would create (O'Riordan 1981, p.380).

Since 1981 much work has been done in the field of deep ecology to develop it into an integrated body of thought. Fox (1986) summarised the deep ecology approach as follows.

> ... the deep ecological framework of discourse could be said to proceed from two basic hypotheses and one ultimate norm. The hypotheses are (i) that "The self is as comprehensive as the totality of our identifications. Or, more succinctly: Our Self is that with which we identify" (Naess 1985) i.e. one's Self is not limited by the boundaries of one's skin but by the boundaries of one's identifications e.g. when someone we love dies a part of our Self dies; and (ii) that the self can and does grow/develop/mature (i.e. widen its sphere and intensity of identifications over time). The norm is that the ideal state of being is one that sustains the widest (and deepest) possible <u>identification</u> and, hence, sense of Self. ... this ideal state of being is referred to as "Self-realization" by Naess and as "ecological consciousness" by Devall and Sessions, and its cultivation - effectively a spiritual discipline - is considered to be the "real work" of deep ecology (Fox 1986, pp.86-87).

Perhaps this 'ecological consciousness' is synonymous with what Capra and O'Sullivan referred to as the 'new consciousness' which, in the 'new kind of society' will promote the systematic avoidance of environmental 'problems' (O'Sullivan 1986).

The 'ideal state of being' would appear to be a potentially valuable standard for assessing the degree to which people identify with nature. There are however obvious difficulties in carrying this out. The first problem would be to obtain an adequate and applicable definition of the ideal state of being. Then a method of assessing an individual's or group's closeness to this ideal would have to be formulated. While a theoretical ideal state could perhaps be claimed to be universally valid, pragmatic attempts to evaluate degrees of identification would have to cope with not only varied physical relations between humans and non-human phenomena, but also different perceptions of the natural environment and of human-environment interactions. While investigation of methods to assess levels of ecological consciousness is beyond the scope of this thesis, two points fundamental to the philosophical stance being adopted emerge from this discussion. First, as suggested by O'Sullivan (1986), human activity founded on ecological consciousness is less likely to cause environmental problems. It is believed that a decrease in environmental problems can frequently be correlated to an improvement in human well-being. Second, perceptions of well-being vary with varying aspects of the physical, biological, and cultural environment; an understanding of local conditions will, therefore, be essential to achieving a worthwhile evaluation of identification with nature.

The philosophical base adopted here requires that a holistic, non-anthropocentric approach be taken in order to achieve a more objective perspective. In order to establish a foundation on which to develop minimum disruption strategies for human interactions with non-human phenomena, two aspects of the relationship between humanity and nature must be recognised:

(i) humans are integral components of ecological systems;

(ii) humans must accept responsibility for sustaining natural processes and systems, irrespective of whether they can foresee direct advantages for humankind.

This then is the crux of the approach to this study: that in order to promote the well-being of humans and non-human phenomena, all of which have rights to exists, humans' interactions with their environment should cause the minimum of adverse effects on ecological systems. Possession of power to alter or destroy natural processes and phenomena does not give humanity the right to exercise that power, rather, it increases the responsibility of humans to ensure that ecological systems are not adversely affected by unwarranted exploitation.

1.4 The development of a conceptual framework

The philosophical base for this study requires that investigations, data collation, and the evaluation of results be carried out on somewhat unconventional lines. This has necessitated the formulation of a novel framework. However, this sort of approach is not without precedent; many researchers attempting to overcome the restrictions and inadequacies of reductionist science have, in recent years, developed more holistic approaches to scientific investigation. By critically evaluating the approaches to research which appear to come closest to satisfying the requirements of this study, a basis for developing an appropriate conceptual framework to guide this research programme has been achieved. This section outlines the development of this conceptual framework.

The recognition that natural phenomena are all interrelated by flows of energy, matter, and information, led scientists to move towards systems analysis as a means of improving understanding about ecosystems. Jeffers (1978) defined systems analysis as:

> ... a broad research strategy that certainly involves the use of mathematical techniques and concepts, but in a systematic, scientific approach to the solution of complex problems. As such, it provides a framework of thought designed to help decision-makers to choose a desirable course of action, or to predict the outcome of one or more courses of action that seem desirable to those who have to make decisions (Jeffers 1978, p.1).

The prospect of attaining a framework which would be of assistance not only to the design of research techniques, but also to the making of significant practical decisions was particularly attractive in the context of this programme. Jeffers outlined the following stages in systems analysis:

(i) recognition of the existence of a problem, or interconnected problems;
(ii) definition and bounding of the extent of the problem;
(iii) identification of the hierarchy of goals and objectives;
(iv) generation of solutions;
(v) modelling;

(vi) evaluation of potential courses of action;
(vii) implementation of the results (Jeffers 1978, pp.2-5).

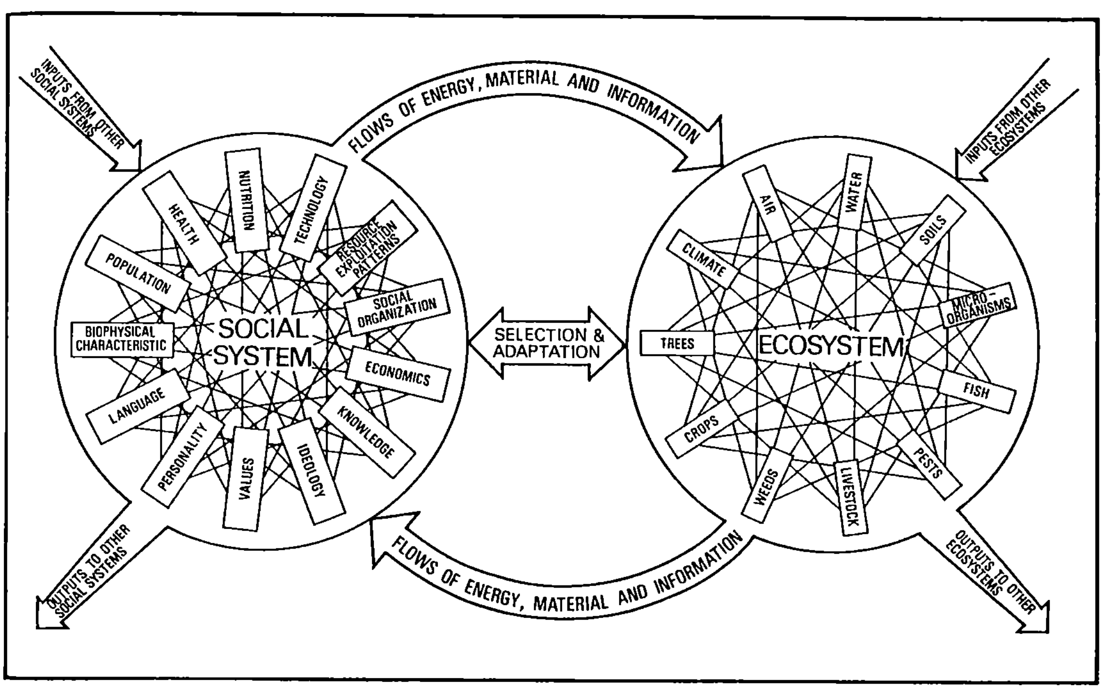
While this introduction to the concept of systems analysis was useful, in that it outlined a methodical approach to problem-solving research, a number of difficulties were apparent regarding the possible application of conventional systems analysis to this research programme. For the researcher to gather all the data necessary to construct a comprehensive mathematical systems model for the area being studied would not be possible in the time available. The nature of the problem being addressed was such that precise boundaries to envelop all aspects of the problem could not readily be drawn. From an initial assessment of the situation following preliminary fieldwork it was clear that the problem could not be confined within a single clearly defined ecosystem or social system; the main characteristic of the problem was that it was rooted in both natural and human environments. The ecological applications on which Jeffers focused did not provide a useful general model for the examination of man's interactions with, and roles in, the natural environment.

A conceptual approach to the study of human interactions with the 'natural' environment, which has been adopted in many disciplines, is human ecology. Young's (1974) comprehensive review of the development of human ecology identified strands of its evolution in biology, sociology, anthropology, geography, and other social and applied disciplines. This has occurred because human ecology is not itself a discipline but 'a scope or way of seeing' (Shepard 1969). Young claimed that little real headway had been made to make human ecology an interdisciplinary field of study. He found that despite sharing similar concepts, scholars tended to rely on developments in the application of human ecology to their own disciplines, and rarely referred to, or apparently knew of, parallel work in other disciplines. Perhaps the most serious result of this lack of interdisciplinarity was that the assumptions underlying adopted methodologies had not been thoroughly scrutinised; the ecosystem concept and systems theory had been transferred from plant and animal ecology without adaptation. Other major problems perceived by Young included confusion over terminology, a lack of understanding of ecological concepts, and the difficulty of dealing with the apparent dichotomy of the biological and cultural aspects of humanity. While the thorough integration of disciplinary strands of human ecology has not yet been achieved, some of the research methods designed and utilised by human ecologists were relevant to the development of a conceptual approach to this study.

Rambo (1982) produced a conceptual model to guide his study of tropical agroecosystems in southeast Asia (Figure 1.1). This model incorporates flows of energy, material, and information between social systems and ecosystems, and indicates that components of social systems are all interrelated, as are components of ecosystems. However, it has one major failing which disqualifies its use in this study. The model represents a dualistic view of the environment; its separation of the social system from the ecosystem falls short of the holistic approach which

FIGURE 1.1

Conceptual model of social system - agrosystem interactions, proposed by Rambo



Source: Rambo 1982, p.91

Rambo says is presently beyond the capabilities of human ecology research in the region in which he is working. While the collection and analysis of adequate data to fully describe all components and interactions of a total system is clearly a massive, and usually impossible, task, this should not preclude the adoption of a holistic conceptual model to guide research about aspects of the total system.

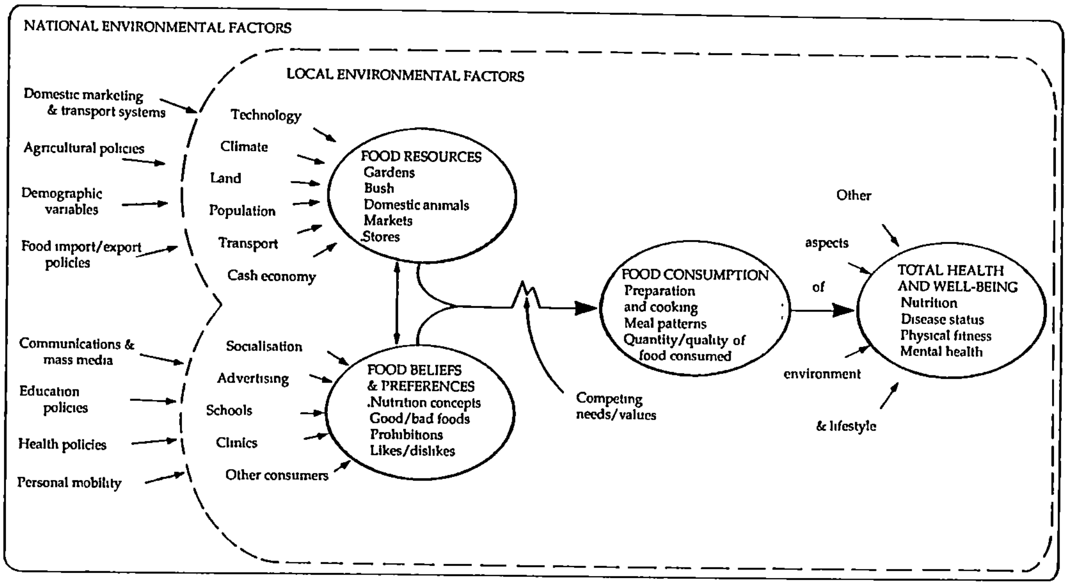
Other human ecologists have come closer to developing useful holistic models. Boyden and Millar (1978) developed a series of three conceptual models which indicate, in increasing degrees of detail, relationships between the 'total environment' and the 'human experience'. Further study of how their characterisation of relationships between environment and quality of life compares with the deep ecology concept of identification would undoubtedly be very valuable. However, these models are not adequate to represent the relationships between natural and human environmental systems which are the focus of the current study. Newcombe and Pohai (1981) used a conceptual model to guide a study which was much closer to the present research (Figure 1.2). The factors identified as significant in this analysis of food habits were related to national and local environments. This model thereby clearly indicates that systems exist on a number of spatial levels, and that inputs from larger systems to smaller systems are significant from the national environment down to the individual. While Newcombe and Pohai largely avoided the overt dualism displayed by Rambo's model, their approach is still strongly anthropocentric, focusing directly on the health and well-being of humans.

Boyden's development of human-environment models was related to his work with the Man and the Biosphere (MAB) programme; some aspects of the Man and the Biosphere conceptual approach are relevant to the present study. The programme began in 1971, sponsored by the United Nations Educational, Scientific and Cultural Organisation (UNESCO), with the objective of encouraging research on environmental problems (di Castri, Hadley, and Damlamian 1981), or more specifically:

> to develop the basis within the natural and social sciences for the rational use and conservation of the resources of the biosphere and for the improvement of the global relationship between man and the environment (UNESCO 1972, p.6).

FIGURE 1.2

A conceptual model for the analysis of food habits in a localised population, proposed by Newcombe and Pohai



Source: Newcombe and Pohai 1981, p.75

Having grown out of the research experiences of the International Biological Programme, the Man and the Biosphere programme initially adopted the ecosystem as its fundamental research unit. Studies of natural ecosystems were to be complemented by studies of socio-economic processes and of the inter-relationships between natural and human systems (UNESCO 1972). This approach to seeking solutions to human environment problems was found to be inadequate, largely because of disparities between the boundaries of human and natural systems. Also, patterns of human use of the biosphere necessitated study of relationships between ecosystems. Human use systems, which were defined as 'organisations through and by which resources are managed' (UNESCO 1974, p.10), were therefore established as research units. These systems were based on spatial units ranging in size and composition from the household and community to the nation state and multinational corporation (UNESCO 1974; di Castri, Hadley, and Damlamian 1981). Three dimensions were to be accommodated by the human use system approach: time, space, and perception; these were said to be essential dimensions of integrated, problem-oriented research (di Castri, Hadley, and Damlamian 1981).

Within the Man and the Biosphere programme individual projects were tackled in different ways. For Project 11, entitled 'Ecological aspects of urban systems with particular emphasis on energy utilisation', considerable effort was put into the development of an 'ecological, integrated and holistic approach' (UNESCO 1976). The ecological approach was based on the direct comparability between human settlements as 'habitat systems' for human populations, and 'natural' ecosystems; the major difference being that culture is a dominant feature of human settlement ecological systems.

The 'human use system' approach was deemed to be unsuitable for this study for two important reasons:

(i) it does not overcome the dichotomy between human culture and human biological roles in the 'natural' environment;

(ii) the approach is anthropocentric in that non-human systems and components are viewed only in terms of their use to humanity.

Brookfield (1982) rejects human ecology because it does not provide a framework for integrative studies, and discards the human-use system because although it can help to improve understanding of how human societies manage resources it is not able to incorporate the activities of humans into the study of ecosystems. Brookfield sees the values underlying conventional social science as a stumbling block. While social scientists are interested only in the transformation of social systems and human exploitation of natural resources, they cannot adequately deal with continuity. This point is vitally important because it illustrates the fundamental difference between human systems and non-human systems: the former are based on transformation, the latter on continuity. If humans are to come to terms with their relationships with the non-human world then methods of study and interpretation which can explain and predict the outcome of continuity as well as of change must be utilised.

An alternative to conventional approaches to research was investigated by Vayda (1983) when he looked at progressive contextualization as a method for research in human ecology. This approach allows adherence to the holistic overview, while focusing attention on particular problems. It differs from systems analysis in that it does not define boundaries to the complexes of interacting causes and effects which are to be studied. Instead, research begins with an examination of specific activities. Causes and effects are then traced in whichever direction is necessary; in theory, the study is not limited by ecological, geographical, or political boundaries. Vayda (1983) makes a case for each of the following five advantages of this approach.

1. It resolves the difficulties of establishing appropriate research units, by not needing such units.
2. The problematic need to make assumptions about the stability of systems is similarly avoided. Actions and interactions are put into context within complexes of causes and effects, but the permanence of such complexes does not necessarily have to be assumed.
3. Progressive contextualization allows greater latitude in the allocation of time, effort, and money for research. While a full understanding of the total context will probably never be achieved, the size of the partial context studied can be determined according to the research resources available.
4. The results of discipline-oriented studies are often not easily communicable to policy-makers. In contrast, the focus of interdisciplinary progressive contextualization can be located where it will be of greatest practical benefit and interest.
5. Unlike conventional systems and neofunctional approaches to research, progressive contextualization can deal with 'unstable and transitory phenomena as well as stable and persistent ones'. Because it can be used to study processes, Vayda believes 'its use can lead to a better-balanced view of life and the world'. He claims that this implies a possible theoretical significance of progressive contextualization which supports his call for its wider adoption for research in human ecology.

This approach held considerable appeal for this research programme for a number of reasons, but problems were also seen. The basic concept of progressive contextualization appears to be structured on a formalisation and encouragement of the alternation between induction and deduction which inevitably occurs in any research. The flexibility allowed by this approach would be valuable while tracing causes and effects related to specific activities, but would be inappropriate when attempting to concisely describe general environmental conditions. Also, it takes an experienced actor to ad lib through an entire performance; for a relatively inexperienced researcher, predetermined guidelines, in the form of a structured fieldwork plan, were considered necessary to maintain a continuity of useful fieldwork throughout the limited time available.

The development of conceptual models to guide the research for this study was founded in the philosophical base and conceptual approach described above. This task involved designing a framework to clarify the relationships between different parts of the field research, and to provide a foundation on which to build an understanding of the systems being studied. Three basic characteristics of systems involving human and non-human components were recognised:

(i) all systems which include human activity involve interactions between physical, biological, and cultural components;

(ii) conceptual system models can be constructed at various spatial and temporal levels;

(iii) to attain a total comprehension of all factors relevant to a given system would require data adequate to fully describe all related systems at greater and lesser levels.

The implications of these characteristics were investigated by reference to the aims and objectives of the study, and the constraints affecting the research programme. The focus of field research was to be the single island of Tongatapu, but limited time and resources precluded the possibility of studying in detail all aspects of fuelwood production and use over the whole island. The decision to concentrate on six study areas effectively defined the spatial levels at which fieldwork results would be significant. However, the field research programme was designed in such a way as to allow at least the possibility of extrapolation of results to a larger spatial level. Even at the spatial level selected for detailed field investigations it would not be possible to collect all the data required to fully describe entire systems.

A thematic approach was therefore developed to provide a consistent focus for the research. This approach consists of four main stages:

1. the statement and definition of the theme;
2. an adequate characterisation of local and regional environments;
3. a description of relevant factors within and acting on local systems in the study areas;
4. description and discussion of the nature and impacts of factors acting on the theme.

On adopting this thematic approach the first task was to state the theme. This was fulfilled by reference to the aims and objectives presented in Section 1.2 above. The core theme was Field Research Aim 1: to describe systems of fuelwood supply and consumption in selected Tongatapu communities. One of the main reasons for describing the fuelwood systems was to facilitate the achievement of Field Research Aim 2: to suggest methods of improving existing fuelwood production systems, or of designing new ones, to provide sustainable supplies adequate to meet likely future fuelwood requirements. While meeting this aim was dependent upon the realisation of the first aim, in terms of the practical value of the research it held significance at least equal to Field Research Aim 1. The central theme for the Tongatapu research thus had two phases: first the descriptive phase, to attain as comprehensive an understanding as possible of the existing situation; and second the creative phase, in which analysis and evaluation of existing problems and potential remedies would lead to the presentation of a strategy or strategies for gaining sustainable improvements. The requirements of the second, creative, phase were important considerations in shaping the objectives which guided the research for the first, descriptive, phase.

The task of the second phase, to generate strategies to overcome local fuelwood problems, would require careful consideration of local and regional environmental conditions. This information would be made available by the research conducted in the first phase of the thematic approach. Additionally, information about possible techniques for achieving adequate and sustainable supplies of fuelwood would be an essential input. To develop viable, practical solutions to particular fuelwood problems would require a long process of evaluating local conditions and the suitability of technical options likely to bring about improvements. For this process to be successful it must involve, and ideally be instigated by, the local people. The best a study such as this one can achieve is to suggest ways in which procedures to seek solutions might be devised.

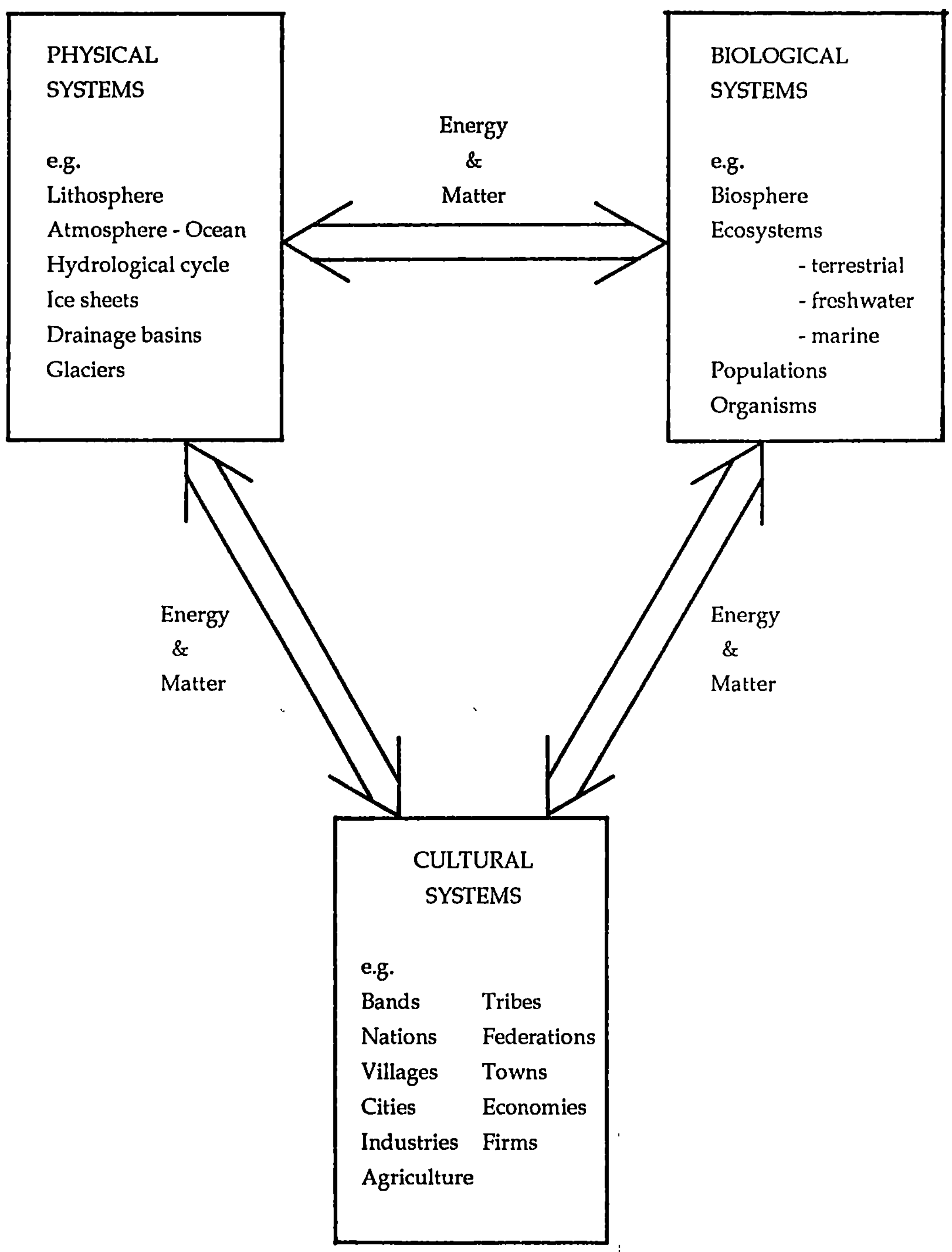
Once the initial step in the first phase had been completed and the theme for the investigation had been adequately defined, the next stage was to collate information to characterise the local and regional environments. A prerequisite to performing such characterisations was the adoption of an adequate definition of the term 'environment'. According to the Collins dictionary, environment means 'external conditions or surroundings' or, as an ecological term, 'the external surroundings in which a plant or animal lives, which influences its development and behaviour' (McLeod 1987). This suggests that the word is thus most meaningful when related to a living organism. For the purposes of this research programme the term is taken to be equally applicable to non-living entities, and to levels of existence broader than the individual. For example, if the focus of a particular study is a village, the external surroundings influencing that village's state or function can be referred to as its environment.

O'Sullivan (1980) has provided a useful conceptual model of the environment without specifying the requirement for it to be related to any given entity. In this sense the term encompasses all physical, biological, and cultural systems, and the interactions between them brought about by transfers of energy and matter (Figure 1.3). The labels given to the three categories are provided as convenient tags to identify those systems which predominantly exhibit physical, biological, and cultural characteristics. 'Cultural' is taken to include 'the attributes of human societies normally separated into economic, sociological, political etc.' (O'Sullivan 1980, p. 191). The cultural grouping includes systems which although fundamentally physical or biological in nature depend on cultural factors to maintain their distinctive attributes. Highways, canalised rivers, and agricultural fields are given as examples of such systems. The physical systems contain all parts of this planet's environment which theoretically could operate independently of organic life, and the biological category is composed of all self-maintaining organic systems. O'Sullivan is thus modelling in a very concise manner the whole worldwide environment.

Two modifications to O'Sullivan's global model were necessary for it to become a useful tool for the research focused on Tongatapu. First, the all-encompassing

FIGURE 1.3

Conceptual model of the environment
(after O'Sullivan 1980)



scale was inappropriate and had to be made flexible so that it could apply at local and regional levels. Second, the focus on systems as the entities to be categorised was considered inappropriate to the model's role in this research programme. Instead, the interacting units examined in the model used here are described as physical, biological, and cultural factors and components. This does not preclude the consideration of systems as elements of the environment but gives greater flexibility in terms of the external influences taken into account.

It is necessary to be aware of the distinction between the two ways that the word environment is used, and in some instances the precise meaning will have to be specified. Where the meaning is of an environment focused on but external to a particular entity the term 'external environment' will be used. Where no particular focus is required, or where the focal object is included, the term 'inclusive environment' will be employed.

The research required to satisfy stage two of the thematic approach was based on the amended version of O'Sullivan's model, as included in the diagrammatic representation of the thematic approach in Figure 1.4. This segment of the research was required to describe components of local and regional environments which had an influence on the theme, that is, on fuelwood supply and consumption systems in Tongatapu communities. The physical, biological, and cultural factors identified are described in Chapter 2. These factors had varying degrees of influence on Tongatapu's fuelwood systems. Factors with only indirect or marginal impacts have been included for a number of reasons. Holistic study regards environmental systems as indivisible wholes, and thus requires investigation and description of components of any system to be comprehensive. In relation to the thematic approach used here, a broad awareness of the study area's inclusive and external environments is required if the full range of factors affecting the theme are to be assessed. Greatest attention is obviously paid to factors having the most significant influence on the theme. The lesser significance of more remote influences can be conceptually modelled as a series of concentric shells, increasing in volume as they become more distant from the focus. Figure 1.5 shows such a model focusing on an individual household, with examples of influences allocated to three shells.

FIGURE 1.4

A diagrammatic representation of a thematic approach to environmental research

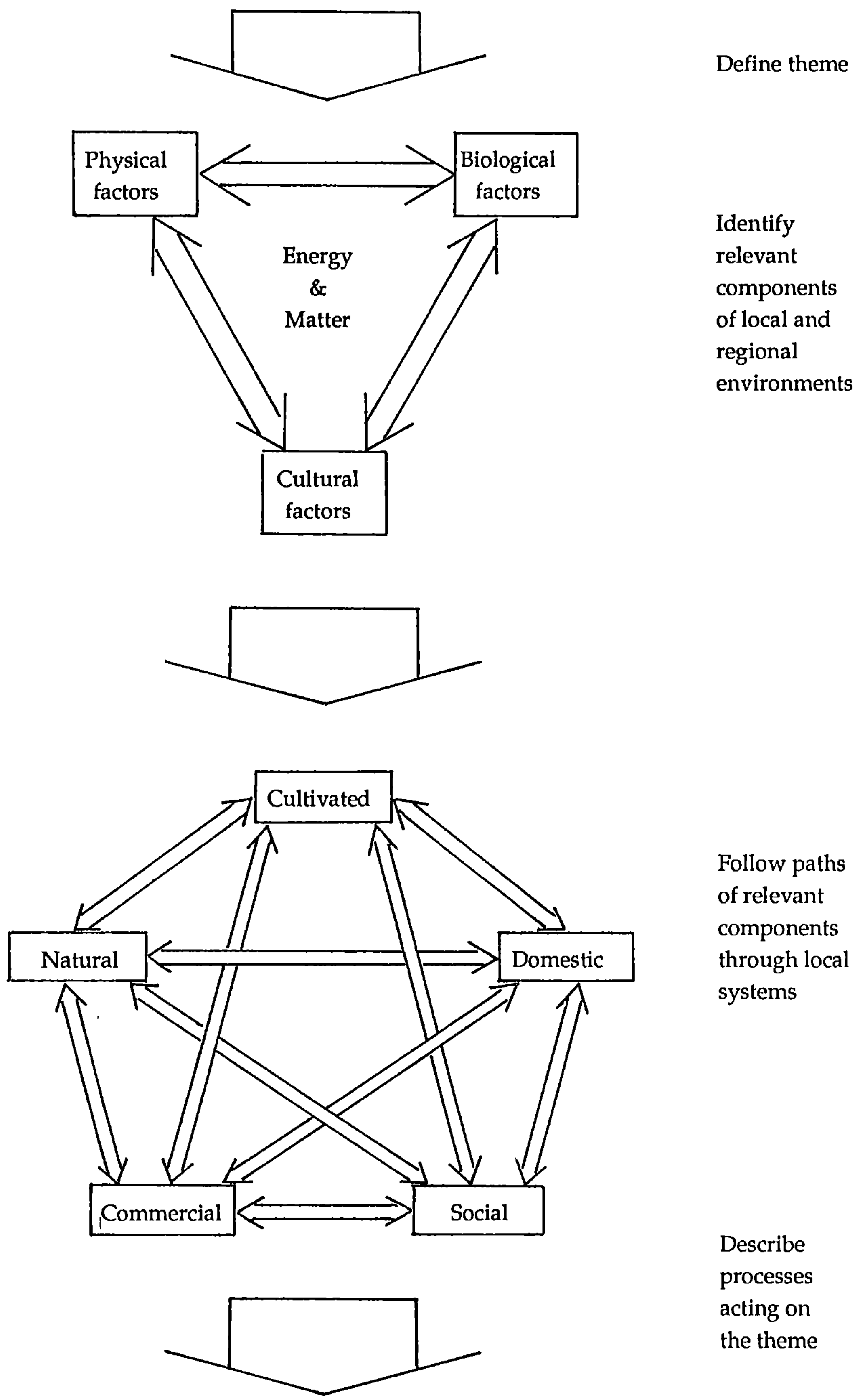
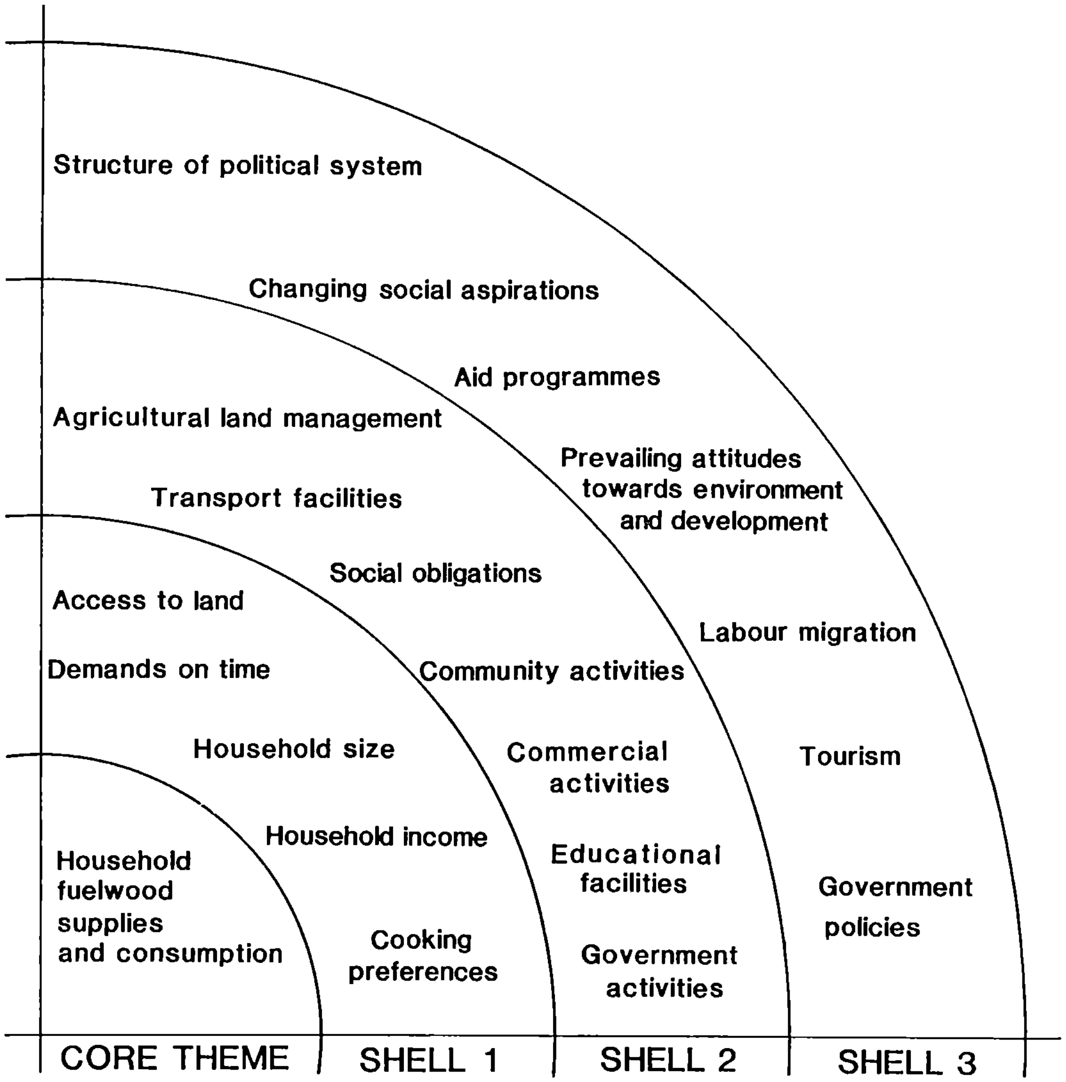


FIGURE 1.5

Example of a model of concentric 'shells' of information having decreasing direct relevance to a core theme



With regard to the Tongatapu research, the inclusion in Chapters 2 and 5 of a broad range of the information collected also serves two particular purposes. The reader is provided with a profile of Tongatapu society as an essential background to consideration of fuelwood issues, and the broad account of social and environmental conditions on Tongatapu at the time of the field research is recorded as a source for future reference.

Having completed stages 1 and 2 of the thematic approach: defining the theme and describing the broad environmental context, the next task, stage 3, was to examine in some detail those aspects of local systems which had particular influence on the theme. The field research techniques utilised to collect information in six study areas on Tongatapu are described in Chapter 4. The model adopted to guide the investigations of these local systems recognised five types of system within a study area's inclusive environment. These were distinguished as being dominated by natural, domestic, cultivated, commercial, and social characteristics (Figure 1.4). Each type of system exists at a variety of spatial levels (Table 1.1), and they all include physical, biological, and cultural components. Adequate data have been collated to characterise these systems at relevant spatial levels, but not to fully describe them. Material collated on relevant aspects of each of these systems is used in Chapter 5 to build profiles of the six study areas. Included in each profile is a sixth component concisely relating activities directly involved in the supply and consumption of fuelwood. The final stage of the first phase of research was the discussion of the material gathered for the individual study areas to present an overall description of the critical processes acting on the research theme. This is included in Chapter 6.

With the requirements of the first, descriptive, phase of the research theme fulfilled, the second, creative, phase could be tackled. This task, of developing a strategy to bring about improvements in the fuelwood situation on Tongatapu, utilised, and built on, the understanding of the Tongatapu fuelwood situation gained in the descriptive phase of the research. Consideration of options for such a strategy was assisted by information about attempts to reduce fuelwood shortages in other countries. The strategy developed is discussed in Chapter 6, Section 6.5.

TABLE 1.1

Levels of operation at which natural, cultivated, domestic, commercial, and social systems operate and can conveniently be studied

Natural systems	Cultivated systems	Domestic systems
Organism	Organism	Individual
Community	Community	Household
Local ecosystem	Allotment/farm	Village
Island ecosystem	Local agro-ecosystem	Local district
Regional ecosystem	Island agro-ecosystem	Island community
Global ecosystem	Regional system	Nation
	Global system	Region
		Globe

Commercial systems	Social systems
Firm or enterprise	Household
Village	Extended family
Market	Village community
Local district	District community
Island	Island community
Nation state	Nation
Region	Region
Global system	Humanity

Having used the thematic approach to investigate and describe the fuelwood situation on Tongatapu, the achievement of the General Research Aims required an evaluation of the methodology to assess its potential value to fuelwood research in other developing countries. This critique, provided in Chapter 7, reviews the success of the research in the Tongan context, then draws on Chapter 3's review of approaches to development and fuelwood issues to suggest how the methodology might best be applied in other situations.

The major tasks undertaken in this research programme, the main inputs used to complete those tasks, and the resultant thesis components are represented diagrammatically in Figure 1.6. This figure is included as a guide to relationships of sections of the thesis with one another and with external sources of information. The four tasks proceed sequentially. Tasks 1 and 2 were essential prerequisites of task 3, the research focused on Tongatapu. This set of research activities required the greatest commitment of resources, and, as indicated in the diagram, resulted in the largest contribution of components included in the thesis. Two thesis chapters, 3 and 4, are located in the 'Inputs' section of the diagram as their main purpose is one of support to the central components.

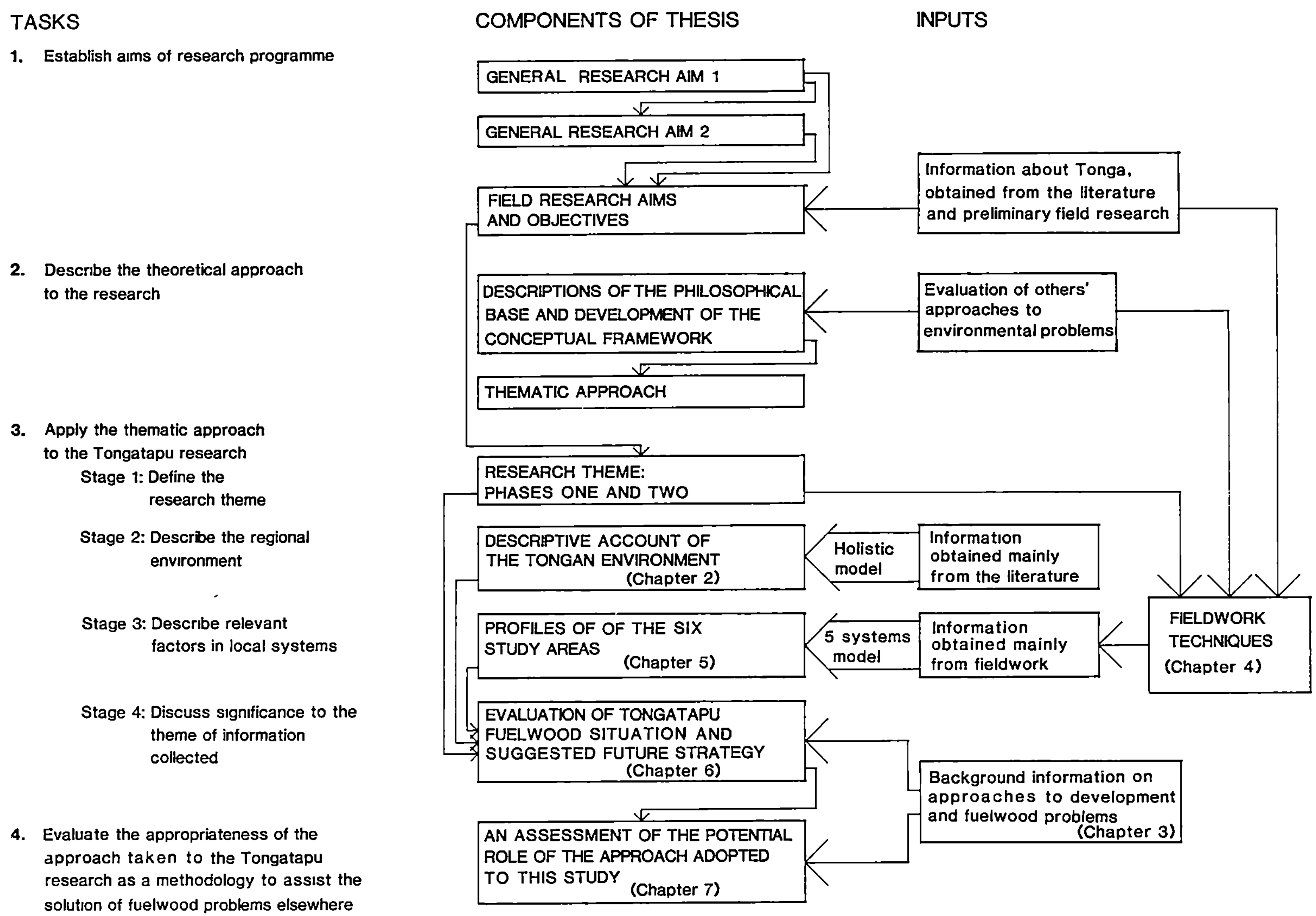


FIGURE 1.6

Diagrammatic representation of the relationships between components of this thesis with the tasks and inputs which generated them

2. A DESCRIPTIVE ACCOUNT OF THE ENVIRONMENT IN WHICH FUELWOOD IS PRODUCED AND CONSUMED IN THE KINGDOM OF TONGA

2.1 Introduction

The material presented in this chapter has been collated to provide a broad description of the environmental conditions in which fuelwood is produced and consumed in Tonga. To address the requirements of stage two of the thematic approach described in Chapter 1 the information is organised to cover aspects of the physical, biological, and cultural characteristics of the Tongan environment. This account does not attempt to provide full details of any particular feature of the environment, but rather brings together information about as broad a range of factors as possible. The role of this chapter can thus be stated as providing a perspective on the information which inhabits the outer shells of the model illustrated in Figure 1.5.

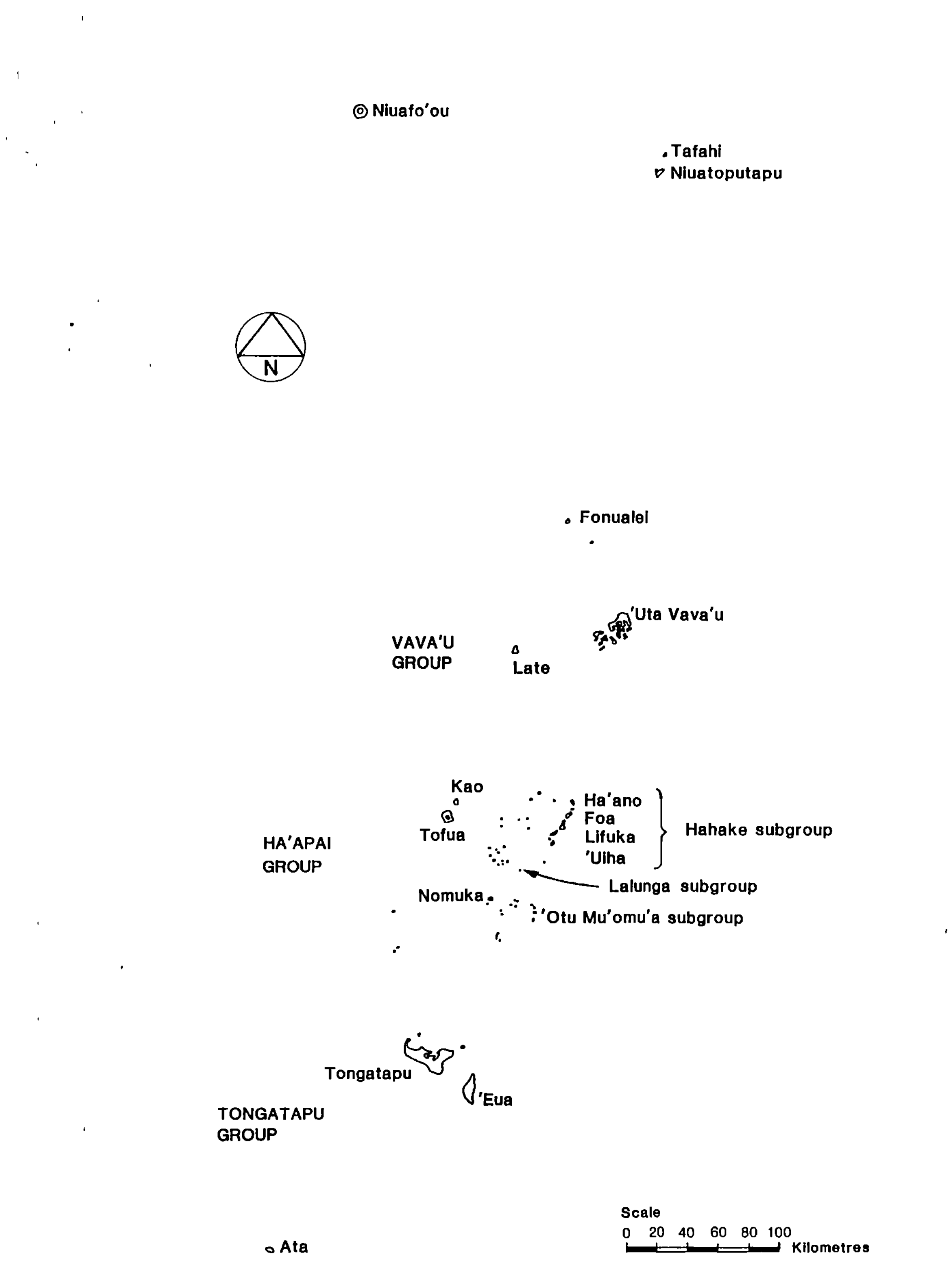
2.2 Physical characteristics

2.2.1 Location, geology, and physiography

Tonga is located in western Polynesia in the South Pacific, between latitudes 15 and 23.5 degrees south, and longitudes 173 and 177 degrees west. Within a territorial area of some 360 000 square kilometres, the Kingdom's 171 islands provide approximately 747 square kilometres of land (Tonga, Central Planning Department 1981; Tonga, Government of, Undated). The majority of these islands are included in the three main groups: Tongatapu, Ha'apai, and Vava'u. The main out-lying islands are Niuatoputapu and Niuafo'ou, which lie 290 kilometres north and 370 kilometres north-north-west of Vava'u respectively, and 'Ata, which is situated some 160 kilometres south-west of Tongatapu (Figure 2.1). Niuafo'ou is a young volcanic island on a small submarine ridge in the Lau basin, with the rim of its caldera some 260 metres above sea level (Schofield 1967; Kaplin 1981; Crane 1979). With this exception, all the Tongan islands sit on the Tongan Ridge at the eastern edge of the Australasian tectonic plate (Melson, Jarosewich, and Lundquist 1970). Following the eastern edge of this plate, the Tonga Trench runs from north-north-east to south-south-west, plunging at its deepest to more than

FIGURE 2.1

Map of Tonga showing relative locations of the island groups



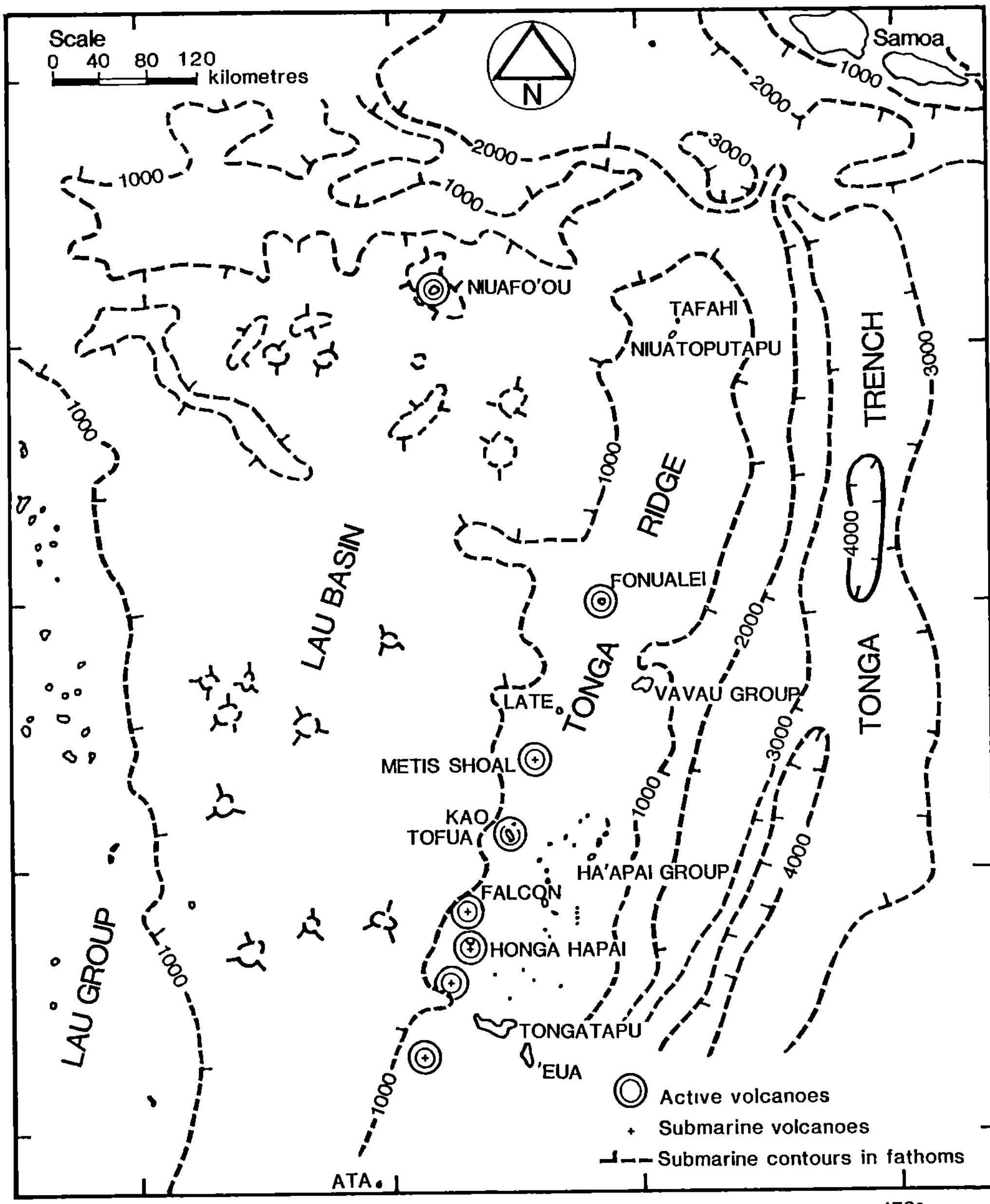
10 kilometres below sea-level (Crane 1979). The Trench indicates the descent of the Pacific Ocean Plate below the Australasian Plate; it is this subduction which has caused the tilting of islands on the Tongan Ridge (Wilson and Beecroft 1983; Schofield 1967), and which has been advanced as an explanation of the earthquake Tonga experienced in 1977 (Crane 1979).

The islands on the Tongan Ridge are arranged in two rows, parallel to the Trench (Figure 2.2). The western line, from Tafahi to 'Ata, consists of geologically recent volcanic islands (Orbell and others 1985); of the ten which are deemed volcanically active, only Fonualei, Late, and Tofua remain above sea-level (Melson, Jarosewich, and Lundquist 1970). Niuatoputapu, the largest of the inactive volcanic islands on this western line, has an area of almost 16 square kilometres, and rises to 107 metres at the summit of its central hill (Wood 1943; Crane 1979). Nearby Tafahi is an extinct volcanic cone, with the highest point on its rim 610 metres above sea level (Crane 1979; Wood 1943). These islands occupy the northern end of a region which has been described as one of the world's most active seismic belts (Isacks, Sykes, and Oliver 1969). The line of volcanic activity extends through the Kermadec Islands to the North Island of New Zealand. There are no active volcanoes in the eastern row of Tonga's islands which are built of Tertiary to Recent volcanic sediments and reef deposits (Orbell and others 1985). These islands range in elevation from sea-level to more than three hundred metres above sea level.

The most northerly of the main Groups of islands is dominated by 'Uta Vava'u (Vava'u island) which rises in a series of three distinct coral limestone terraces to 213 metres above sea level. The island's area of 90 square kilometres includes arms which extend southwards towards a cluster of about forty islands ranging in size from a few hectares to 9 square kilometres. The main island displays the greatest relief of any of the coral limestone islands in this Group. With the exception of a few western islands, such as Hunga, which are edged by precipitous coral cliffs, other islands have only limited areas of steep and hilly land (Orbell and others 1985). The sea channels approaching 'Uta Vava'u from the south are celebrated for their splendid, fjord-like scenery and the protection they afford vessels in bad weather. The western, volcanic, islands in this Group include Late and Fonualei, which are situated approximately 70 kilometres west-south-west, and 70 kilometres north-west of 'Uta Vava'u respectively. The volatility of this region

FIGURE 2.2

Map of Tonga showing active volcanoes and submarine contours



Source: Schofield 1967, p.1425

was illustrated about twenty years ago by the volcanic eruption at Metis Shoal (south of Late) in 1967-1968 (Melson, Jarosewich, and Lundquist 1970).

The western boundary of the middle Group of Tongan islands, Ha'apai, is dramatically defined by the volcanic islands of Tofua and Kao, the latter presenting a perfect volcanic cone which rises to 1109 metres, the highest peak in Tonga (Swaney 1990). Tofua, by far the largest of Ha'apai's islands, has a total area of 55 square kilometres. The rim of this active volcano's caldera rises to 506 metres, and encloses a lake estimated by Crane (1979) to be 6 kilometres wide. Seventy kilometres to the east, the main islands of the Hahake (Eastern, or Ha'apai) sub-group: Ha'ano, Foa, Lifuka, and 'Uiha, extend in a chain from the north-north-east to the south-south-west. Wilson and Beecroft (1983) identified the uplifting of the eastern coasts of these raised limestone islands as evidence of tectonic tilting. The greater part of each of these islands, except Foa, is less than 10 metres above sea level, with large areas below 5 metres. Even on Foa, at 13 square kilometres the largest in the chain, the highest point is just 20 metres above sea level. As well as raised limestone islands, the eastern islands of the Ha'apai Group include raised volcanic islands, and sand cays which consist of low coral limestone platforms overlain by coral sands (Wilson and Beecroft 1983). The largest sand cay, Uoleva, lies in the Hahake sub-group between Lifuka and 'Uiha.

The Ha'apai Group covers an extensive sea area, and as well as the western volcanic islands and the Hahake sub-group referred to above, includes the Lulunga (Western, or Kotu) and the 'Otu Mu'omu'a (Southern, or Nomuka) sub-groups. The Lulunga sub-group is situated south-west of Lifuka, and north of the 'Otu Mu'omu'a sub-group (Figure 2.1). Wood (1943) lists twenty islands in this sub-group and claims that the highest, 'O'ua, reaches an elevation of just 43 metres above sea-level. The largest of the Lulunga islands is Ha'afeva, with an area of approximately 2 square kilometres. Wilson and Beecroft (1983) refer to Ha'afeva and Tungua, which at 1.5 square kilometres is the next largest island in the sub-group, as low, dome shaped coral atolls consisting of coral limestone basements overlain with andesitic tephra cover beds. Their surfaces are described as very gently undulating, achieving maximum elevations of 12 metres and 18 metres respectively.

The 'Otu Mu'omu'a sub-group contains twelve islands (Wood 1943) of varied geology and physiography. Nomuka, at 7 square kilometres the largest island in the sub-group, is a raised limestone island which displays three coral pinnacles over 25 metres in elevation (Wilson and Beecroft 1983), and supports a pond of fresh water (Wood 1943). The next largest island in the sub-group is Nomuka-iki, a raised volcanic island with an area of 68 hectares. Of similar origin is Mango, which Wilson and Beecroft (1983) describe as having a distinctive rolling to hilly topography culminating in peaks of 38 metres and 42 metres at each end of this 53 hectare island.

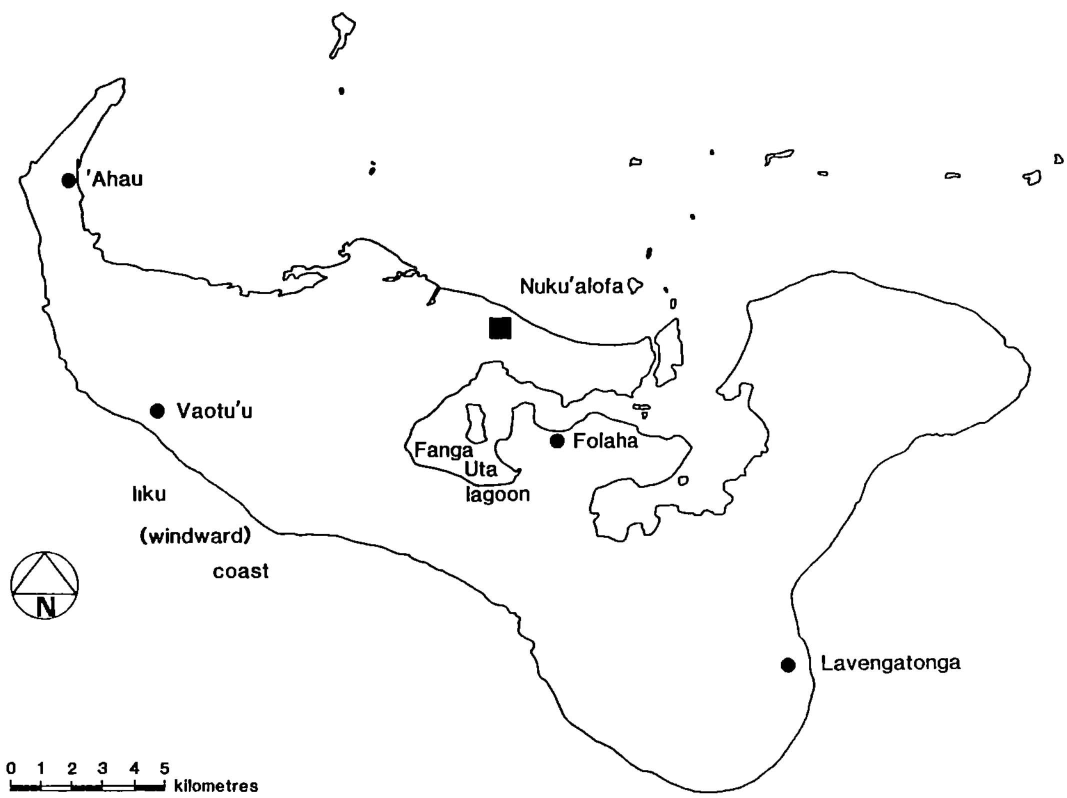
The dominant physical characteristics of the Ha'apai Group are the relatively small sizes of the islands, and the large sea area which they occupy. For the eastern islands alone, the total land mass of less than 90 square kilometres (Wood 1943) is scattered over nearly 6000 square kilometres of sea.

Compared to the widespread Ha'apai islands, the land masses of the southern-most Group, Tongatapu, are concentrated in a small area. The largest two islands in the Kingdom, both situated south of latitude 21 degrees south, are Tongatapu and 'Eua, which cover 257 and 87 square kilometres respectively. Tongatapu is a raised coral limestone platform with a maximum elevation less than 70 metres above sea-level. This high-point occurs near the most southerly point of the island. From here the land slopes gradually towards the Fanga 'Uta lagoon and the low-lying northern shore with its shallow fringing reef beyond. The south and east coasts are lined with limestone cliffs and reef terraces which face the dominant south-east trade winds (Figure 2.3).

The dramatic cliffs which line the eastern coast of 'Eua show clear evidence of having been uplifted on at least three separate occasions. 'Eua is one of the oldest islands in the Pacific (Crane 1979), and contains a volcanic core which supports layers of foraminiferal, algal, and coral-reef limestone (Wilde and Hewitt 1983). From a summit more than 300 metres above sea-level, the slopes on the western side of the eastern ridge descend to a central valley which has been interpreted as being an uplifted lagoon (Wilde and Hewitt 1983). The western boundary of this valley is defined by a second ridge which is separated from the coast by a series of western slope terraces.

FIGURE 2.3

Map of Tongatapu showing locations of study areas



2.2.2 Hydrologic features

The various aspects of the hydrologic cycle have different impacts on the Tongan islands but all are significant. With a sea area more than 500 times its total land area, the Kingdom of Tonga is dominated by water. The ocean isolates the widespread land-based human and non-human communities from each other, and from the rest of the world. Oceanic activity is the main determinant of coastal geomorphology, and has been of major significance in the formation of most islands. The actions of waves and tides are ameliorated to differing degrees by a variety of coastal formations and plant communities, so that environmental impacts vary from island to island, and particularly between the windward and leeward sides of islands.

Swamps occur on sheltered coasts between fringing reefs and dry land, and at the edges of lagoons. These can be valuable buffer zones to protect inland areas from detrimental effects of the sea. The largest lakes in the Kingdom are found in the volcanic craters of Tofua and Niuafo'ou, with smaller ones on Nomuka and 'Uta Vava'u (Wood 1943). The only islands to have running surface water are 'Eua, where several small creeks flow from springs, and Niuatoputapu which supports one stream (Wood 1943). The topography of the raised coral limestone islands ensures there is minimal surface water flow. On low ground with heavy soils rain accumulates in large puddles before being dispersed by evaporation and slow soakage, while lighter soils quickly allow water through to the porous limestone bedrock. Because of the low humus content of most inland soils only relatively small amounts of water are retained, and for relatively short periods.

On the raised coral islands freshwater is held in aquifers within the limestone rock in a 'lens' which floats on denser saltwater (Waterhouse 1984). The Ghyben-Herzberg equation, which relates the thickness of the freshwater lens to the densities of freshwater and seawater, suggests that in a homogeneous and isotropic aquifer the depth of the lens below sea level should be forty times the height of the water table above sea level. This calculation requires the assumption that the freshwater is static and the saltwater which surrounds it is tideless (Waterhouse 1984). These conditions are not met on any of the Tongan islands and so estimates of the thickness of a freshwater lens based on the Ghyben-Herzberg relation should be used only as approximations which need to be refined. On the Ha'apai island of Lifuka, overpumping has exhausted the supply of freshwater and led to the reticulation of brackish water in Pangai and Hihifo.

The tectonic uplifting of 'Eua together with the geological structure of igneous rocks overlain by various types of limestone make the modelling of that island's groundwater systems very difficult. Subsurface water catchments on any of the limestone islands could be appreciably larger than the surface topography suggests (Waterhouse 1984). Hydrogeological data are still too sparse to accurately determine the volumes of freshwater lenses on any of Tonga's main islands.

2.2.3 Soils

2.2.3.1 General

The location of Tonga's islands within the range of active volcanoes has resulted in the development of fertile soils. Crane quotes New Zealand soil scientist Gary Orbell as saying:

> Most tropical countries have their fair share of poorer soils, but in Tonga we are constantly amazed at the superior quality of the greater proportion of your soils (Crane 1979, p.18).

In his review of South Pacific soils Cowie outlined the source of this superior quality.

> The soils of Tonga are mainly formed from thick, relatively young but weathered deposits of volcanic ash overlying coral limestone. Most of these soils are very fertile ... (Cowie 1981, p.5).

Tongans have traditionally differentiated between two main soil types: kelefatu and tou'one. Kelefatu, upland soils derived from volcanic ash, are generally found at elevations greater than 3 metres above sea-level, while tou'one, lowland soils derived from sand, generally occur close to sea-level (Thaman 1976). Minor soil types sometimes distinguished by physical appearance include: kelekele ua, loamy sands intermediate between kelefatu and tou'one; kelekele 'umea, very clayey, waterlogged hydromorphic soils; and kanikita, soils derived from coarse volcanic material on volcanically active islands such as Niuafo'ou and Tofua (Maude 1965, Thaman 1976). Maude and Thaman both make the point that

Tongan farmers have considerable knowledge about soil fertility in specific areas resulting from their experience in cultivation.

No serious scientific study of Tonga's soils had been undertaken until the 1960s. Maude (1965) was able to cite only one publication dealing with Tongan soils (on the basis of one sample), except for comments in Department of Agriculture annual reports. Maude collected soil samples from Tongatapu, Ha'apai, and Vava'u, and reported the results of chemical analyses carried out by the Fiji Department of Agriculture (Maude 1965). These results indicated that pH values were higher (more alkaline) in samples of lowland soils (tou'one) than upland soils (kelefatu); that more than 85 percent of samples of both types of soil had medium total nitrogen contents (between 0.20 and 0.49 percent); and that the majority of both tou'one and kelefatu samples had low carbon contents (generally less than 4 percent, and never as high as 10 percent). Calcium and magnesium availability was shown to be high or very high in more than 90 percent of kelefatu samples, and very high in all seven tou'one samples. The results obtained for available phosphorus and potassium showed values spread across at least four of the five rating categories for the samples collected from Tongatapu, Ha'apai, and Vava'u (Maude 1965). The first data adequate for the development of taxonomic and mapping units resulted from a 1968 reconnaissance survey of Tongatapu by H.S. Gibbs of the New Zealand Soil Bureau (Gibbs 1972 and 1976). Since then the New Zealand Soil Bureau has surveyed, and produced maps and reports for 'Eua, for ten of the Ha'apai islands, and seventeen islands in the Vava'u Group. In 1985 a consultant's study found evidence of soil deterioration caused by continuous cropping. Further, more detailed, studies were recommended (Potter 1986).

2.2.3.2 Soils of Tongatapu

Gibbs summarised the characteristics of Tongatapu's soils as follows.

> Tongatapu has extensive areas of deep friable brown clay soils ... very well supplied in nutrient requirements for plant growth. ... and they have excellent physical, chemical and biological properties (Gibbs 1976 p.10).

Gibbs divided the upland soils (kelefatu) into two categories: Vaini clay and Lapaha clay, each of which was sub-divided into three sub-categories to facilitate description of 'rolling' and 'mottled subsoil' phases, as well as the dominant Vaini clay and Lapaha clay sub-categories. The lowland soils, tou'one, were also described by Gibbs in two categories: Nuku'alofa soils and Sopu soils. These categories were sub-divided into: Nuku'alofa sand, Nuku'alofa sandy loam, Sopu sand, and Sopu loam.

Following the publication of the Soil Map of Tongatapu (Gibbs 1972), supplementary field investigations were undertaken by J.D. Cowie, P.J. Brophy, M.L. Leamy, D.M. Leslie, and G.E. Orbell, all from the New Zealand Soil Bureau, and G.B. Hougland, a US Peace Corps volunteer. These surveys provided detailed data which confirmed the validity of the primary differentiation between kelefatu and tou'one soils, but also led to some rearrangement of the soil legend used by Gibbs, and more precise definition of the taxonomic units for the soils derived from andesitic tephra (Cowie 1980). A revised map and accompanying report are being prepared by the New Zealand Soil Bureau (David Leslie, Soil Resources Section, New Zealand Soil Bureau, personal communications 25 November 1985 and 29 January 1987). The proposal of the Bureau is that Tongatapu's soils should be described in six series: Nuku'alofa, Sopu, Lapaha, Vaini, Fahefa, and Fatai (Cowie 1980; Cowie, in preparation). The correlation of these series with the taxonomic units used by Gibbs is shown in Table 2.1.

The major differentiation between upland soils relates to the age of the volcanic deposits from which they are derived. The first of two significant volcanic events laid down material which now forms the strongly weathered base for soils on the eastern half of the island. The andesitic ash deposited during the second volcanic eruption, which occurred to the west of Tongatapu, is now moderately weathered and is distributed across the whole island. The soils of the Vaini, Fahefa, and Fatai series are younger, less strongly weathered, and deeper than the Lapaha series (Cowie 1980; David Leslie, Soil Resources Section, New Zealand Soil Bureau, personal communication 25 November 1985). The depth of volcanic deposits tends to increase from approximately 1 metre in the east, to between 2 and 3 metres in the west. The Lapaha soils occur on the eastern half of the island in areas where a thin layer (less than 35 centimetres) of moderately weathered ash overlays the older material. The Vaini clays are derived from parent material which consists of a relatively thick layer (between 35 and 100 centimetres) of

TABLE 2.1

Correlation of Cowie's soil series for Tongatapu with the units suggested by Gibbs

Gibbs (1972)	Cowie (1980) and (in preparation)	Main descriptive criteria
Soils of the beach ridges		
Nuku'alofa soils	Nuku'alofa series	<40 cm dark coarse sand or sandy loam on yellow sand overlying coral limestone
Soils of the coastal swamps		
Sopu soils	Sopu series	Humus rich A horizon of varying depth on coral sand
Soils of the raised coral surface		
Lapaha clay	Lapaha series	<30-40 cm of younger tephra, confined to A horizon, over older tephra
Lapaha clay, mottled subsoil phase	Vaini series, shallow phase	30-40 to 60 cm of younger tephra over older tephra, younger tephra in upper part of B horizons
Vaini clay	Vaini series	60-100 cm of younger tephra over older tephra
	and Fahefa series	>100 cm of younger tephra over older tephra
Vaini clay, mottled subsoil	Fatai series	Gleyed as evidenced by paler hues and oxide nodules. Generally >100 cm of younger tephra, but may be rewashed

Sources: Gibbs 1972 and 1976; Cowie 1980 and in preparation.

moderately weathered andesitic ash. The Fahefa and Fatai clays are both formed on thick (1 metre or more) deposits of moderately weathered andesitic ash (Cowie, in preparation). The thickness of the younger tephra does not decline evenly but is extremely variable. Over a short distance at the Government

Experimental Farm, Vaini, depths of the younger tephra were found to range from 35 to 150 centimetres (Cowie 1980).

The soils of the beach ridges and coastal swamps, Nuku'alofa and Sopu series, differ fundamentally from the upland soils, in that their dominant parent material is not volcanic ash, but coral sand. The considerable variations in the characteristics of the soils within these series, stem from their geographical locations. Nuku'alofa sand, found on undulating beach ridges, generally consists of excessively drained, relatively unweathered coral sand. Nuku'alofa sandy loam occurs on older, low beach ridges and flats where some andesitic ash has been added to the sand, and displays better drainage characteristics. Sopu sand soil develops on the tidal and semi-tidal flats bordering the lagoons, and is poorly drained; conditions here encourage the development of a thin surface layer of humus rich sand. Where lagoon sediments have combined with coral sand, Sopu loam is formed; this is generally located in low-lying coastal swamps bordering lagoons (Cowie, in preparation).

2.2.4 Climate

Tonga's climate is determined very largely by the country's location, just north of the Tropic of Capricorn, and the presence of only small land masses in vast areas of ocean. Cumberland (1960) points out that the climates of small tropical islands are characterised by the small annual range in mean temperature. Barrau (1961) said that the stable temperature regime, the high relative humidity, and the relatively high rainfall, combine to give many of the islands in the tropical south-west Pacific a distinctive type of climate which Martonne (1948) had called 'tropical Oceanic' or, more specifically, 'Polynesian'. A meteorological description would stress the influence of the trade winds' maritime tropical (mT) air, and classify the climate as Am in the Koeppen system (Thaman 1976).

Because Tonga's islands are distributed across eight and a half degrees of latitude, climatic variation across the Kingdom is considerable. These differences are reflected in the mean annual temperatures: 23 degrees Celsius in Tongatapu, 25 degrees in Vava'u, and 27 degrees in Niuafo'ou; and in mean annual rainfall: 1834 mm in Tongatapu, 2312 mm in Vava'u and 2596 mm in Niuafo'ou (Thaman 1976; Wilde and Hewitt 1983; Wood 1943; Orbell and others 1985; Rathey 1984). The mean annual daytime temperature range of 4 degrees Celsius at Nuku'alofa (Thaman 1976) is similar to the range in Vanuatu, Suva (Fiji), Niue, the Cook Islands, and Darwin (Australia); greater than that for Western Samoa, Kiribati, and the Solomon Islands; but considerably less than the range experienced in the more southerly centres of Sydney (Australia), and Auckland (New Zealand) (Kennedy 1966). Tonga's recognised warm season (faha'ita'u mafana) lasts from November to April, and the cool season (faha'ita'u momoko) from May to October (Thaman 1976). In Vava'u the average annual minimum temperature is 15.5 degrees Celsius, but on Tongatapu one night in 1986 the temperature dropped to 9 degrees, 2 degrees below the average annual minimum.

Annual average rainfall for Tongatapu is approximately 1800 mm; Rathey (1984) gives two figures: 1834 and 1857 mm, while others have suggested annual averages from 1500 mm to 1889 mm (Swaney 1990; Crane 1979; Thaman 1976). A likely reason for this divergence in the published data is the considerable variation in rainfall which occurs from year to year. In 1971 the annual total for Tongatapu was 2655 mm while in 1981 it was 864 mm (Rathey 1984). In Vava'u the highest annual rainfall between 1947 and 1980 was 3019 mm, while the lowest annual total was 1282 mm (Orbell and others 1985). The annual mean for Vava'u is 2289 mm, and the mean number of rain-days per year is 146; comparative figures for Ha'apai are 1764 mm and 148 rain-days (Orbell and others 1985; Wilson and Beecroft 1983). The highest recorded rainfall in the Kingdom occurs on the remote northern islands, with Niuatoputapu receiving an average of 2359 mm annually and Niuafo'ou 2596 mm (Rathey 1984).

As already suggested, there is considerable variation in rainfall from year to year; this is also the case from month to month. Nuku'alofa's average rainfall per calendar month between 1945 and 1970 ranged from 84 mm for June to 246 mm for February, while monthly means for Vava'u between 1947 and 1980 ranged from 107 mm for June to 374 mm for March (Thaman 1976; Orbell and others 1985). The summer rainfall is largely caused by low pressure troughs which move through the trade wind belt (Thaman 1976). At this time of year the intertropical front between the north-east and south-east trades is at its most southerly. It is the coming together of these two air-masses, with differing temperature, density, and humidity characteristics, that brings about the cyclonic storms (or hurricanes) and many of the thunderstorms which affect Tonga in summer months (Cumberland

1960; Thaman 1976). The strong winds, which are accompanied by heavy rain, often come from the north or north-east, in contrast to the dominant summer easterlies and the winter south-easterlies.

The seasonal variation in precipitation is sometimes acute, leading to prolonged periods of drought, when the dry season extends into the summer months. Rathey (1984) reported that droughts lasting between 6 and 9 months occurred in 1953/54, 1966/67, 1969/70, 1978/79, 1981, and 1982/83. But for heavy falls in December, a serious drought would have inflicted Tongatapu in 1985/86. More than a quarter of 1985's total rainfall (358 mm of 1272 mm) fell during that one month, and no measurable rain was recorded during January 1986 (*Tonga Chronicle,* 31 January 1986, p.4). Comparisons between potential evapo-transpiration and rainfall are useful indicators of drought hazard. The data in Table 2.2 were calculated by Rathey to show the frequency at which potential evapo-transpiration exceeded rainfall over a thirty-five year period (Rathey 1984).

TABLE 2.2

Number and percentage frequency of months within a period of 35 years when potential evapo-transpiration on Tongatapu exceeded rainfall, by calendar month

	J	F	M	A	M	J	J	A	S	O	N	D
Number of occurrences	11	9	5	11	20	19	15	12	10	12	15	20
Relative frequency (percent)	31	26	14	31	57	54	43	34	29	34	43	57

Source: Rathey 1984, p.86.

The average annual relative humidity in the Kingdom is about 75 percent. The daily average for Tongatapu ranges from 67 percent to 87 percent, with monthly means varying seasonally from 65 to 70 percent in winter to more than 80 percent in summer (Sefanaia 1982; Crane 1979). Wilson and Beecroft (1983) reported the seasonal range for Ha'apai to be 76 to 80 percent with an annual average of 78 percent. The average annual relative humidity for Vava'u is similar, at 79 percent (Crane 1979).

2.2.5 Natural disasters

Natural disasters are relatively frequent occurrences in Tonga.

> In Tonga, since 1875, there have been 41 damaging hurricanes; 24 earthquakes of Richter 7.0 or above; seven periods of severe drought; nine volcanic eruptions and three known tsunamis; a total of 83 recorded events, or one every one and a quarter years (Lewis 1982, p.234).

Other climatic hazards include whirlwinds, thunderstorms, and tropical cyclones which do not achieve the sustained windspeed of 120 kilometres per hour required to qualify as hurricanes.

Tonga is most prone to hurricanes and cyclones (afa) during the warmer months from November to April. It has been frequently claimed that the more northerly islands of the Kingdom are more susceptible to hurricanes (Wood 1943; Thaman 1976; Rathey 1984), but Lewis (1981) states that over long periods of time regional variations of risk cannot be substantiated. The most damaging of four hurricanes since 1973 was 'Isaac', which struck the whole Kingdom in March 1982. Two tropical cyclones hit the country in 1986: 'Keli' caused minor damage on Tongatapu in February, and 'Martin' reached Ha'apai on 14 April at reduced strength after causing local devastation on the Fijian island of Vanua Levu (*Tonga Chronicle,* 21 February and 18 April 1986). The damage incurred by infrequent whirlwinds ('ahiohio) is usually confined to small areas; an 'ahiohio at Lapaha, Tongatapu, in August 1986 razed a path just 6 metres wide but 5 kilometres long (*Tonga Chronicle,* 8 August 1986).

Droughts quite often occur between April and December, and usually last for one to two months (Thaman 1976). While these do not usually present a significant hazard, prolonged periods of drought which have much more serious effects are experienced, on average, once or twice per decade (Rathey 1984). Droughts in 1977 and 1981/82 were coupled with hurricanes, thus compounding environmental impacts.

Because of Tonga's location, adjacent to a tectonic subduction zone, it experiences earthquakes quite frequently. While most are not severe, a few have been among the largest magnitudes recorded anywhere in the world (Wood 1943; Lewis 1981 and 1982). The 1917 earthquake, which measured 8.7 on the Richter scale, raised the floor of Niuatoputapu's lagoon so much that it dried out. Another in 1919 registered Richter 8.4, but the strongest in recent years occurred in 1977, at Richter 7.7 (Lewis 1981; Rathey 1984). Tidal waves associated with earthquakes have caused damage on the low coral islands of Lifuka and 'Uiha in Ha'apai (Wood 1943).

The now dormant volcanic island of Niuafo'ou has been the site of five eruptions this century. The most violent of these, in September 1946, led to the total evacuation of the human population. Following an hour of earth tremors, lava erupted from fissures in the rim of the caldera and from the sea (Crane 1979). Having inspected the damage caused, the Minister of Lands, the Honourable Havea Tu'iha'ateiho, told the British Consul eighteen days after the eruption, that craters and cracks in the ground were smoking, that the north reef had been uplifted by 9 metres or more, that the water level in the lake had been raised, and that earthquake shocks were occurring daily (Letter from C.W.T. Johnson (British Consul) to Grantham 27 September 1946, quoted in Rogers 1981, pp.150-151). In 1854 King George Tupou 1 ordered inhabitants to move from Tofua because of threatening volcanic activity (Crane 1979), but, at least in historic times, none of the more southerly volcanic islands has been as active as Niuafo'ou. Volcanic and tectonic activity have caused the emergence of several shoals and islands within Tongan waters, but all those recorded since European contact have been prevented from forming permanent landmasses by rapid erosion of the sea (Crane 1979).

2.3 Biological characteristics

2.3.1 Primary vegetation[1]

Before human activity caused dramatic changes to the natural vegetation, most of Tonga's land area was covered with forest which Crane (1979 p.20) calls 'sub-tropical rain-forest'. Thaman describes remnants of the previously dominant cover on Tongatapu as 'tropical lowland forest' and as 'native inland forest' (Thaman 1976 p.44 and 1984 p.14), while Dahl refers to Tonga's inland forests under the heading of 'lowland rainforest' which is a sub-category of 'tropical rainforests' in the IUCN classification system (Dahl 1980 pp.14-15 and 52). The most extensive remnants of primary forest exist on 'Eua, Tofua, and Late; only one parcel of relatively undisturbed inland forest more than a few acres in size remains on Tongatapu. On the higher islands the character of the forest changes with elevation and exposure. For example, on 'Eua the forest remnants in the central valley typically consist of tall tropical rainforest communities dominated by kotone (*Myristica hypargyraea*) (Sykes 1983). More open forest in the north and south-west includes stands of toi (*Alphitonia zizyphoides*) and tavahi (*Rhus taitensis*) (Maude 1965). The tall rainforest on the west-facing slopes are rich with a mixture of canopy and understorey trees, lianas, and terrestrial ferns. The vegetation on the top of the eastern ridge takes the form of low forest dominated by species such as feto'omaka (*Garcinia myrtifolia*) and uhiuhi (*Podocarpus pallidus*), and dense forest in which tamanu (*Calophyllum vitiense*) and ngatata (*Elattostachys falcata*) are dominant (Sykes 1983; Maude 1965). The plant communities on the steep limestone cliffs vary according to the degree of exposure and soil conditions (Sykes 1983). On several of the volcanic islands, sites of recent lava flows or ash deposition are being colonised. Maude (1965) reported that extensive areas on Niuafo'ou were still bare but creepers and toa (*Casuarina equisetifolia*) were establishing themselves, while some areas of loose volcanic material on the steep slopes of Tofua had developed a sparse cover of ferns and grasses (Maude 1965). Crane asserts that the climax plant associations on the thin soils of the tops of the highest volcanic islands consist of herbaceous species only. These include mosses,

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1. Because Tonga has been inhabited for more than three thousand years, one cannot be sure that any given parcel of existing vegetation has not in the past been cleared or otherwise managed for human use. The term 'primary' is used here to refer to areas of vegetation for which no information is available to show that the area has been cleared. This implies that the ecosystem is in a state of dynamic equilibrium with its physical environment.

fungi, orchids, and lilies, as well as grasses, and ferns such as hulufe (*Asplenium nidus*) (Crane 1979; Yuncker 1959).

The most comprehensive account of primary vegetation on Tongatapu has been given by Thaman (1976). He divides his description into six categories:

1. coastal littoral forest;
2. coastal savanna;
3. swamp forest;
4. marshland;
5. mangrove swamp;
6. tropical lowland forest.

Brief characterisations of each of these are given here.

Coastal littoral forest occurs in areas exposed to strong winds and salt spray, mainly on the east, south, and west coasts, on sandy or rocky soils. Almost all of the species represented in the three zones of this forest are widely distributed in the tropical Pacific region (Thaman 1976; Yuncker 1959). The seaward edge of the forest consists mainly of low salt-tolerant shrubs, herbs, grasses, and vines, including ngahu (*Scaevola frutescens*), ate (*Wedelia biflora*), kavahuhu (*Euphorbia atoto*), mohuku'apopoa tahi (*Thuarea involuta*), 'lautolu tahi (*Vigna marina*), and fue tahi (*Ipomoea pes-caprae*), interspersed with fa (*Pandanus* species mainly *P. tectorius*). Directly behind this is found a zone of dense forest of larger trees such as fau (*Hibiscus tiliaceus*), loupata (*Macaranga harveyana*), futu (*Barringtonia asiatica*), fao (*Ochrosia oppositifolia*), toa (*Casuarina equisetifolia*), nonu (Morinda citrifolia), telie (*Terminalia catappa*), and fa (*Pandanus tectorius*). The inland margin and open areas within the forest are often colonised by pioneer species such as talatala (*Lantana camara*), pula (*Solanum verbascifolium*), and vaine (*Passiflora* species) (Thaman 1976; Yuncker 1959).

On the south and east coasts of Tongatapu, limestone terraces between littoral forest communities and the sea support coastal savanna vegetation. The seaward margin is characteristically comprised of prostrate species including ngingie (*Pemphis acidula*), and kihikihimaka (*Sesuvium portulacastrum*). The savanna itself consists of low herbaceous vegetation such as ate (*Wedelia biflora*), totoa (*Ischaemum murinum*), fue tahi veveli (*Canavalia sericea*), and mohuku:apopoa tahi (*Thuarea involuta*), and scattered groupings of fa (*Pandanus tectorius*), and touhuni (*Tournefortia argentea*) (Thaman 1976; Yuncker 1959).

Swamp forest occurs in areas along the north coast where hydromorphic soils are periodically inundated by heavy rain or high tides. Dominant trees of this open to semi-closed forest include feta'anu (*Excoecaria agallocha*), lekileki (*Xylocarpus granatum*), filimoto (*Xylosma orbiculatum*), fau (*Hibiscus tiliaceus*), hangale (*Lumnitzera littorea*), ifi (*Inocarpus edulis*), and loupata (*Macaranga harveyana*). Understorey species include kavahaha (*Derris trifoliata*), lalatahi (*Vitex trifolia*), and tutuhina (*Clerodendrum inerme*), as well as the naturalised exotics kuava (*Psidium guajava*), talatala (*Lantana camara*), and iku'ikuma (*Stachytarpheta urticaefolia*) (Thaman 1976; Yuncker 1959).

Thaman labels as marshland just two areas of northern Tongatapu where water stands throughout the year. Naturalised exotics such as kuava (*Psidium guajava*), are the dominant tree species here, along with indigenous fau (*Hibiscus tiliaceus*), feta'anu (*Excoecaria agallocha*), and hangale (*Lumnitzera littorea*). The herbaceous vegetation includes vailima (*Paspalum conjugatum*), kuta (*Eleocharis dulcis*), and totoa (*Ischaemum murinum*) (Thaman 1976; Yuncker 1959).

Mangrove swamp, found in shelter areas of the north coast and at the margins of the inland lagoon, consists of trees growing below the high tide limit. The stands are almost entirely made up of tongolei (*Rhizophora mangle*), tongo ta'ane (*Bruguiera conjugata*), and *Rhizophora mucronata*, all of which are referred to as tongo (Thaman 1976).

The parcels of tropical lowland forest which remain on Tongatapu are characterised by a closed canopy up to 20 metres or more high, a limited understorey, and a variety of epiphytes and lianas. Dominant tree species include tavahi (*Rhus taitensis*), toi (*Alphitonia zizyphoides*), ngatata (*Elattostachys falcata*), te'ete'emanu (*Ervatamia orientalis*), fo'ui (*Grewia crenata*), and masi (*Ficus* species). Understorey species of the dense forest include takafalu (*Micromelum minutum*), and maile (*Alyxia stellata*), while exotics such as kuava (*Psidium guajava*), and talatala (*Lantana camara*) commonly colonise the more open sites (Thaman 1976; Yuncker 1959).

2.3.2 Secondary vegetation

Disturbance to primary vegetation has occurred on all the inhabited islands in Tonga; on some it has been all but totally cleared. This inevitably encourages invasion by pioneer species. A number of indigenous species are successful colonisers given favourable conditions; these include fau (*Hibiscus tiliaceus*), tavahi (*Rhus taitensis*), and tuitui (*Aleurites moluccana*) (Maude 1965). However, aggressive introduced species often out-compete indigenous trees to colonise large areas. Particularly significant among these have been sialemohemohe (*Leucaena leucocephala*) and kuava (*Psidium guajava*). Kuava is established as the dominant secondary species in parts of central and western Tongatapu, and in 'Eua's central valley. Sialemohemohe has covered large areas of eastern Tongatapu in almost exclusively monospecific stands, occurs in isolated patches in central and western Tongatapu, and is well-established on Ha'apai islands such as Foa. Five varieties of *Leucaena leucocephala* have been identified in Tonga, the first of which is believed to have been introduced in 1926 (Fakalata 1986). The dominance of this species has recently been undermined by devastating attacks by the leucaena psyllid *Heteropsylla cubana* which has affected *Leucaena leucocephala* throughout south-east Asia and the Pacific (Fakalata 1986). The attack began in 1984, rapidly defoiating entire stands of sialemohemohe. The effects of a severe drought supplemented the impacts of the psyllid attack, so that in mid-1986 no convincing signs of sustained recovery were seen. The die-back of sialemohemohe in eastern Tongatapu has encouraged increasing abundance of another tree native to America, pula (*Solanum verbascifolium*). Other exotic species which take advantage of cleared land include talatala (*Lantana camara*), lopa (*Adenanthera pavonina*), and sita (*Melia azedarach*).

Apart from trees, such as those mentioned above, a number of grasses and herbaceous weeds of exotic origin are aggressive colonisers. Perhaps most successful of these is saafa (*Panicum maximum*), a coarse grass which grows up to 3 metres high, and has established monospecific stands on large areas of cleared land on Tongatapu (Yuncker 1959). Two other grasses common throughout Tonga as secondary vegetation are vailima (*Paspalum conjugatum*) and pakopako (*Cyperus rotundus*); both are pantropic in distribution but of uncertain origin (Yuncker 1959; Thaman 1976). Thaman lists a total of forty-three weed species, categorised according to places of origin (Thaman 1976). He suggests that the majority have been introduced since European contact, and these are the species which have become dominant in secondary vegetation. The following are examples of herbaceous weeds found throughout Tonga: fisi'uli (*Bidens pilosa*), misimisi (*Canna indica*), 'akauveli (*Indigofera suffruticosa*), mateloi (*Mimosa pudica*), tono (*Centella asiatica*), kihikihi (*Oxalis corniculata*), and filo (*Plantago major*) (Thaman 1976; Yuncker 1959).

2.3.3 Agricultural crops

A variety of subsistence and commercial food crops is grown in Tonga; Thaman (1976) lists twenty-eight 'important' species, and seventeen 'supplementary' food plants. Hardaker (1975) found that staple root crops were planted on 51 percent of the cultivated area surveyed in 1969/1970. Covering 25 percent of the cultivated area was cassava, manioke, (*Manihot esculenta*), an easily propagated food plant originating in the American tropics, which is now widely distributed (Hardaker 1975; Williams and Chew 1980). Thaman (1976) found that manioke was the dominant crop on just 11 percent of the total area of his sample of bush allotments, but on 37 percent of the subsistence area. The woody stem grows to 2.5 metres or more high before the bunched tubers are ready for harvesting (Williams and Chew 1980).

Yams occupied 14 percent of the cropped area surveyed by Hardaker (1975), and 7 percent of Thaman's total sample area (22 percent of the subsistence area) (Thaman 1976). The most common species of yam grown in Tonga is 'ufi (*Dioscorea alata*), but 'ufilei (*Dioscorea esculenta*) is also cultivated (Thaman 1976; Hardaker 1975). Many varieties of 'ufi are grown, and tubers of various sizes are produced, some up to 2.4 metres long (*Tonga Chronicle*, 15 August 1986, p.5). Yams require fertile soil if they are to yield large quantities (Williams and Chew 1980).

Of the four types of taro commonly grown in Tonga, the American talo futuna (*Xanthosoma sp.*) is the most popular. Another variety of *Xanthosoma* taro, talo tea, also originated in tropical America and was introduced to Tonga after European contact." The two taro species traditionally cultivated as staple crops, swamp taro or talo tonga (*Colocasia esculenta*) and giant taro or kape (*Alocasia macrorrhiza*), are ancient introductions from southern Asia (Thaman 1976; Yuncker 1959). Many varieties of these taro species are recognised in Tonga, and between them they provide staple food plants which can be grown in a range of conditions. Hardaker (1975) found kape planted on less than 2 percent, and other taro species on 6 percent, of the cultivated area he surveyed. Thaman (1976) recorded kape on less than 1 percent of his total sample area (1 percent of the subsistence area), and American and swamp taro species on 9 percent (29 percent of the subsistence area).

Another important root crop, the sweet potato or kumala (*Ipomoea batatas*), was brought to Tonga from tropical America before European contact (Thaman 1976), but better varieties have been brought to Polynesia by Europeans (Barrau 1961). Sweet potatoes were found on 5 percent of the cultivated area surveyed by Hardaker (1975), and on 1 percent of Thaman's (1976) total sample area (3 percent of the subsistence area). Thaman's result was low because his survey was conducted outside the season for growing sweet potatoes.

Following the traditional root crops, the next most important group of short to medium term crops would be the *Musa* cultivars - bananas and plantains. Many different clones are grown in Tonga, but three main groups are readily discernible: siaine, the bananas commonly consumed in Western countries; pata, small sweet bananas; and hopa, larger plantains (Hardaker 1975). There is some confusion over the speciation of *Musa* plants. Thaman (1976) gives hopa the specific name *Musa paradisiaca*, and says that siaine and pata are varieties of the species *Musa sapientum*. Yuncker (1959) listed Tongan varieties within two subspecies of *Musa paradisiaca*; the fruit of the *normalis* subspecies was normally cooked before eating, while the fruit of subspecies *sapientum* varieties was eaten raw. It has been suggested that Pacific bananas occur in the Australimusa group which is distinct from the commercial bananas derived from the wild species *Musa acuminata* and *Musa balbisiana* (Williams and Chew 1980). Yuncker (1959) said that no wild species occurred in Tonga; it seems unlikely therefore that the *Musa* cultivars currently growing in Tonga belong to the Australimusa group. New *Musa* clones have certainly been introduced by Europeans, including misipeka, lady's finger banana, brought to Tonga by Mr Shirley Baker in the 1870s (Thaman 1976). Hardaker (1975) calculated that 26 percent of the cultivated land he surveyed supported bananas.

A few indigenous species and pre-European introductions are cultivated as supplementary food plants. These include: edible hibiscus, pele (*Hibiscus manihot*);

and cabbage tree, si (*Cordyline terminalis*). Early European introductions include: watermelon, meleni (*Citrullus vulgaris*); pineapple, faina (*Ananas comosus*); maize, koane (*Zea mays*); pawpaw, lesi (*Carica papaya*); green onion, onioni tonga (*Allium ascalonicum*); pumpkin, hina (*Cucurbita pepo*); and chilli pepper, polo fifisi (*Capsicum frutescens*) (Thaman 1976). More recent introductions include: peanut, pinati (*Arachis hypogaea*); tomato, temata (*Lycopersicon esculentum*); bell pepper or capsicum, polo palangi (*Capsicum annuum*); green bean, piini (*Phaseolus vulgaris*); European cabbage, kapisi (*Brassica oleracea* var. *capitata*); Chinese cabbage, kapisi siaina (*Brassica chinensis* and *Brassica pekinensis*); cucumber, kiukamipa (*Cucumis sativus*); radish, latisi (*Raphanus sativus*); vanilla, vanila (*Vanilla planifolia*); coffee, kofi (*Coffea arabica*); and lemon grass, moengalo (*Cymbopogon citratus*) (Thaman 1976).

Non-food plants cultivated alongside food crops include: paper mulberry, hiapo (*Broussonetia papyrifera*); pandanus, lou'akau (*Pandanus* species); bamboo, pitu (*Bambusa vulgaris*); hibiscus, kaute (*Hibiscus* species); samoa (*Crinum asiaticum*); and gardenia, siale (*Gardenia* species); (Thaman 1976).

On virtually all cultivated land, trees form a top canopy layer above the crop plants mentioned above. While the number and variety of trees vary considerably, the coconut palm, niu (*Cocos nucifera*), is almost always present, and is the most common planted tree. Other food-bearing trees planted or protected after natural regeneration include: a range of citrus trees (*Citrus* species); mango, mango (*Mangifera indica*); Polynesian plum, vi (*Spondias dulcis*); Malay apple, fekika (*Syzygium malaccense*); soursop, 'apele 'initia (*Annona muricata*); avocado,'avoka (*Persea americana*); cashew, apu (*Anacardium occidentale*); and peach, piisi (*Prunus persica*) (Thaman 1976). Citrus trees in Tonga are commonly referred to by the generic local name moli. This term is used throughout this thesis because reliable information on specific names was generally not available.

2.4 Cultural characteristics

2.4.1 The development of Tongan society

The islands of present-day Tonga are thought to have been discovered by explorers from Fiji between 1500 and 1300 BC (Spenneman 1986), and archaeological and linguistic evidence suggests that they were the first islands in

Polynesia to be settled (Bellwood 1978). The first settlements were established, probably on Tongatapu, by members of the Lapita cultural group (Poulsen 1977) who occupied coastal areas where seafood and firewood were readily available. Archaeological findings have indicated that by 500 AD most of the Tongan population had moved their homes to inland sites, and that agriculture had become the major source of food. This settled lifestyle based on farming led to the development of a social hierarchy which by about 1000 AD had been formalised into the leadership system of the Tu'i Tonga (Spenneman 1986). Oral traditions relate that the first Tu'i Tonga was 'Aho'eitu, the son of the god Tangaloa 'Eitumatupu'a and 'Ilaheva, a girl from Niuatoputapu who was later known as Va'epopua (Rutherford 1977b). 'Aho'eitu's rule as overall spiritual and civil leader, or sacred king, began about 950 AD, and he was succeeded by a line of Tu'i Tonga which extended to the nineteenth century.

The intricacies of traditional Tongan social structure were such that historians have presented differing explanations of the hierarchy of political power and status. The conventional interpretation is that the Tu'i Tonga ruled as supreme individual leaders until the fifteenth century when Kau'ulufonuafekai, the twenty-fourth Tu'i Tonga, created the position of <u>hau</u> in order to delegate temporal rule. His younger brother, Mo'ungamotu'a, was appointed to the new office, and assumed the title of Tu'i Ha'atakalaua (Latukefu 1975; Afeaki 1983; Rutherford 1977b). The sixth Tu'i Ha'atakalaua founded a third dynasty, the Tu'i Kanokupolu, for his son Ngata, who was charged with overseeing the troublesome Hihifo district of western Tongatapu. In time, the Tu'i Kanokupolu line of chiefs became powerful enough to secure the position of <u>hau</u>.

An alternative interpretation of the historical power structure of Tonga society suggests that the hereditary model borrowed from European monarchies is not appropriate (Gunson 1979). Gunson differentiates between the two perceptions of Tonga's social history as follows:

> The old idea was that political power passed through several dynastic lineages in succession and was transmitted by a process of devolution and entitlement. The revised view offered here is that political power, as

> opposed to sacred status, was always accepted as the prerogative of the most successful chief and that challenge by peers was an essential feature of political life (Gunson 1979, p.28).

Gunson argues that the hau system of temporal leadership existed even at the time of 'Aho'eitu, the first Tu'i Tonga, and had its roots in an ancient religion, with dual chiefs reflecting the fertility and aggression aspects of the sacred phallus. There were three qualifications which the hau had to meet: membership of the highest caste; confirmed leadership qualities; and prowess as a warrior (Gunson 1979). This view proposes that the appointment to the position of hau was of much more practical significance than succession to a dynastic title. While the title of Tu'i Tonga carried with it the prestige of supreme religious leader, and the titles of Tu'i Ha'atakalaua and Tu'i Kanokupolu identified their holders as chiefs of the highest social caste, the ultimate political power was vested in the hau. The position of hau was linked to each of the dynastic titles at different times, but succession to the 'hauship' did not follow the strictly formalised hereditary patterns of European monarchic dynasties; the candidate had to show that he or she was a worthy leader, capable of fulfilling the duties which such a powerful position required.

The complexity of Tongan society has also led to variations in interpretations of social classes below the leadership caste. Wood lists six divisions in ancient Tongan society:

> (1) The King and those of royal blood (Hau).
> (2) Chiefs (Hou'eiki).
> (3) Gentlemen (Mu'a).
> (4) Esquires or officers (Matabule).
> (5) Commoners (Tu'a).
> (6) Captives or slaves (Bobula).
> (Wood 1943, p.3).

Sahlins (1958) reduced the number of significant, identifiable status levels to three:

- the chiefs and their immediate relatives (eike);
- the chiefs' attendants (matapule);
- commoners (tua).

He discounts the existence of the mu'a class, as Gifford had found no evidence of it, and disregards the 'slave' level because its significance was unknown. In his study of Polynesian societies, Sahlins located Tonga in the group displaying the greatest stratification. Characteristics of societies in this category included:

> Structurally complex ranking systems, usually with three status levels; pre-eminent stewardship by high chiefs; severe punishments and dispossession of those who infringe chiefly decrees on land or sea use; ... close-in marriages among chiefs strictly enforced; ... elaborate obeisance postures and other forms of respect including developed chiefs' languages and carrying of chiefs on litters, etc.; unique rites for all life crises of high chiefs, held on a spectacular scale (Sahlins 1958, p.11).

These features are indicative of the methods used to uphold and perpetuate the power structure within a highly-developed, stratified society such as existed in Tonga at the time of European contact. As illustrated by the differences in the descriptions of status levels given by Wood and Sahlins, the intricacies of stratification in Tongan society were particularly difficult for foreigners to unravel. The society was characterised by complex hierarchies of political and familial power, supported by an intricate web of socio-economic institutions. While dividing the structure into distinct status levels helps to facilitate a clearer understanding, it oversimplifies the system of power distribution amongst chiefs and their attendants. One of the earliest writings about Tongan society, John Martin's 1817 presentation of William Mariner's account, clearly acknowledges the inadequacy of segmenting the society into status levels.

> To divide society into distinct classes, and to discourse of the degree of rank or respect accruing to individuals, accordingly as they may belong to one or other of these classes, would be a task very difficult to execute, and perhaps impossible with respect to the people of these islands; at least, not without making numerous exceptions and explanations, ... (Martin 1981, p.287).

Rank was recognised within three spheres of social life: religious, civil, and professional. This meant that a person of low civil rank could command the respect of high-ranking chiefs because of superior religious status. A particularly emphatic example was the priest, who ordinarily ranked relatively low on the social scale, but who was regarded during oracle ceremonies to have assumed, by divine inspiration, the being of a god (Martin 1981).

The traditional regime of chiefly status was changed somewhat by King George Tupou I when he granted estates of land to selected chiefs, creating thirty-three nobles. The official status of descendants of the dispossessed chiefs is commoner, but they are still accorded special respect.

Religious status also changed during the reign of Tupou I due to the acceptance of Christianity. Tongans are such fervent church-goers that for the majority Sundays are dedicated to attending church and eating the main meal of the week which has usually been baked in the 'umu. In many villages the church is the main focal point for the community. Where more than one church exists in the same village, which is common, some friendly rivalry takes place, not least in the volume of hymn-singing. On a larger scale the construction of large church buildings as an illustration of a church's ability to raise funds appears to be another demonstration of rivalry. Donating to their church is a significant social obligation for the majority of Tongans. While membership of some churches is less well respected by followers of other branches of Christianity, in general churches work together for community development.

Churches, in common with most other sections of contemporary Tongan society, benefit significantly from remittances sent by Tongans working overseas. Dependence on remittances varies from household to household but, in general, living standards would be badly affected if receipt of this foreign exchange were to cease. The conventional reasoning to explain labour migration would include both push and pull factors: the inability to get their own land has, for some, made even the maintenance of a satisfactory subsistence livelihood difficult; the lack of opportunities for paid employment has set unacceptable limits to self-improvement; the chance to earn enough money overseas to support a family in unprecedented comfort is very attractive; advertisements of material goods available to those successful in Western societies draw people towards the commercial labour market (See also Section 2.4.3). Crocombe (1983) put a different slant on reasons for Tongans migrating. He suggested that well educated Tongans lived overseas because the style of leadership in Tonga was such that they did not have the scope to make their optimum contribution to their own society. Recent moves, by the best educated people's representatives ever to sit in the Legislative Assembly, to gain greater input to the decision-making process in the Tongan government seem to support Crocombe's observation.

2.4.2 Politics and government

The present structure of Tongan government was largely determined during the second half of the nineteenth century. Modifications have been made since then, and earlier cultural traditions still have some influence, but the core of the modern government was established during the reign of King George Tupou I. The two pillars of the new government structure were the unification of all Tonga under a single monarch, King George, and the drafting and acceptance of a constitution. Part II of the Constitution of Tonga, 1875, which was devoted to the form of government, commenced with these two clauses:

> The form of Government for this kingdom is divided into three divisions: - 1st, the King, Privy Council, Cabinet. (The Ministers.) 2nd, the Legislative Assembly. 3rd, Judicial. These three shall always be distinct, and it shall not be lawful for any judge to be a member of the Legislative Assembly.
>
> 34. The form of Government for this kingdom is that of a Constitutional Government under His Majesty, King George Tupou, his heirs and successors (Latukefu 1975, p.96).

Government ministers are appointed by the King, and are deemed by the Constitution to be members of the Privy Council, as are the two Governors of Ha'apai and Vava'u (Latukefu 1975). The King presides over the Privy Council which is the highest governing body in the Kingdom, and which, when an appeal judge joins the Council, forms the Privy Council Court of Appeal. In July 1990, the newly established Court of Appeal became the highest court in the country in all matters except cases concerning disputes over titles and estate boundaries, over which the Privy Council Court of Appeal still presides (Fonua 1990b). Even prior to this new Court being formed, the Privy Council could not reconsider criminal cases (Afeaki 1983; Taulahi 1979; Crane 1978). The Cabinet consists of the Prime Minister, the Governors of Ha'apai and Vava'u, and the Ministers of the Crown responsible for the Ministries of: Agriculture; Civil Aviation; Education; Finance; Foreign Affairs; Health; Labour, Commerce and Industries; Lands, Survey and

Natural Resources; Police; Works; and, since 1988, Justice. The four Ministers currently responsible for Civil Aviation, Education, Finance, Health, Works, and Justice, and the Governor of Vava'u, are not noble by birth, but by virtue of Clause 55 of the constitution they sit as nobles in the Legislative Assembly (Fonua, Undated; Fonua 1988; Latukefu 1975). The Cabinet is effectively the executive body which directs the government's activities in accordance with the decisions of the Privy Council, endorsed where appropriate by the Legislative Assembly. The Ministers and Governors are theoretically open to two forms of sanction: the King can dismiss any of them at any time, and they can be impeached by the Legislative Assembly if their administration is deemed not to accord with the law (Latukefu 1975).

The Legislative Assembly includes all members of Cabinet, nine (previously seven) representatives of the people, and an equal number of nobles' representatives. Increasing the number of representatives to nine, allowed the Niuas and 'Eua to have specific representation in addition to the three representatives for Tongatapu, the two for Ha'apai, and two for Vava'u. Elections for both nobles' and people's representatives are held every three years. The Legislative Assembly sits for up to five months each year, following the ceremonial opening of the Parliamentary session by the King in June. The major roles of the Legislative Assembly are to enact laws, which must be sanctioned by the King, and to review certain activities of the Privy Council. In particular, ordinances of the Privy Council must be confirmed by the Assembly in order to become law, and the Assembly annually debates the recurrent and development expenditure estimates presented by the Privy Council.

While free elections are an important part of the political process, those members of the Legislative Assembly elected by the people do not have the numbers to impose their will against decisions supported by both the ministers and the nobles representatives. Until recent years such a clearly polarised situation seems rarely to have occurred. However, an item in the 1986 budget clearly illustrated how it is possible for measures perceived by the Ministers as essential for the country's development, to be seen by many ordinary Tongans as detrimental.

In his budget statement of June 1986 the Minister of Finance, the Honourable James Cecil Cocker, presented to the Legislative Assembly a package of tax changes designed to increase business investment. This included cuts in company taxes, and the adoption of a flat rate of personal income tax of 10 percent to replace the existing scale which had a top rate of 40 percent. To partially offset the loss of tax revenue a new sales and services tax was introduced (*Tonga Chronicle,* 20 June 1986; Fonua 1986). These moves were viewed with consternation by many Tongans, particularly those who had received overseas education which encouraged critical appraisal and the questioning of authority. It was argued that while those with high incomes would prosper, people earning less than $6000 per year would find the maintenance of a comfortable living standard increasingly difficult. Despite complaints about the tax measures from people's representatives, the budget policies were approved by the Legislative Assembly. Of the six members of the Legislative Assembly who voted against the sales tax Bill only one was a noble (Fonua 1986). Once the budget policies had been accepted, the Speaker adjourned Legislative Assembly sittings for a fortnight to allow members to visit every district of the kingdom to explain the new tax arrangements to the people. Members from all sections of the Assembly addressed traditional fono meetings in an attempt to allay people's fears and overcome misunderstandings. While the parliamentarians expressed satisfaction with the fono visits (*Matangi Tonga* **1**(1), September/October 1986; *Tonga Chronicle,* 1 August 1986), discontent among the people continued long enough to be a major factor in the February 1987 General Election. The new candidates elected as people's representatives were the very people who, because of their overseas education, had been referred to in 1986 by Noble Fusitu'a, the public relations officer for the Tonga Legislative Assembly, as

> ... new foreign elements who intend to separate the people from the chiefs and the Legislature, despite the fact that they are just one body ... (*Matangi Tonga* **1**(1), September/October 1986, p.8).

The rejection of long-standing representatives to make way for six new candidates appears to indicate a degree of dissatisfaction with the process of government, and a desire by the people of Tonga to have a greater say in the decisions which not only affect their present well-being but will also shape the future of Tonga.

This apparent determination to have a more effective voice in government could dramatically change the nature of Tongan politics.

While the Tongan system of government was derived from the British model, it is not possible for the representatives of the majority of the people to control the Parliament. Various interpretations have been placed on this arrangement depending on the perspective of the observer. A leading commentator on Pacific affairs has argued that Tonga does not have a democracy.

> Tonga is one of the world's few remaining kingdoms. It is not democratic, and most forms of power and privilege are concentrated in the hands of a small, predominantly hereditary, elite, plus an expanding bureaucracy. Neither are noted for their efficiency. The climate of world opinion is no longer sympathetic to such a form of government, and this is increasingly so in Tonga also. But the aristocracy and its associated non-aristocratic elite, like any privileged minority in any human society, is unlikely to reshape the society voluntarily, either far enough or fast enough to meet the mounting desire for change (Crocombe 1983, pp.131-132).

Crane was less harsh a critic when he reported a debate in the Tongan Parliament which resulted in a consensus that the kingdom has its own special form of democracy called 'Tongan Democracy' (Crane 1978, p.34). The worth of the political system in Tonga should not be judged in isolation, nor should comparisons be made with 'democratic' systems in other countries without careful consideration of social and cultural factors, and the wishes of the people. Forty years ago Simkin reported that while economic democracy existed as a direct consequence of the Tongan land tenure system, political democracy was much less developed. He found that the Privy Council was the supreme executive authority, that its members could dominate the Legislative Assembly, and that there were few signs of imminent adoption of a truly democratic system of government.

> The chief barrier to this development seems to be a general satisfaction of the commoners with things as they are. They have always been content to leave things to the chiefs, and have no serious grievances to stimulate them to political energy. Democratic institutions are seldom real

> or stable if they drop from the clouds; they become rooted in a society only when its people have learnt to appreciate and operate them, as a result of struggles to remove hardships. In Tonga progress towards political democracy is retarded, not so much because the present government is rapacious of power, as because it is productive of popular good (Simkin 1945, p.107).

Much has changed in Tongan society since 1945, largely reflecting changing relations with the international community, but the structure of Tonga's government remains fundamentally the same. People's attitudes to politics and the role of government have been influenced by the continuous flow of information they have received about lifestyles in other, more industrialised, countries, particularly Western capitalist societies. The relationship between the people of Tonga and their political system in the 1980s has been neatly outlined by Afeaki.

> If 'politics' is defined as a 'struggle for power', there is comparatively little of it in Tonga. Most people appear to be unaware of, or not interested in, what goes on in the government. Whether they really lack interest is another matter, but on the surface, they seem secure within their well-defined traditional social structure. ...
>
> A small number, however, have started to question the relevance of the system and the efficiency and integrity of some of the elements of persistent 'Ancient Polynesia'. Their discontent, re-inforced by their higher education and broader experience is creating political waves beneath the surface which may one day emerge naturally and profitably if given sufficient outlet. Alternatively it could erupt in a way that could be disastrous to the country (Afeaki 1983, p.57).

Tongan society is clearly changing rapidly, and there is much discussion about how political processes and the structure of government must be amended to accommodate this change. A series of interviews with respected Tongan leaders from varied backgrounds revealed a remarkable consistency of attitude towards 'Tongan Democracy'. When asked what would happen if the people were to demand a democratic system, the Prime Minister, Prince Fatafehi Tu'ipelehake GBE KBE, replied:

> That is the interesting point, democracy. My interpretation for the word 'democratic' is what could be used by the country for its advantage. Tongan democracy would be only what is good for Tonga and on that understanding Tonga's interpretation of democracy is applicable only for Tonga but not to apply Tonga's interpretation to say New Zealand or Africa (Fonua 1987c, p.35).

Prince Tu'ipelehake also stated that leadership is not something that can be learned quickly; those from families which have traditionally provided leaders will be better equipped than those who aspire to become leaders overnight. 'Inoke Faletau, the Director of the Commonwealth Foundation, used similar sentiments as the basis of his argument in favour of the Tongan system.

> We have our King who selected his Ministers from those whom he knows are experienced in their field and also understand how the government runs. They are the heads of their Ministries which provide services for the public. In Parliament we have Nobles and peoples representatives who voice the interests and concerns of the people regarding government policies. I think it is a fair system because the Cabinet Ministers can't have it entirely their way without the support of either the Nobles or the peoples representatives. The same is also applied to representative members (Fonua 1987a, p.21).

The basis of Tongans' confidence in the political system is their trust that members of the Legislative Assembly, whether elected by the people or not, have the well-being of the country as their prime concern. However, some believe that the system is not operating to optimum advantage. Laka Niu, a New Zealand trained lawyer and newly elected Tongatapu no. 2 people's representative, has expressed optimism for the future and explained that the government system implemented by Tupou I is well suited to the Tongan social structure.

> If we can get it running it will maintain our present system of government for a thousand more years. But I am sure if a foreign democratic system was introduced we would have already had civil strife as occurs in other countries. ... The nobles and the people in representation may be considered as one because you can't have a noble without his people. It is obvious that a big noble is the one

> who has the support of his people. This two-thirds majority was necessary to keep watch over the activities of the King and his Ministers (Fonua 1987b, p.13).

The three Tongans quoted above are all well-educated and have experienced life in industrial Western countries. The fact that they support a political system which non-Tongans have described as non-democratic indicates that there are fundamental differences between Tonga and Western societies. For outsiders to attempt to persuade Tonga to adopt a 'better' system would be a repudiation of democratic values. Tonga's politicians are encouraging change in their society, and as it changes so the forms of political decision-making and government will have to adapt. To be successful the new forms must be acceptable to all Tongans; precipitate adoption of an alien system could be disastrous.

The Tongan people are justly proud of retaining self-government while other Pacific countries succumbed to colonial powers (Cumberland 1960; Crocombe 1971; Kennedy 1958). King George Tupou I's motives for establishing the constitution were that Tonga should be recognised internationally as an independent self-governing nation, and that the internal stability essential for long-term independence should be ensured (Latukefu 1975; Rutherford 1977a). He resented suggestions from Wesleyan missionaries that Tonga should be annexed to Britain (Latukefu 1977). An illustration of Tonga's continued determination to jealously guard its independence is the Prime Minister's unwillingness to sign the Pacific Nuclear Free Zone Treaty on the basis that Tonga should not put itself in a position where it could be criticised by other countries resulting from possible infringements of the Treaty (Fonua 1987c).

Tonga's constitutional independence is unlikely to be seriously threatened in the foreseeable future, but the Kingdom's considerable dependence on others is bound to continue. Tupouniua (1975) identifies four categories of dependence prevalent in Pacific islands: economic, military, educational or intellectual, and cultural. During the period of the Treaty of Friendship and Protection from 1900 to 1970, Britain assumed responsibility for Tonga's foreign affairs and defence (Davidson 1971). While Tonga has developed its defence force since 1970 it would still be dependent on assistance from friendly military powers (such as New Zealand, Australia, and the United Kingdom) if a serious attack on the country were to be repelled. Such potential dependence on others for defence does not significantly affect the day-to-day lives of most Tongans, but some government activities with regard to promoting effective independence do have an impact on lifestyles. Government policies which have promoted Tonga's independence include encouraging and supporting Tongan control over inter-island and international shipping, and the establishment of the country's own airline. However, almost all development is heavily reliant on overseas finance and many projects depend on imported expertise (Walsh 1982).

While the retention of a powerful monarchy might be anathema to proponents of Western-style democracy, both the institution and individual monarchs have greatly contributed to the preservation of Tonga's independence and socio-cultural integrity. King George Tupou I's role in establishing the constitution has already been mentioned. Queen Salote, Tupou I's great-great-granddaughter, reigned from 1918 to her death in 1965. Her endearing personality made her a most valuable ambassador for the country in the international community, and her patient skill in handling domestic problems illustrated her genuine care for, and deep understanding of, all her subjects (Latukefu 1975; Wood and Wood Ellem 1977). The respect which Queen Salote Tupou III generated from the people of Tonga strengthened their trust in the system of government by constitutional monarchy. Early in Queen Salote's reign, challenges to the authority of the Tupou dynasty were launched by traditional rivals. With considerable political adroitness Queen Salote not only contained the opposition but turned difficult situations to her own advantage (Gunson 1979).

While Queen Salote strongly promoted national unity and the values of traditional Tongan culture, her eldest son, who had been educated in Australia, sought to prepare Tonga for greater interaction with the cultures of more affluent countries. On returning from the University of Sydney with B.A. and LL.B. degrees, Tupouto'a Tungi was given the Cabinet portfolio of Education. A year later, in 1944, he added Health to his responsibilities, and when he became Premier in 1949 he also took control of Agriculture and Foreign Affairs (Taulahi 1979). As well as being well-educated, imaginative, and ambitious he held higher status, in terms of both traditional and constitutional rank, than any other man in the kingdom. These characteristics combined to secure his dominant role in Government while Premier (Davidson 1971). When he succeeded his mother to the throne, King Taufa'ahau Tupou IV continued to pursue his own ambitions for the development of Tonga. The Constitution of Tonga clearly endorses the monarch's prerogative to do so: the King is Chairman of the Privy Council and appoints all its members; he has the right to veto any laws presented to him by the Legislative Assembly; he can call Parliament to sit at any time, and may dissolve it whenever he wishes; he can make treaties with foreign states (Crane 1978; Latukefu 1975). His constitutional rights to govern help him to implement his decisions but cannot help him to make the decisions which will bring optimum advantage to his country. Certainly he has the benefit of the family background which his brother, Prince Fatafehi Tu'ipelehake, thought was essential for a successful leader (Fonua 1987c). While social and political conditions are very different, there appears to be a similarity now with the times when Tu'i Tonga and Tu'i Kanokupolu were selected in traditional Tonga. Lineage determines who should be leader, but poor leadership will not be tolerated. Previously it was competing chiefs who made or broke new leaders; today it is more likely to be the commoners, who would be much less reticent now to demand change if they believed their aspirations for the future of Tonga were seriously threatened.

There is growing evidence that the relationship between the government and the commoners is developing such that the people are indeed having a greater influence on decisions which affect their lives. Much of this increasing involvement has come about because of overseas education. Of the four commoners currently in the Privy Council three have Doctor of Philosophy degrees; while this education has certainly helped prepared them for positions of responsibility and leadership, association by marriage with the hou'eiki rank has given them status in traditional terms (Afeaki 1983). Four of the six new people's representatives elected to the Legislative Assembly in February 1987 had Bachelor's degrees, making a total of six people's representatives with University education (*Matangi Tonga* 2(2), March/April 1987). While commoners are having more impact, the nobility still wield a greater degree of power for two main reasons: their traditional roles of leaders and advisers to the King; their constitutional right to control land (Ward and Proctor 1980). Political power in Tonga is thus finely balanced between the traditional status system and Western style democratic processes to give the common people more influence.

Local government as known in Western societies does not exist in Tonga, but the central government is represented by a district officer for each of twenty-one districts, and a town officer for each village. Since 1963 these officers have been elected by the people; prior to 1963 they were appointed by the Prime Minister. The role of these officers has traditionally been to relay instructions from the Prime Minister (in Tongatapu) or the Governor (in Ha'apai and Vava'u) to the people. To facilitate this the town officer can call a fono meeting at which attendance is mandatory for all villagers aged 16 years and over (Crane 1978). The fono can also be a forum for discussion of matters of particular concern to villagers, and provides opportunity for the town officer to make other relevant announcements. In towns such as Nuku'alofa there is no organised municipal government, but the traditional institutions of town officer and fono are retained in constituent villages (McTaggart 1972). A call for the development of town councils in settlements which were obviously more complex than traditional villages was made more than twenty years ago (Walsh 1964) but has not been implemented. In the absence of such councils Ministries and Departments of the national government hold responsibility for even relatively minor affairs within Tonga's towns.

2.4.3 Population

The total population of Tonga has been increasing since the first official census figures were published in 1891 (Tonga, Kingdom of, Undated). The rate of growth has varied since then in such a way that a plot of the available data approximates to a sigmoidal curve (Table 2.3, Figure 2.4). This pattern of population growth is normally expected of homogeneous populations in stable environments (Kormondy 1976). The curve for Tonga's human population does appear to indicate that the population size is levelling off. Estimates of total population made during the 1976-1986 intercensal period yielded figures in excess of the 1986 census result (Table 2.4). This was probably due to high rates of labour migration. While the total number of people in Tonga seemed to be stabilising, their distribution continued to change (Table 2.5). The population of Tongatapu continued to grow strongly, so that it represented 67.3 percent of the country's 1986 population. While the proportion resident in Vava'u has decreased steadily since 1956, from 22.0 percent to 16.0 percent, the number of people living there is still growing, albeit more slowly. In Ha'apai however the population plummeted from a high of 10 792 in 1976 to just 8979 in 1986. This represented just 9.5 percent of the total population. Actual numbers also fell in 'Eua, from 4486 in 1976 to 4393 in 1986. The remote northern islands of Niuafo'ou and Niuatoputapu added just 51 to their population in the ten years prior to 1986, and reduced their proportion of the total population to 2.5 percent from 2.6 percent in both 1966 and 1976. The pattern of regional migration in 1976 is illustrated in Figure 2.5. Regional population statistics from the 1986 census suggest that the trend of migration to Tongatapu was continuing. The decline of 'Eua's population following strong growth between 1956 and 1976 from 1925 to 4486, suggests a change in the pattern of migration to and from that island.

Migration from small to large islands, and then to urban capitals has been the pattern of movement in many countries throughout the Pacific (Crocombe 1983). Tonga's population growth has been concentrated on Tongatapu, and the greatest rise has occurred in and around Nuku'alofa. Average annual growth rates between 1976 and 1986 were 0.48 percent for Tonga, 1.03 percent for Tongatapu, and 1.50 percent for Nuku'alofa (based on calculations using data from: Tonga, Kingdom of, Undated; and Tonga, Statistics Department, Undated(b)). Between 1976 and 1986 the trend was for populations of villages in and close to the capital to increase, while the populations of rural villages declined. Of the fifteen villages located within 10 km (by road) of central Nuku'alofa, ten showed increases in population greater than the overall Tongatapu rate of increase for the ten year period of 10.8 percent; three increased by less than 10.8 percent; one remained static; and one showed a decline in population (Figure 2.6). In addition two new villages, Popua and Tukutonga, were included in the 1986 census which were not listed in 1976. Of the forty-six villages more than 10 km from central Nuku'alofa (excluding islands with populations of less than twenty), four increased their populations between 1976 and 1986 by more than 10.8 percent; six increased by less than 10.8 percent; and four changed by less than 1.0 percent. Of the thirty-two villages whose populations decreased, twelve registered a decline of more than 10.0 percent over the ten year period (Tonga, Kingdom of, Undated; and Tonga, Statistics Department, Undated(b)).

The most dramatic recent population growth has not occurred within the urban centre, but on the outskirts of the town. Of the three villages which make up Nuku'alofa, central Kolofo'ou grew by just 10.5 percent, from 9081 to 10 039,

TABLE 2.3

Population statistics for the Kingdom of Tonga 1891 to 1986

Year	Males	Females	Total
1891	-	-	19 196
1900	-	-	20 019
1911	-	-	21 712
1921	-	-	23 759
1931	-	-	27 700
1933	-	-	30 693
1935	-	-	31 873
1936	-	-	32 790
1938	-	-	33 785
1939	-	-	34 130
1956	28 938	27 900	56 838
1966	39 837	37 592	77 429
1976	46 036	44 049	90 085
1986	47 589	46 946	94 535

Sources: Tonga, Kingdom of, Undated; Tonga, Kingdom of 1981; Tonga, Statistics Department, Undated

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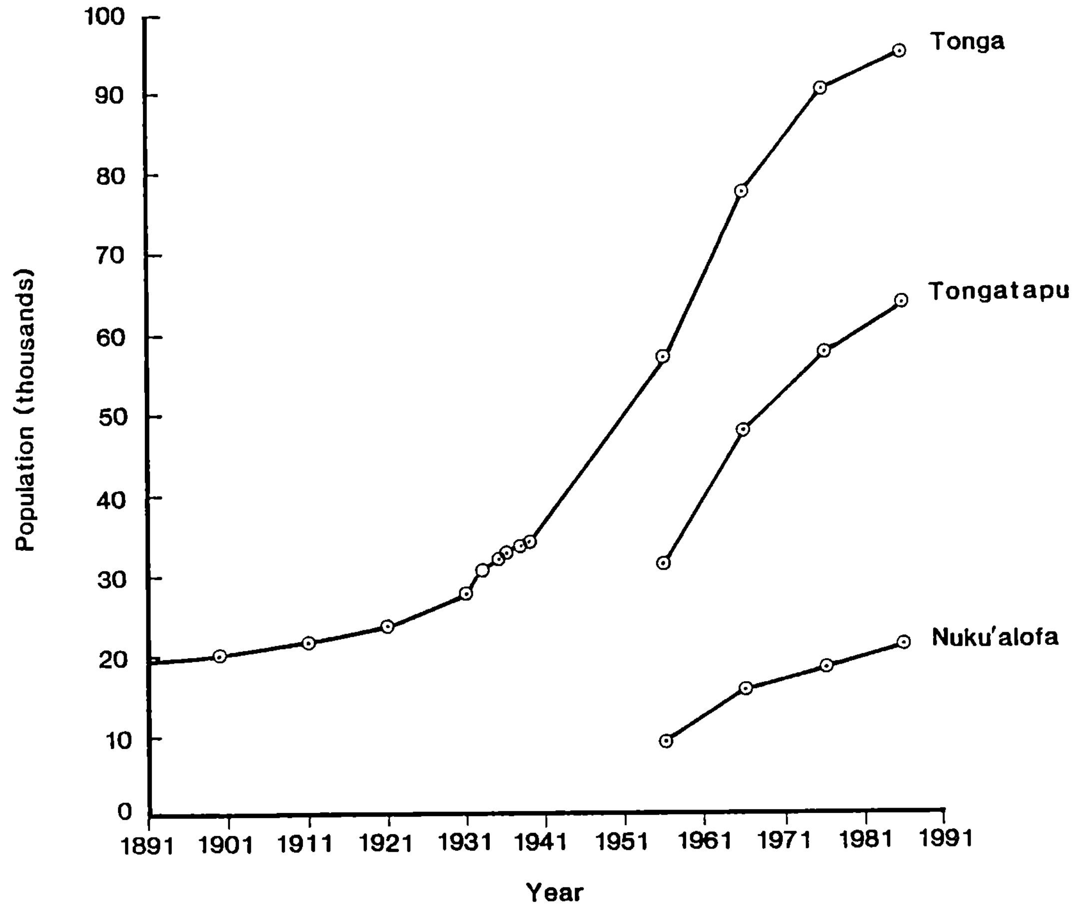
between 1976 and 1986. To the east, Ma'ufanga increased its population by 1171, 32.2 percent, to 4807 during the same period. The growth rate in Kolomotu'a to the west was 14.7 percent over the ten years, taking its total population to 6419. Strong growth occurred in several nearby villages, notably Haveluloto, Pea, Ha'ateiho, and Puke, but by far the most dramatic increase was recorded in Tofoa/Koloua with a 1986 population 198 percent greater than the 1976 figure. The number of people in the village rose from 772 to 2300, representing an average annual growth rate of 11.5 percent, twenty-four times the national average. Popua and Tukutonga, two villages to the east of Ma'ufanga which were not listed in the 1976 census, had 1986 populations of 618 and 220 respectively. The 27 469 people living in the built-up area contiguous with central Nuku'alofa in 1986 comprised 43 percent of Tongatapu's population, and 29 percent of the country's total.

FIGURE 2.4

Human population totals for Tonga, Tongatapu, and Nuku'alofa from census results between 1891 and 1986



The concentration of population near the capital town has brought about the devotion of a large proportion of government funds to this area to provide educational, health, and other services. This in turn has attracted more people to Nuku'alofa. Probably the main attraction of urban life is the prospect of obtaining paid employment, either in government service or with private enterprise. For many, gaining a monetary income is the first step on the path to emigration, either temporary or permanent, the aim of which is to earn more money. Since 1971 remittances from Tongans working overseas have comprised at least 25 percent of Tonga's national income (Connell 1986). Receipt of these relatively large amounts of money has two main effects: it increases economic dependence

TABLE 2.4

Some estimates of Tonga's total population during the 1976-1986 intercensal period

Year	Estimated Total Population	Source
1980	94 760	Tonga, Central Planning Department 1981
1982	97 000	Crocombe 1983
Mid 1982	98 000	Pacific Energy Programme 1982
1984	96 500	UNDP/World Bank Energy Sector Assessment Program 1985
1984	96 592	Tonga, Statistics Department, Undated(a)

TABLE 2.5

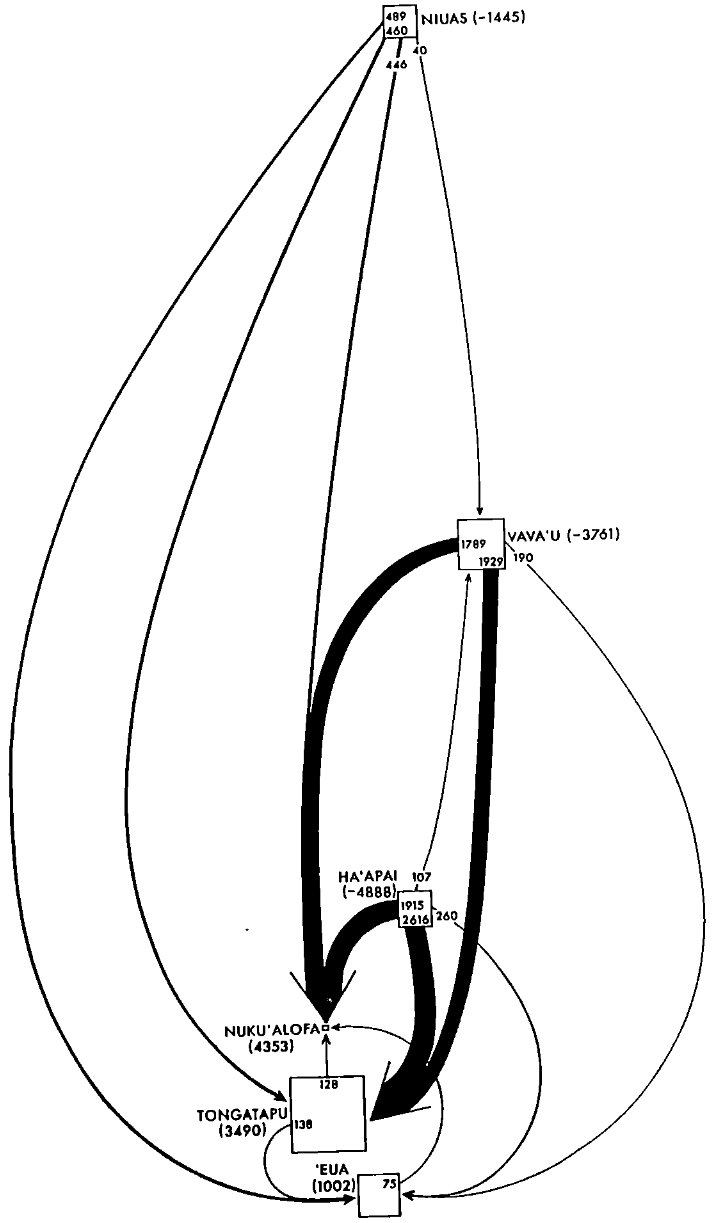
Regional population statistics for Tonga 1956 to 1986

	1956		1966		1976		1986	
Division	Number	%	Number	%	Number	%	Number	%
Tongatapu	31 264	55.0	47 920	61.8	57 411	63.7	63 614	67.3
Vava'u	12 477	22.0	13 533	17.5	15 068	16.7	15 170	16.0
Ha'apai	9918	17.4	10 591	13.7	10 792	12.0	8979	9.5
'Eua	1925	3.4	3391	4.4	4486	5.0	4393	4.6
Niuas	1254	2.2	1994	2.6	2328	2.6	2379	2.5
Totals	56 838	100.0	77 429	100.0	90 085	100.0	94 535	100.0
Nuku'alofa	9202	16.2	14 816	19.1	18 312	20.3	21 265	22.5

Sources: Tonga, Central Planning Department 1981; Tonga, Statistics Department, Undated(b).

FIGURE 2.5

Tonga: net migration, lifetime migrants aged 15 years and over, 1976



Note: 1. Persons not stated (15) and born overseas (1081) excluded.

Source: Walsh 1982, p.108.

on cash within Tonga, thereby diminishing reliance on, and investment in, subsistence production; and it enhances the attraction of industrial countries and Western lifestyles. Working overseas is not just a Tongan phenomenon; labour migration has become part of the Polynesian way of life, as illustrated by the fact that there are more Cook Islanders in New Zealand than in the Cook Islands (Crocombe 1983). Throughout the South Pacific migration has been generated mainly by 'pull' rather than 'push' factors (Low 1981). Local resources have generally been quite adequate to support relatively comfortable traditional lifestyles. With the exception of being forced to move by natural disasters, people were not induced to migrate in large numbers until their aspirations became focused on perceived social and economic advantages of Western culture. The desire to live and work in a Western society is now so great that when New Zealand initiated a visa-free holiday entry scheme, Tongans flooded into Auckland - the city with the world's largest Polynesian population. The scheme commenced on 1 December 1986; by the time it was prematurely terminated on 18 February 1987, 5000 Tongans (5.3 percent of the country's population) had left for New Zealand (*Matangi Tonga* 2(2), March/April 1987).

The ramifications of the continuous outflow of Tongans in search of greater material wealth reach all sections of Tongan society. Apart from the encouragement of internal migration the main immediate demographic effect is the impact on the age structure of Tonga's population. In 1976 there were 91.4 children and old people for every 100 aged between 15 and 64 years (Rathey 1984; Tonga, Kingdom of, Undated). Over the long-term such a high dependency ratio results largely from the trend of a rapidly decreasing death rate combined with a slowly decreasing birth rate. The situation can be exacerbated very rapidly by migration of people of working age. Dependency ratios in 'Eua and the Niuas were significantly higher than the national average, at 99.5:100 and 100.5:100 respectively (Rathey 1984). Average household sizes have decreased throughout the Kingdom, with the exception of a few villages, but most markedly in Ha'apai, the Niuas, and 'Eua (Table 2.6).

FIGURE 2.6

Map of Tongatapu showing locations of villages in five categories of population change between 1976 and 1986

Legend

● Population increased by more than 10.8 percent

○ Population increased by less than 10.8 percent

□ Population decreased by less than 10 percent

■ Population decreased by more than 10 percent

△ Population change less than 1 percent

– – – Limit of area within 10 km by road of central Nuku'alofa

TABLE 2.6

Numbers of households and average household sizes in Tonga, 1976 and 1986, by region and selected towns and villages

Region, Town, or Village	Numbers of Households		Average Numbers of Persons per Household	
	1976	1986	1976	1986
Regions				
Tongatapu	8578	9721	6.69	6.54
Vava'u	2423	2547	6.22	5.96
Ha'apai	1775	1616	6.08	5.56
'Eua	748	790	6.00	5.56
Niuas	384	417	6.06	5.71
Totals	13908	15091	6.48	6.26
Regional Towns				
Nuku'alofa	2719	3234	6.73	6.58
Neiafu	549	657	6.03	5.91
Pangai/ Hihifo	410	426	6.01	5.59
'Ohonua	211	214	6.00	5.80
Hihifo	122	123	6.04	5.64
Tongatapu Villages				
Folaha	114	115	6.47	6.14
Lavengatonga	50	54	7.02	5.65
Vaotu'u	77	69	6.79	6.74
'Ahau	45	43	6.82	6.56
Vava'u Villages				
Ofu	55	36	5.11	6.06
Feletoa	68	72	5.69	6.71
Longomapu	95	110	6.21	6.49
Tu'anuku	74	58	5.70	5.71
Ha'apai Villages				
Faleloa	90	81	6.20	5.09
Nomuka	153	132	6.31	5.21
'Uiha	116	113	6.41	5.89
Felemea	64	58	5.77	4.28
'Eua Villages				
Kolomaile	78	95	5.97	4.95
Petani	46	47	5.87	5.98
Mata'aho	45	48	6.11	5.02

Sources: Tonga, Kingdom of, Undated; Tonga, Statistics Department, Undated(b) .

2.4.4 Socio-economic characteristics

2.4.4.1 The national economy

Tonga's economy is dependent on remittances and aid from overseas. According to the retiring chairman of the Bank of Tonga in 1988, Mr Russell G. Leitch, dependence on aid will continue indefinitely (*Matangi Tonga* 3(3), May/June 1988, p.36). With imports valued at nearly T$59 million and total exports less than T$8 million, the 1985 balance of trade showed a deficit of T$51 million (Tonga, Statistics Department 1986). This deficit had risen from T$28 million in 1981 and T$37 million in 1982 (Misquitta and Rafferty 1984). In 1985 the value of imported petroleum fuels was equivalent to the combined value of all exports (Tonga, Statistics Department 1986).

Tonga's exports are dominated by agricultural produce. In 1985, coconut products, including coconut oil, copra meal, desiccated coconut, and whole coconuts, represented 48 percent of the total value of exports while all agricultural produce made up 86 percent. For the year ending 30 June 1985, agriculture, forestry, and fishing accounted for 41 percent of the gross domestic product; for 1988/1989 the figure was 39 percent (Europa Publications 1989; *Matangi Tonga* 5(4), August/September 1990, p. 34).

Cyclone Isaac in 1982 had a devastating effect on Tonga's agricultural production, reducing the value of exports to T$4.3 million from T$7.5 million in the previous year (Birman and others, Undated). Particularly hard hit was the export of coconut products (Misquitta and Rafferty 1984). While Tonga had been gauged to be in 1981 the least economically vulnerable of South Pacific states (Hamnett and others 1984), this dramatic reminder of the impact of natural disasters contributed to changes in the government's economic policy. The decision was made to actively promote greater commercialisation. The most fundamental immediate change occurred in the approach to establishing the level of government spending. The former method of basing expenditure on revenue was replaced by a budgetary system that first determined government spending, then sought ways of obtaining the funds required (*Matangi Tonga* 2(1), January/February 1987, p.10). Fiscal measures introduced in 1986 to further encourage commercial activity caused some concern within the Tongan community. From 1 July 1986 a wide range of goods and services became subject to a 5 percent sales tax. At the same time, a flat rate of income tax at 10 percent was applied to all earnings in excess of T$1600 per year. It has been estimated that these two moves increased the amount of tax paid by a householder with three children and earning T$2000 per year from T$4 to about T$75 per year. The same adjustments to tax rates reduced by about T$1500 per year the amount paid by somebody earning an annual income of T$10 000 (Fonua 1986). Included in the same budget package was the restructuring of the residential company tax, reducing rates by ten percentage points, and a 10 percent wage rise for public servants earning T$2500 or less per year. In response to criticism that the changes would lead to a widening of the gap between the 'haves' and 'have-nots', the Minister of Finance stated that it was the government's responsibility to create the right atmosphere for those who wished to make the most of business opportunities. He argued strongly that the changes in economic policy were essential to promote commercial activity and encourage foreign investment. In explaining the strategy to Nuku'alofa residents the Minister stressed the overall objective of reducing dependence on agricultural activities to move towards a commercial focus for the economy. He also stated that the two most important issues with regard to the tax reform were retaining well educated Tongans within the country and slowing down imports (Fonua 1986; *Matangi Tonga* 2(1), January/February 1987, p.10).

The objective of import substitution appears to have been subsidiary to earning foreign exchange. Expanded economic activity over the past decade has ranged across primary, secondary, and tertiary sectors. In the primary sector coconut production is still most significant. The export of bananas has been enhanced by a scheme funded by New Zealand's aid programme (Needs 1988). In 1985 banana exports accounted for 12 percent of total export value, ahead of fish exports, the third most important export commodity, at 10 percent of total value (Tonga, Statistics Department 1986). The commercial fishing industry has received technical and financial assistance from the United Nations, Australia, and Japan, to increase supplies to the domestic market as well as for export. Promotion of commercial fishing has been a valuable mechanism for channelling development assistance to islands in the Ha'apai and Vava'u groups. A cash crop from which

Vava'u, due to its favourable environment, has gained particular advantage is vanilla, which is Tonga's highest priced agricultural product (*Matangi Tonga* **2**(4), July/August 1987, p.36). The vanilla industry contributed T$0.4 million (5.6 percent) to the total value of Tonga's 1985 exports. Water melons and root crops such as yams and taro have been significant agricultural exports, and other crops such as ginger, capsicum, tomatoes, and pineapples have contributed in lesser degrees to total exports. Quantities of water melons, taro, and tomatoes exported have been affected significantly over the years by quarantine regulations, strong competition from other Pacific nations, and import quotas. Among crops assessed as possible exports, coffee was identified in 1986 as having considerable potential (*Matangi Tonga* **1**(1), September/October 1986, p.13).

The dominant groups of exported manufactured items in 1985 were knitwear (with exports worth T$330 000, 4.6 percent of total export value), mechanical excavators (T$250 000, 3.5 percent), and sports equipment (T$190 000, 2.7 percent). Hand crafted products contributed T$23 000 to the value of exports; these items included traditional baskets, mats, and tapa cloth (Tonga, Statistics Department 1986). The diversity of manufacturing and processing industries operating in Tonga has increased substantially over the past decade. This has provided to the domestic market a range of locally produced goods capable of substituting for imports. In 1986 at least one export oriented company, the Scan Tonga engineering firm, manufactured products designed specifically to meet local household needs. Other local companies produced goods ranging from footwear and furniture to solar hot water systems and fishing boats. A major initiative in import substitution came in 1987 with the establishment of the Royal Beer Company brewery.

In the tertiary sector of the economy considerable attention has been paid to the encouragement of tourism. Estimated foreign exchange earnings from tourism have increased from T$1.7 million in 1975 and T$6.0 million in 1980, to T$14.6 million in 1987 (Tonga, Central Planning Department 1981; Europa Publications 1989). The total of 32 683 air passengers arriving in Tonga in 1989 included more than 11 000 visitors from just three foreign countries: New Zealand, the USA, and Australia ('Eva, Your Holiday Guide to Tonga **6**, August/September 1990, p.1).

The Tongan government has been actively seeking private finance to improve tourist accommodation in the Kingdom. Infrastructural developments initiated directly by the government include the upgrading of Tongatapu's Fua'amotu International airport. It has recently been suggested that education and finance are both required immediately if tourism is to be significantly boosted (Tupou 1991). Education is said to be needed not only to provide a workforce for the tourist industry but also to prepare the general public to educate tourists about the Tongan way of life. Tupou considers new approaches to securing overseas finance are necessary because local financial institutions are not able to provide adequate funds for investment in tourism. Among the keen supporters of tourism in Tonga can be counted His Majesty King Taufa'ahau Tupou IV, who believes the benefits it can bring could not be attained from agriculture, Tonga's traditional major earner of foreign exchange (Fonua 1990a).

2.4.4.2 Land management

Tonga's present system of land tenure has its roots in developments in the Tongan society of the second half of the nineteenth century. The details of the evolutionary process have been described by Maude (1971) and outlined by Thaman (1976). The core feature of the process of general allocation of land to commoners is the right of each adult male taxpayer to apply for two allotments of land. This principle was formalised in the 1875 Constitution. The allocations which can be sought consist of a rural tax allotment not exceeding 8.25 acres (3.34 hectares), and a town allotment not exceeding 0.4 acres (0.16 hectares) and not less than 30 perches (759 m^2) (Tonga, Central Planning Department 1981). The 1875 Constitution also made provision for estates to be granted to chiefs. All land remains in the legal ownership of the Crown.

Security of tenure over individuals' tax and town allotments is now provided by registration with the government, which gives an indefeasible title to land (Puniani 1984). In 1985, 44 percent of Tonga's total land area was allocated as registered tax and town allotments, and 19 percent had been allocated to allotments but not registered. The next largest categories of land were 11 percent as government land (including uninhabited islands and forest reserves) and 7 percent in hereditary noble estates (Tonga, Government of, Undated). Foreign leases applied to less than 3 percent of the total land area in 1985.

In 1945 Simkin described Tonga's land tenure system as follows.

> Here is a system of tenure which recognises the importance of land as a community asset, removes it from the dangers of soil mining and commercial speculation, makes it available on easy and uniform terms, and recognises that good husbandry is more important than high rents. Economic democracy and social security are its natural consequences. Every commoner can obtain the same amount of land as his fellows and on the same terms. His allotment is sufficient to provide him and his dependants with food and with most of the other requirements of the Tongan standard of living. He need never fear unemployment, want, exploitation, debt or loss of independence. In all normal circumstances his economic welfare depends upon his own efforts (Simkin 1945, p.105).

With Tongatapu's population growing from 16 000 in 1939 to 64 000 in 1986, it is no longer possible for allotments to be provided to all those eligible to apply for them. Over the country as a whole the proportion of eligible Tongans holding a tax allotment is falling; from 42 percent to 35 percent between 1966 and 1976 (Tonga, Central Planning Department 1981). For Tongatapu the equivalent figures were 39 and 32 percent, and for Nuku'alofa residents 32 and 27 percent respectively (Thaman 1976; Tonga, Kingdom of, Undated). Many of those unable to secure registration of an allotment were still able to find land on which they could cultivate subsistence crops. Sevele (1973, p.112) claimed '... every household in Tonga could gain access to some land through one means or another'. Family ties were commonly a route to finding land. With international labour migration at a relatively high level a significant number of registered land-holders were overseas; their land was often used by others, with either informal of formal agreement with the land-holder or his representative. Some households earning adequate incomes preferred to purchase their food and so did not cultivate their land. Others used only part of the allotment(s) available to them. Those having greatest difficulty gaining access to agricultural land on Tongatapu were internal migrants from other islands, who had come to Nuku'alofa to seek paid employment. If they already had registered land on their home island they would not qualify for another allotment on Tongatapu, and unless they had relatives prepared to lend them land they would often find it difficult to make informal arrangements.

Whatever their background no Tongatapu farmers who wanted extra land for commercial cropping could find it easily. Demand for agricultural land has been so strong that high monetary payments have been required by those with powers of allocation (Needs 1988). Difficulties in attaining land have restricted villagers' abilities to undertake cash cropping at least since the 1960s. Maude reported in 1973:

> ... in Tongatapu, where the demand is greatest, the amount of spare land has decreased markedly in the last decade as a result of the allocation of allotments in the eastern half of the island, and an increase in banana planting by landholders in response to the improved market in New Zealand. Furthermore, the customary obligation to assist relatives and others, evolved in a society with a subsistence economy, applies less strongly to the rather different conditions of commercial agriculture. Men borrowing land are increasingly having to pay a cash rental. ... the ordinary landless villager finds land borrowing for cash production an increasing problem (Maude 1973, pp.173-174).

Since the early 1980s increasing additional pressures have been placed on the land by proposals for increased tourism developments and improved infrastructural facilities. Feeding the expanding construction industry with building materials has also taken up ever greater areas of land in the form of limestone quarries.

2.5 Energy resources, needs, and policies

Tongan society depends on two types of energy source: indigenous biomass and imported petroleum fuels. Biomass is used primarily for domestic purposes, particularly cooking, and petroleum fuels are consumed mainly for transport and electricity generation.

Estimates of quantities of biomass fuels used have varied. The UNDP/World Bank energy assessment team which visited Tonga in 1984 estimated total biomass energy consumption in 1983 to have been 26 170 TOE (tonnes of oil equivalent). This total included 13 500 TOE consumed in the domestic sector, 12 010 TOE in agro-industries, and 660 TOE in manufacturing and commerce (UNDP/World Bank Energy Sector Assessment Program 1985). The domestic sector consumption total was based on a tentative estimate of 400 kg of air-dry fuelwood per person per year in rural areas and 80 kg in urban Nuku'alofa. Based on survey estimates of daily usage in 486 households on Tongatapu, the UN Pacific Energy Development Programme (1985) arrived at a per person consumption figure of 1.8 kg per day, or 657 kg per year. That survey found that domestic cooking accounted for 95 percent of household woodfuel consumption; other uses being food preserving, pandanus boiling, and coconut oil making. Householders' estimates of fuelwood use gleaned by the author's interview survey yielded per person consumption figures of 2.7 kg of wood plus 1.1 kg of coconut fuels per day. Possible reasons for the discrepancies between consumption estimates are discussed in Section 6.3.2.

Of the 14 290 TOE of petroleum products reported by the UNDP/World Bank team to have been imported into Tonga in 1983, 2350 TOE (16 percent) was bunker fuel which was re-exported. Of the 11 940 TOE used in the country 2720 TOE (23 percent) was consumed for power generation, and 7990 TOE (67 percent) was transport fuel. Only 680 TOE (5.7 percent) of petroleum products was consumed in the domestic sector (UNDP/World Bank Energy Sector Assessment Program 1985). Since 1984/85 growth in electricity consumption has exceeded Government of Tonga predictions. In 1986 the Government's Energy Planner expected that the number of connections to the grid would rise from 7676 in 1984/85 to 9525 in 1989/90, and consumption from 12.0 to 14.1 million kWh per year, representing increases over the five year period of 24 and 18 percent respectively, at average rates of 4.4 and 3.4 percent per year (UN Economic and Social Commission for Asia and the Pacific 1988). The UNDP/World Bank team suggested there was a possibility that power demand on Tongatapu could grow by as much as 5 percent per year, or 28 percent over a five year period. In fact, the number of connections rose to 12 215 and annual consumption of electricity to 20.5 million kWh, representing average annual increases of just under and just over 10 percent respectively (*Matangi Tonga* 5(5), October/November 1990, p.34).

By 1990 the existing power generation system on Tongatapu could not meet peak demand. As a precursor to planning improvements to Tonga's power supply a grant from the Asian Development Bank was arranged to finance a study to assess future electricity requirements (*Matangi Tonga* 5(2), March/April 1990, p.31).

Motor spirit consumption rose from 4.17 to 5.31 megalitres between 1980 and 1983; 5.82 megalitres were imported in 1985 (UNDP/World Bank Energy Sector Assessment Program 1985; Tonga, Statistics Department 1986). A 66 percent increase in the quantity of motor spirit imported between 1984/85 and 1989/90 has been reported, accompanying a 95 percent increase in annual new vehicle registration (*Matangi Tonga* 5(5) October/November 1990, p.34). This increase in demand for transport fuels is reflected in increased traffic congestion on Tonga's roads.

In 1984 energy consumption in the average home, whether rural or urban, was dominated by the use of fuelwood for cooking. The UN Pacific Energy Development Programme (1985) found that less than 5 percent of rural households and less than 20 percent of urban households had switched entirely to other cooking fuels. However, a significant proportion of monetary income was spent on commercial fuels and electricity. The mean annual amount spent per person on commercial energy in urban areas was T$53.06 (12 percent of income) for domestic use, and T$12.94 (3 percent) on petrol and diesel. Equivalent data in rural areas were T$28.76 (9 percent of income) and T$16.36 (5 percent) respectively (UN Pacific Energy Development Programme 1985). The gross energy content of non-wood household commercial fuels and electricity, excluding batteries, used annually by the average urban resident totalled about 1090 MJ, and for the average rural resident about 650 MJ. These figures represent approximately one eighth and one seventeenth of the gross energy content of the fuelwood consumed by the average urban and rural residents respectively. Energy contents of petrol and diesel fuel used were about 870 MJ for urban residents and 1200 MJ for rural residents. Adding these data to the consumption of household fuels gives an overall ratio of gross energy contents between fuelwood and non-wood commercial energy (excluding batteries) of approximately 5 to 1 (calculations based on data from UN Pacific Energy Development Programme 1985).

A higher proportion of urban than rural households used electricity for lighting, while for kerosene the reverse was the case. More than two-thirds of households in the urban area used electric irons compared to about one-third of rural households. Other electrical appliances in use in 1984 ranged from electric jugs to video machines and freezers; all were more common among urban than rural households (UN Pacific Energy Development Programme 1985).

In manufacturing and service industries there has been a trend away from biomass fuels towards electricity and petroleum fuels. For example, in 1985/86 two of the main bakeries in Nuku'alofa replaced their wood-fuelled ovens; one with electric ovens, the other with oil fired equipment. This move away from wood is likely to have been influenced by the decline of sialemohemohe (*Leucaena ieucocephala*) following the attack by the psyllid *Heteropsylla cubana*. Many of the operations carried out by small industries required electricity to run machinery. Where biomass fuels remained of greatest value was in heating air or other media for drying. For example, at a small scale, mixtures of coconut waste and wood were burnt in village copra dryers, and at a large scale, coconut husks fuelled the boiler raising process steam at the desiccated coconut factory.

Increased and more efficient utilisation of biomass fuels has featured prominently among proposals for improving Tonga's energy situation. The use of senile coconut stems to fuel a 3 MW steam turbine power plant at the Popua power station was suggested by an energy assessment mission which visited Tonga in 1982. The mission believed sufficient senile coconut trees could be made available on Tongatapu on a 62.5 year rotation (Pacific Energy Programme 1982). The UNDP/World Bank team which visited in 1984 recommended the economic feasibility of using the same resource to fuel a 1.5 MW power station be investigated (UNDP/World Bank Energy Sector Assessment Program 1985). There are two readily applicable technologies which could use fuelwood to generate electricity: steam production and by gasification. Both could be adopted at a range of scales appropriate to Tongan industries and power plants and could be adapted for co-generation of electricity and process heat. There is a range of technologies available for using biomass resources to provide process heat via the media of air, steam, water, and oil. Using automated feed mechanisms operation of such equipment is convenient, so that if adequate quantities of suitable fuel are available these technologies could provide valuable alternatives to electricity. The impact on domestic energy supplies of biomass fuel use by industry and the Tonga Electric Power Board would depend in the short term on the type of fuel, the quantities used, sources, and methods of collection. For example, to adopt the proposal to utilise senile coconut stems for power generation would rely on secure supply of stemwood to the power plant. This would need a procedure to ensure that:

1. a practical plan be devised for scheduling the felling of senile stems;
2. all stems cut be transported to centralised locations for milling;
3. all offcut material be transferred to the power plant for use as fuel.

If the coconut stemwood resource could not be guaranteed for a steam power plant, the Pacific Energy Programme (1982) mission recommended the option of retrofitting a gasification system at the Popua power station. The gasifier would be fuelled by coconut husk and shell. The total quantity of fuel required would be less, because the gasifier system has a better conversion efficiency. However, the impact on domestic users could be greater than with the steam system, as husk and shell is more commonly a major household fuel than is stemwood. Which communities were most affected would depend on whether the husk and shell used was taken from stocks normally sold to urban residents or brought directly from rural areas. Similar variations in impact would apply if the consumption of fuelwood by industrial enterprises were to rise.

The alternative power source which has been given most serious attention for Tongatapu over the past seven years is wave power. Wave monitoring equipment has been installed at a potential site, but economic and technical difficulties have so far prevented the project from proceeding further. Other options for centralised electricity generation which have been put forward include nuclear power and the incineration of hazardous wastes imported from the U.S.A. (*Metangi Tonga* 6(1) January/February 1991, p.8; *Metangi Tonga* 3(3) May/June 1988, pp.19-22). The potential of a range of other alternative energy sources for utilisation in Tongan conditions has been discussed by Birman and others (Undated).

With regard to meeting domestic energy needs at the household level, trials have been undertaken of photovoltaic systems to meet the most common needs: lighting, small appliances (such as radios), and charging of dry cell batteries. Such systems are better suited to the smaller, more remote, islands and are unlikely to represent an economically feasible option for Tongatapu. The main area of assistance offered for improving energy systems in Tongatapu's low income assistance offered for improving energy systems in Tongatapu's low income households has been the promotion of woodfuel burning stoves. Programmes of design and dissemination have been conducted by the University of the South Pacific through its Institute of Rural Development, by the UN Pacific Energy Development Programme through the Energy Planning Unit, and by the Foundation for the People of the South Pacific. Stove types offered cover a wide range, from a single pot charcoal stove to a concrete three pot stove, and a bench incorporating a drum 'umu along side an open fireplace. Acceptance of stoves varied considerably between households. Only 2 percent of households included in the UN Pacific Energy Development Programme (1985) survey owned wood or charcoal burning stoves. In 1986 the Scan Tonga engineering company started making wood burning domestic cooking stoves from mild steel sheet. The construction cost of about T$250 put it out of the price range of most households. Harwood (1985) recommended that while there was a large potential market for wood burning stoves in Tonga, further assessment of the acceptability of various stove types by Tongan households was required. He suggested the establishment of a stove demonstration centre in Nuku'alofa, and a programme of field trials to be coordinated by the Government's Energy Planner.

It is not possible to discuss the full range of energy issues, but those of most concern to the National Energy Planner in 1986 were:

> (a) the continued exploration and study of indigenous energy resources for fuelwood use; (b) the continued development of energy alternatives in order to reduce dependence on imported fuel; (c) the economizing of the use of all energy resources, both imported and indigenous, through the implementation of appropriate conservation measures; (d) the creation of a National Energy Act which will set standards for the Kingdom with respect to energy usage; (e) the gradual phasing in of an electricity tariff pricing structure which reflects the total cost; (f) the promotion of the involvement of private sector in the development of alternative energy and conservation methods, and initiation of demonstration, education, and training activities; (g) the establishment of codes to ensure energy efficiency in new building construction and energy using installations; and (h) the provision of adequate energy, particularly electricity, for

> domestic, commercial and industrial uses at the lowest possible real costs for all uses (UN Economic and Social Commission for Asia and the Pacific 1988, p.93).

In essence these issues of concern express the government's desire to minimise expenditure of foreign exchange while still providing adequate energy resources to meet subsistence and development needs. Methods identified to achieve this are substitution of imported petroleum fuels by indigenous energy sources, and increased efficiency of energy utilisation. Techniques for implementing these changes include regulation, pricing strategies, and education, each of which can be carried out through government mechanisms. Further development of alternative energy sources will require technical assistance, but is still seen to operate under government supervision.

3. A REVIEW OF APPROACHES TO DEVELOPMENT AND FUELWOOD ISSUES IN DEVELOPING COUNTRIES

The two main aspects of the aims of this research programme both address fuelwood problems in developing countries; first at a very broad level, and then with regard to a specific location. Before proceeding to the details of the Tongatapu research, some significant aspects of fuelwood and development issues at the international scale are briefly examined in order to expand the impression provided of the context in which Tongatapu's fuelwood situation is located.

3.1 An assessment of the role and significance of fuelwood in developing countries

It has been estimated that wood provides about 10 percent of total human energy consumption each year; less than oil, coal, and natural gas, but twice as much as nuclear energy (Foley and others, Undated). This statement severely underestimates the significance of fuelwood to the maintenance of human life. Some two thousand million people rely on wood to meet their everyday energy needs, particularly cooking (Foley 1985). The contribution made by fuelwood to human well-being is, therefore, much greater than its provision of 10 percent of total energy consumption implies. Wood is predominantly, though not solely, used by people with essentially subsistence lifestyles who cannot afford to purchase the commercial alternatives (Cecelski, Dunkerley, and Ramsay 1979; Foley 1983; Howes 1989). The extra significance this gives the supply of woodfuels has been acknowledged by the World Bank.

> At present rates of exploitation, accessible forest resources in many countries will be practically obliterated within 20 to 30 years. The situation is a grave one, not only because biomass fuels are an important energy source, but because they are used by the majority of the population who have no real alternative other than a deterioration in living standards (World Bank 1983, p.9).

Accurate totals of woodfuel consumption are virtually impossible to attain, but FAO estimates over the past forty years indicate a steady increase in production volumes. Madas (1974) cites average annual world consumption figures of 866 million m^3 for 1950/52, and 1088 million m^3 for 1960/62. Madas expected fuelwood consumption to continue to rise until 1980 and then to decline, to give an annual world consumption in the year 2000 between 1000 and 1200 million m^3. FAO data for the years 1977 and 1987 show a 29 percent increase in world fuelwood and charcoal production, from 1329 to 1719 million m^3 (FAO 1989). Their estimates for the component relating to developing countries interestingly show a lesser rise of just 25 percent, from 1153 to 1444 million m^3, but the developing countries' proportion of world production was still well over 80 percent. While the recent FAO estimates significantly exceed Madas's forecasts, they are almost certainly underestimates of actual fuelwood consumption figures. Openshaw (1978) reports survey results indicating that in some areas actual consumption of woodfuel could be as much as twenty times that suggested by official statistics. Openshaw estimated that world woodfuel consumption in 1976 was 3050 million m^3 rather than the official figure of 1184 m^3. He suggested that woodfuel represented not the official 47 percent but 63 percent of world wood consumption.

Whatever the true total consumption, surveys have shown that the energy content of wood used per person for cooking in developing countries is very much greater than energy consumption for comparative tasks in developed countries. Hall, Barnard, and Moss (1982) reported biomass energy consumption figures for surveyed villages in nine developing countries to range from 5.3 to 27 gigajoules (GJ) per person per year. Foley (1983) assumed a per person average of 12 GJ as the basis for a family figure of 72 GJ, which was more than twelve times the equivalent 5.9 GJ used for cooking by the average U.K. family.

Surveys in developing countries have repeatedly shown that per person consumption varies considerably between countries, between urban and rural locations, and with characteristics of individual households (Openshaw 1978; Hall, Barnard, and Moss 1982; Ghosh 1984; Leach 1987). Reasons for these variations are not simply direct economic factors such as monetary price, costs in terms of labour input, and the availability of substitute fuels. Features of the physical environment, such as climate, and of the social environment, such as traditional cooking practices, combine in patterns unique to each community. Seasonal variations in consumption reflect, for example, constraints on fuelwood collection by weather conditions, and extra consumption for special social events.

Irregular changes to requirements occur due to events such as increases in household size and adoption of new cooking practices.

The significance of changes in fuelwood consumption to human well-being depends on the nature of the modification and on the situation of the individual or household. Changes relate either to an upgrading or a downgrading in fuel energy utilisation. If a family consumes less fuelwood because it is using a greater quantity of commercial fuels, well-being is likely to be improved. On the other hand, if fuelwood is being replaced by crop residues or animal dung, deleterious effects can be expected. In the first case, the change probably followed a decision to invest surplus income with the specific aim of improving the family's living conditions; in the second case, the change was almost certainly forced by deteriorating circumstances. The seriousness of households being pushed into downgrading their domestic fuel consumption has been widely recognised (World Bank 1983; Pachauri and Pachauri 1985; Munslow 1988). Sadly, this recognition has not been matched by solutions.

Fuelwood issues are but one facet of human-environment relations that present formidable difficulties in many societies that are attempting to 'develop'. There are many different perspectives on what development means. Aspects of a range of approaches to development issues are briefly discussed in the following section.

3.2 Approaches to development in rural areas of developing countries

Development is a broad term which carries a variety of meanings depending on users and context. To quote Utsunomiya:

> The word development is ambiguous, imprecise and is surrounded by confusion and disagreement. Conventional approaches to development are insufficient to cope with the issues of new social problems. We are badly in need of a new conceptualization of development (Utsunomiya 1980, p.4).

In an attempt to reduce the ambiguity the Independent Commission on International Development Issues stressed that development should not be confused with growth; that:

> ... the prime objective of development is to lead to self-fulfilment and creative partnership in the use of a nation's productive forces and its full human potential (Brandt 1980, p.23);

and that:

> Development is more than the passage from poor to rich, from a traditional rural economy to a sophisticated urban one. It carries with it not only the idea of economic betterment, but also of greater human dignity, security, justice and equity (Brandt and others 1980, p.49).

Harrison explains that while consensus exists on development needing to bring about 'the eradication of absolute poverty and hunger and want' (Harrison 1983, p.342), what else is meant by development is wide open. While meanings of development are seldom explicitly defined, variations in objectives are clearly illustrated by different approaches. From the conventional Western perspective economic growth and development have often been viewed as being synonymous, or at least inextricably linked. Even when the main goals of development are conceded to be non-economic, the route proposed for achieving those goals has usually been the pursuit of economic growth through changes to be made at the national level. For example, the public document outlining the proposals for the second United Nations development decade opened its explanation of the meaning of development as follows.

> It cannot be over-emphasized that what development implies for the developing countries is not simply an increase in productive capacity but major transformations in their social and economic structures. Their economies are characterized by dualism which has often the effect of making technological and economic advances sharpen the contrast between their modern and backward sectors and widen social and economic disparities. There are inequalities and rigidities in their social structures emanating from systems of land tenure, administrative

> hierarchies, educational systems and inadequate educational opportunities, external forces, and various traditional practices and customs. Within this framework, an increase in output or income only represents one of the indicators of development (UN Department of Economic and Social Affairs 1970, p.5).

The social criteria for development are thus explicitly acknowledged, but their significance is apparently dependent on their roles as precursors to entry into the global economic system. Improvements in income distribution, employment, education, health, and food supplies are seen as factors contributing to economic change as well as resulting from it. Sustained increases in per person gross product are considered to be essential to the process of social change (UN Department of Economic and Social Affairs 1970). Gillis and others (1983) make a clear distinction between economic growth and development. They say that economic development implies:

> ... growth *plus* fundamental changes in the structure of the economy, a rise in the share of national product originating in the industrial sector, urbanization, participation by the nationals of the country itself in the process by which these changes are brought about (Gillis and others 1983, p.68).

Having made this distinction they go on to argue that growth is essential if meaningful economic development is to be achieved.

> If there is no growth, then some people can be made better off only by taking income and assets from others. In poor countries, even if a few people are very rich the potential of this kind of redistribution is severely limited. Even if the metaphorical pie were cut into precisely equal pieces for all, the slices would be very thin indeed.
>
> Economic growth, by contrast, opens up the possibility of making at least some people better off without having to make anyone worse off (Gillis and others 1983, pp.68-69).

A brief summary of changes in attitude towards development was included in the World Bank's 1985 World Development Report. Following World War Two the dominant belief was that adequate transfers of capital to developing countries would raise production and incomes, in a similar fashion to the successful Marshall Plan in Europe. Investment was directed to industrial equipment and infrastructure such as roads. This push towards industrialisation was largely in keeping with what Rostow's model had predicted was required for a country to 'take-off' into self-sustaining economic growth (Myint 1973). However, developing countries' policies of import controls aimed at fostering domestic industrial growth severely distorted the value of products on the international market and protected inefficient enterprises. These difficulties were counteracted by the subsequent adoption of more open, market-oriented policies. It was not until the 1970s that the appropriateness of centralised, economic approaches to development was seriously questioned. Increasing numbers of economists realised that the Rostow model which described the stages of industrialisation in Europe was, by and large, not applicable to Third World situations. The inappropriateness of expecting the British Industrial Revolution to be replicated throughout developing countries was acknowledged in economics texts (Myint 1973; Lobley 1976; Gillis and others 1983).

> A number of economic studies of the relationship of economic growth and income distribution, as well as more casual observations of the incidence of poverty in individual countries, led some economists and aid supporters to conclude that the major beneficiaries of development efforts had often been the middle- and upper-income groups; growth had not 'trickled down' to the poor (World Bank 1985, p.98).

The efforts of governments in developed and developing countries, and of bilateral and multilateral aid organisations, were seen to be inadequate or inappropriate to meaningfully improve the lot of the poor. A great deal of money had been invested in development projects which did not achieve their goals because they had not been appropriate to local conditions. Development assistance agencies had to acknowledge that the meaning they had conventionally placed on 'development' was quite different from what those they were aiming to help believed the term to mean. Perhaps the most significant outcome of this realisation was the increased effort put into formulating approaches to development which would ensure satisfaction of basic needs. Over the past two decades a broad spectrum of approaches has developed. Different approaches are needed to suit varied cultural and ecological conditions.

> A people aware of their cultural identity can adopt and adapt elements true to their value-system and can thus support an appropriate economic development. There is no uniform approach; there are different and appropriate answers depending on history and cultural heritage, religious traditions, human and economic resources, climatic and geographic conditions, and political patterns of nations. But there is a common notion that cultural identity gives people dignity (Brandt 1980, p.24).

Approaches to development are not only numerous and varied, but constantly increasing in number and variety. Both starting points and goals are forever in a state of flux. The availability of resources required to facilitate developmental activities changes continuously, and expectations of what development can achieve are constantly modified by exposure to more information about life on 'the greener side of the fence'. Not only do individuals' views of development change; so do the aspirations of whole societies. As indicated by the World Bank's interpretation of changing perspectives of development, summarised above, the attitudes of developed country institutions also have an important bearing on strategies followed in the pursuit of development.

In order to study and comment on different approaches to development it is necessary to adopt a framework of categorisation to which discussion can be related. The perspective of the analyst can materially influence the way in which approaches are described and compared. One analysis of development strategies and one approach to the classification of development theories are briefly outlined here.

Griffin (1989) has presented a classification of six distinct strategies of economic development; these are:

1. a Monetarist strategy, which concentrates on enhancing the efficacy of the market in allocating resources;
2. the Open Economy strategy, also relying on the market but emphasising foreign trade and foreign investment as the leading sector;
3. Industrialisation, achieving growth through the rapid expansion of the manufacturing sector;

4. the Green Revolution strategy, focusing on agricultural growth;
5. Redistributive strategies, designed to give priority to measures directly benefiting the poor; and
6. Socialist strategies of development, distinguished by state and collective ownership of productive assets, accompanied by central economic planning.

While advocates for each type of strategy would no doubt argue that in every case the ultimate aim was development of the whole society, initial advantages would be gained by different sectors depending on the strategy adopted. The strategies can be grouped according to which components of society would be most likely to receive these immediate advantages. Strategies 1 to 4 operate largely through encouraging commercial activity by those individual members of society who already have control of resources surplus to their basic requirements, and who are therefore amenable to taking risks in investment. Within category 6, the socialist strategies, Griffin identifies four approaches to economic development. Each utilises strong investment in the accumulation of capital. Characteristics of societies following such strategies are:

> ... a scarcity of personal services, a fairly uniform distribution of consumption goods among households and a relatively even spread of the benefits of growth (Griffin 1989, p.31).

The redistributive strategies, category 5, attempt to achieve aspects of both the capitalist and socialist approaches. Griffin outlines three strands within this category. The first emphasizes the creation of employment for the poor; the second promotes directly sharing with the poor the wealth gained from economic growth; the third gives priority to the satisfaction of basic needs.

Consideration of the contrasts between the basic needs approach and the alternative options illustrates the variations in the meanings of 'development'. Capitalist strategies require reinvestment of income for the benefit of those sectors of the economy which the market declares will yield greatest profit. Similarly, under a socialist strategy, reinvestment is required for capital formation. The basic needs approach directs income to those lacking benefits enjoyed by other members of the society, thus moving towards greater equality. Related to this redistribution of wealth is political empowerment of the poor which Griffin says implies '... a qualitative transformation of the relationship between the governed and those who govern them' (Griffin 1989, p.31).

Corbridge (1988) constructed a framework for describing theories of development based on a somewhat different pattern of categorisation. His first category encompasses the liberal theories of development, all focusing on the roles of the market and of comparative advantage. These theories are based on the underlying assumption that 'all societies lie along the same continuum between tradition and modernity' (Corbridge 1988, p.34). It follows that the task needed to achieve development is simply to progress along this route. The focus of Corbridge's second category is not the inevitable achievement of development, but the unavoidable 'development of underdevelopment'. It is based on Neo-Marxist theory which challenges the notion of comparative advantage. Instead the Third World is identified as the periphery to the metropolitan core. Through the capitalist system surpluses are transferred from the bottom to the top; from the poorer sections of developing countries to the elite, and thence to the metropolitan rich. Corbridge quotes Andre Gunder Frank as saying:

> ... at each stage along the way the relatively few capitalists above exercise monopoly power over the many below, expropriating some or all of their economic surplus and, to the extent that they are not expropriated in turn by the still fewer above, appropriating it for their own use ... at each point the international, national and local capitalist system generates economic development for the few and underdevelopment for the many (Frank 1969, p.7-8, quoted in Corbridge 1988, p.37).

The third category in Corbridge's analysis includes three strands of Marxist theories of development. The first perceives metropolitan capitalism as forcing its way into traditional economic systems because its domestic markets cannot yield an expanded surplus. Having initially supported the pre-existing economic system, as it takes firmer roots in the society capitalism comes to subordinate and eventually remove the pre-capitalist mode. A second strand of Marxist theory claims that:

> ... for Marx, capitalism, and indeed imperialism, is always progressive and is everywhere associated with an increase in democracy, individual freedom, scientific rationality and undreamed of technological advance (Corbridge 1988, p.43).

The considerable industrialisation of developing countries since World War Two is seen as totally consistent with Marxist theory, and is indeed welcomed as 'a precursor to global revolution and the transition to socialism' (Corbridge 1988, p.43).

Those who support the third strand of Marxist theory outlined by Corbridge reject the claim that the extension of industrialisation into the Third World periphery is developmental. Instead they argue that the new international division of labour does not alter the structure of inequality but rather exploits cheap labour, with the collaboration of repressive elite regimes, for the benefit of trans-national corporations. Economic growth is instigated, but because the new economies are confined to local enclaves development is not achieved.

While all the theories Corbridge examined made some valid contribution to the understanding of the impacts of capitalism on developing countries, none, in its own right, was considered adequate.

> ... each tends to mistake one conjuncture, one configuration, within the capitalist world system for the 'essence' of that system. Similarly, there is a tendency to privilege either structure over agency, or agency over structure, to the extent that the reproduction of each is guaranteed only by the dogmatism of concepts (Corbridge 1988, p.64).

Corbridge was optimistic that shortcomings of these dogmatic theories could be overcome by work being carried out by a number of development and industrial geographers and other scholars, in particular the Regulationist school of French post-Marxists. Their approach used a 'regime of accumulation' and a 'mode of regulation' to model capitalist development and crisis in the twentieth century. The role of social change in influencing national components of the global system was acknowledged, as was the impermanence of global economic patterns (Corbridge 1988). While such an approach is more likely than the liberal, neo-

Marxist, and Marxist theories to satisfactorily explain global economic development, it will be of little direct value to those in developing countries who wish to improve their own and their neighbours' living conditions. As with most theories of development this approach is global in scale and Western in perspective.

Proponents of alternatives to the extension of metropolitan capitalism into the Third World do not claim that industrialisation is unnecessary or intrinsically evil, but base their condemnation of the capitalist system on criticisms of the manner in which recent industrialisation has proceeded. Hayter (1981) stated that industrialisation would be required to raise a society out of a state of underdevelopment; the problem was that governments had very largely been persuaded to promote only industries which directly benefited foreign companies and investors. Nearly twenty years ago Eppler predicted that adverse social impacts could outweigh economic advantages generated by capitalist economic growth.

> Whatever the one or the other of us in our country may wish, we should start from the knowledge that in the social sphere, too, continuous development is much less likely in many countries than the dramatic and sometimes forcible release of tension. Wherever we look we come to the same conclusion: in the Third World the white man has started something for which the term 'development' is not an accurate description but a euphemism. The continuation of what was and what is does not by a long chalk add up to a future. Nothing swings back into line.
>
> ... It will require a planned, purposeful, joint international intervention if this course is to be altered in time. The Third World has not much time left (Eppler 1972, p.23).

Schumacher also observed that the intrusion of capitalism into developing countries had not resulted in development.

> One of the unhealthy and disruptive tendencies in virtually all the developing countries is the emergence, in an ever more accentuated form, of the 'dual economy', in which there are two different patterns of living as widely separated from each other as two different worlds. ...

> In the dual economy of a typical developing country, we may find fifteen per cent of the population in the modern sector, mainly confined to one or two big cities. The other eighty-five per cent exists in the rural areas and small towns. ... most of the development effort goes into the big cities, which means that eighty-five per cent of the population are largely by-passed. What is to become of them? (Schumacher 1974, pp.159-160)

Schumacher's book 'Small is Beautiful' had a seminal influence on development theory not only through its original critique of the Western economic system, but also by presenting the foundations of an alternative approach to development. Having assessed the shortcomings of capitalist industrialisation in the Third World and examining the conditions of those excluded from the modern sector in developing countries, he concluded that smaller political units should be employed to facilitate development to benefit those with the greatest needs. Implementation of new and appropriate modes of production would require technologies suited to local conditions and affordable by the local population. 'Intermediate' technology was seen to be:

> ... immensely more productive than the indigenous technology (which is often in a condition of decay), but it would also be immensely cheaper than the sophisticated, highly capital-intensive technology of modern industry. At such a level of capitalisation, very large numbers of workplaces could be created within a fairly short time; and the creation of such workplaces would be 'within reach' for the more enterprising minority within the district, not only in financial terms but also in terms of their education, aptitude, organising skill, and so forth (Schumacher 1974, pp.175-176).

Growing awareness that the spreading of capitalism into Third World countries was not bringing about what most people expected 'development' to achieve, has led to considerable attention being put into seeking alternative strategies. Over the past two decades concerned individuals from various sectors of Third World and Western societies have worked towards improving living conditions for all inhabitants of developing countries. While the fundamental requirement to eliminate absolute poverty has been virtually universally acknowledged, approaches to development range across a broad spectrum. The dominant view in Western societies remains that economic growth must be pursued as vigorously as possible. The global economic system is seen by many as the only feasible mechanism for adjusting the distribution of wealth between developed and developing countries. Continuing belief in the supremacy of comparative advantage and the 'open' market tends to lead more conservative Westerners to consider that overcoming poverty is a task for developing countries themselves to undertake once they have profited from involvement in the international economy. More and more Westerners are accepting the opposing philosophy, that developed countries are the ones who gain most from capitalist exploitation in the Third World. This leads them to acknowledge their responsibility for contributing towards the maintenance of at least basic living conditions for those adversely affected by destructive changes to traditional modes of production.

There is, of course, also a strong humanitarian drive in most people to alleviate the suffering of other human beings. Emotional responses are ridiculed by economic rationalists for being subjective rather than objective. This is a spurious and nonsensical complaint. Rather, to base the formulation of plans for global development on a perceived need to gain a narrow bundle of benefits for a (relatively) small number of people over a very short period of time is itself much more subjective. Such a stance relates only to a self-centred minority and not to the real situation which can be properly understood only by a comprehensive evaluation that includes acknowledgement of the needs of others.

By the mid-1980s academics involved in the assessment of advances in developing countries were aware of numerous constraints in social and political as well as economic institutions. Factors adversely affecting activities designed to yield social and economic development were identified at all levels.

> Economic growth in many developing countries has stagnated in recent years because of the world recession and the adoption of monetarist policies in the industrial countries. In a number of Third World nations, these problems have been exacerbated by political indifference, corruption and poor economic management. In the political sphere, human rights and freedoms have often been suppressed by dictatorship. The power of military elites, who often rule Third World countries directly, has

> adversely affected economic performance through the continued diversion of scarce domestic resources for security purposes. ... Social inequalities remain marked and, in spite of progress in health and education, differential access to the social services has compounded an uneven process of social development which has characterized many developing nations (Midgley 1986, pp.1-2).

Proposals for extending meaningful social and economic development to all sectors of society mostly seek to involve the active participation of the beneficiaries in development projects. Several role models have been used to express the types of activity considered to be successful in making positive changes where they are most needed. The Gandhian approach of making more effective use of resources available within a village to achieve changes desired by that community has been broadly recognised as relevant to current conditions in poorer communities (Harrison 1983; Grant 1990; Brodhead 1988). Sarvodaya ('the welfare of all') organisations are very active in promoting local development activities in India and Sri Lanka (Brodhead 1988; Ariyaratne 1981). Another example of the utilisation of Gandhian principles is the Intermediate Technology Development Group, founded in 1965 by Dr E.F. Schumacher. This organisation has promoted, and provided technical expertise to assist with, the design and construction of diverse technologies suited to village conditions. One example of a successful programme is the dissemination of wood-burning stoves to rural and urban communities in Sri Lanka (Navaratna 1983; Stewart 1983; Ceylon Electricity Board and Intermediate Technology Development Group (UK) Undated). While large numbers of imposed development projects have failed, there are examples of successful activities around the world which can provide useful lessons in how steps can be taken to at least start to overcome poverty (Aziz 1978; Gregersen 1982; Stewart 1985; Leach and Mearns 1988). A characteristic they have in common is the recognition of local conditions, not just the physical environment and technical facilities but human needs, aspirations, and constraints.

In his analysis of how outsiders approach rural development issues in the Third World, Chambers (1983) suggests there are two groupings of development workers. The differences between the groups are so great that he describes them as different cultures:

> ... a negative academic culture, mainly of social scientists, engaged in unhurried analysis and criticism; and a more positive culture of practitioners, engaged in time-bounded action (Chambers 1983, p.28).

Chambers categorises the explanations of rural poverty generally adopted by these cultures as the political economy cluster and physical ecology cluster of explanations. While there are several distinct schools of thought among the 'negative academics' who adopt 'political economy' explanations, they agree on a central concept that rural poverty is 'a consequence of processes which concentrate wealth and power' (Chambers 1983, p.37). These processes are seen to act at three levels: internationally, through colonial and post-colonial exploitation; nationally, by the urban middle class gaining at the expense of the rural poor; and locally, by rural elites consolidating their power and wealth. For positive practitioners adopting the physical ecology cluster of explanations, rural poverty is commonly attributed to 'population growth and pressures on resources and the environment' (Chambers 1983, p.38). While there are factors, such as war, which both camps recognise, neither grouping is likely to include in their analysis information about all the complex interactions which would be required to achieve a comprehensive understanding of the causes of rural poverty. Chambers suggests the best aspects of the two approaches should be utilised in developing a new framework for tackling rural poverty.

> A balanced pluralist approach, empirically based and with a wide span in both political economy and physical ecology, is more likely to fit the reality and reveal what best to do.
>
> This pluralism is an ideology based on doubt, puzzlement, and agnostic openness to evidence and argument. It seeks enlightenment in both poles of contrary views, in practice seeing error less in what people say than in their condemnation of what others say. It is multidisciplinary by commitment. ...
>
> Pluralism in rural development is also a way of life. It demands straddling - between academic analysis and practical experience and between the social questions of political economy and the material questions of physical ecology. This is not easy (Chambers 1983, pp.44-45).

The pluralist approach to rural development depends on its third leg:

> The two cultures - academic and practical - share the top-down, core-periphery, centre-outwards biases of knowledge. Both are therefore in danger of overlooking that other approach to understanding, from the bottom up, from the periphery towards the core, from the remote towards the central. For the two cultures are cultures of urban-based outsiders. The third culture, of the rural people in a particular place, is the true centre of attention and of learning. ... To understand rural poverty better, and to judge better what to do, outsiders, of whatever persuasion, have to see things from the other end (Chambers 1983, p.46).

In recent years outsiders attempting to instigate rural development have sought to achieve better understanding of the needs of rural people and of likely constraints to the successful implementation of development projects. Agencies which have traditionally followed the top-down approach have begun to investigate methods of establishing closer and more balanced relations with those they aim to assist. These investigations are being carried out at both the 'academic' and 'practitioner' levels (Cernea 1985; Lisk 1985; UN Economic and Social Commission for Asia and the Pacific 1986; Regional Wood Energy Development Programme in Asia 1988). Some pluralist evaluations of rural development activities have also been produced (Harrison 1983; Poulton and Harris 1988; Midgley and others 1986).

Reports of assessments of rural development from the perspective of the intended beneficiaries are less commonly produced; this is unfortunate as accounts presented by local people can add an extra dimension to reports from 'outsiders'. Some commentators are difficult to categorise as 'local' or 'outsider', due to their being the former by accident of birth and the latter by way of formal education and choice of career. Utula Samana, a member of the Papua New Guinea parliament, is in such a position but he has been able to utilise his broad experience to illuminate his view of rural development rather than allow it to divorce him from local conditions. With regard to the value of large-scale mining in Papua New Guinea he has commented:

> I think that if the state depends so much on these mines and on large-scale development generally, then it is not promoting development for the people - that is, human development - it is promoting 'devil-upment'. The signs of 'devil-upment' are very clear: destruction of the environment and the livelihood of the people, destabilization of the social units, which contribute directly to rural-urban drift. Because you are creating enclave development and putting less emphasis on a communication system, on the creation of infrastructure to develop agriculture in order to strengthen the social organization that already exists, people are forced to look for opportunities in urban areas and mining towns. Through this large-scale development you are promoting what the author of *Small is Beautiful*, E.F. Schumacher once called the process of mutual destruction; actually he called it the process of 'mutual poisoning'.
>
> ... Rural life becomes a poison because the Government is not assisting rural development. Concentration on the urban areas means that in the rural areas where the techniques are not being modified to take account of increased use of land, the water supply is being polluted, people are getting sick and health services are not maintained at adequate levels, and access to better schooling is absent (Samana 1988, pp.4-5).

Samana offered as a remedy for this deterioration in rural conditions not the injection of resources from outside but:

> ... decentralization of political and administrative powers to the third tier of government, that is, local or community government. This decentralization of powers aids effective and meaningful rural development, protection of village people's resources (land, fish, timber and other resources) and development of these resources to service their own needs on a scale that they can afford financially and politically, without losing control of their destiny (Samana 1988, p.93).

Samana felt strongly that Papua New Guineans should generate their own forms of development appropriate to local conditions. Believing maintenance of the quality of the environment to be a fundamental objective, he suggested that

Melanesians had much in common with 'Greenies' in the West fighting for environmental causes. He perceived not only that Western models of development were responsible for ecological destruction that threatened human survival, but that locally developed strategies would be required to bring about development that was sustainable. Building on his understanding of human-environment relationships and of Melanesian forms of social cooperation, he has explained how development can occur without leading to the widespread anguish caused by large-scale exploitation by outsiders of Papua New Guinea's resources.

The clear divergences between Samana's proposals for rural development and the government's promotion of mineral exploitation illustrate the gulf between the top-down and bottom-up approaches to development. Not only are they at opposite ends of the scale in terms of capital requirements, but also at opposite extremes of the spectrum of impacts on the local natural and cultural environments. Many other Pacific observers have commented on the destructive nature of Western development and its inappropriateness to the Pacific way of life. Hau'ofa (1987) expressed dismay at Western influences leading to increased disparities in wealth and power in island societies.

> There are people who believe that our economy is wrong and that the conditions of the underprivileged in the island will continue to deteriorate. My experiences over the last decade have led me toward the same conclusion, but I also think that in the foreseeable future at least, the present system will continue, ... It is the privileged who decide on the needs of their communities and the directions of development and whose rising aspirations and affluence entail the worsening conditions of the poor (Hau'ofa 1987, p.11).

A second Tonga born commentator on Pacific affairs has clearly expressed the need for change in development policies. Sevele (1980) listed four basic values: dignity, freedom, diversity, and solidarity, which should characterise any just national development policy. He argued for the adoption of a new philosophy of life, based on those four values, to underpin a new approach to development planning. This appeal was not just for a fresh 'academic' assessment of development requirements but a call for changes in the actions of practitioners:

> I would like to make a plea to you all. Let us not allow this Seminar to be just another gathering of the so-called intellectuals. I think we are all agreed to a greater or lesser extent on what development should be. Let us be involved in this game of development planning. Let us be actors and not mere spectators. ... As someone once said, 'One cannot be good simply by avoiding evil; to be indifferent or apathetic to the needs of one's neighbour, to stand aloof from a world begging for help, is already to be guilty' (Sevele 1980, p. 103).

This call to action was not an attempt to accelerate economic growth but more a demand that Pacific islanders should regain their independence from those outsiders who have dominated their economies and thus their societies. Pulea also expressed a fear of Pacific culture being overtaken by Western influences.

> Since Pacific Islanders have no development theory related to their own environment, development is only encouraged towards a monetarized economy, but this does not develop the full bases for the people to attain a good and satisfying quality of life.
>
> ... Preoccupation with western cultural heritage could lead to the abandonment of Pacific traditions and culture in order to advance technologically, but this would not promote the socio-cultural progress of the nation. Surely excellence in culture is just as important as economic progress (Pulea 1985, p.35).

Pacific islanders have particularly difficult tasks confronting them with regard to development decisions. Small islands remote from major markets are generally at a comparative disadvantage in terms of selling primary commodities, and even more so for marketing manufactured goods whose production has required inputs of imported materials. The promotion of limited industrialisation has already been seen to exacerbate problems of internal migration, but once the provision of everyday necessities has been commercialised the need for paid employment expands into every part of a nation.

Tonga's stated development objectives aim to facilitate entry of the whole population into the market economy while also meeting social goals and protecting the country's environmental resources.

> The long-term economic and social objectives of Tonga are to:
>
> Achieve a sustained increase in the production of goods and services, and real incomes of the people;
>
> Achieve effective management of the national economy;
>
> Achieve a fair distribution of goods, services and income between the people in different parts of the Kingdom;
>
> Enhance the quality of life and security of the people, the cultural heritage of the nation, and the preservation of the environment;
>
> Develop harmonious relations and mutual cooperation in economic, social and related spheres with all nations and international organisations (Tonga, Central Planning Department 1981, p.14).

These objectives and the strategy proposed to achieve them reflect a commonly attempted merger between the maintenance of the best characteristics of the existing or traditional society and the material gains promised by expanded involvement in the global capitalist economy. While identification of factors that will in future prove to be constraints to economic growth is notoriously difficult, there are conditions which are accepted as closely associated with successful development of a free market economy. Some socio-political characteristics favourable to economic growth could well act in a manner adverse to the promotion of some of the cultural and environmental benefits made explicit in the national development objectives. As is the case in most societies, Tongans will be faced with essential choices about their collective future. Such challenges will not only arise in the national arena but also be presented to local communities. The success which the Tongan people have in resolving potential conflicts between traditional and capitalist values will to a large degree determine the nature and extent of the nation's future development.

An issue which has come to the fore in recent years with regard to consideration of development in both 'developed' and 'developing' countries is sustainability. The term 'sustainable development' is as open to varied interpretation as are most development concepts (Pearce, Markandya, and Barbier 1989), but it offers the opportunity for groups from varied backgrounds to relate their perspectives on development to a common theme. Even though specific objectives vary, proposals based on the full range of development philosophies can be enhanced by sustainability. Fundamental to Gandhi's and Schumacher's visions of small-scale development was the desire to ensure that benefits gained by adoption of improved technologies could be sustained by utilisation of resources to which continued access would be assured. At the other end of the spectrum, trans-national corporations generally expect financial returns from their activities to be sustained over the anticipated lifetime of any particular enterprise in order to provide continuing benefits to their shareholders. The imperative for sustainability can also focus on components of the natural environment, such as endangered species, or on particular components of human society, such as cultural traditions. In his description of the aims and proposed implementation of the World Conservation Strategy, Allen interpreted sustainable development as:

> development that is likely to achieve lasting satisfaction of human needs and improvement of the quality of human life (Allen 1980, p.23).

This definition begs several important questions: which humans? which needs? who determines what is meant by quality of human life? how are conflicts resolved when improvement for some is dependent on deterioration for others? Allen acknowledges that a world strategy for the conservation of living resources is but one step towards achieving sustainable development; strategies are also essential for:

> ... a new international economic order, for human rights, for overcoming poverty, and for population ... (Allen 1980, p.29).

Perhaps the most difficult problems arise when action to achieve sustainable development is sought. Most people would agree that all human beings should have access to adequate resources to achieve sustained satisfaction of their basic needs; instigating the global changes to the distribution of resources necessary to bring this about has so far been impossible.

The General Assembly of the United Nations took a step towards determining how necessary changes could be made by establishing the World Commission on Environment and Development. The Commission was set the task of formulating 'a global agenda for change' to bring about international cooperation on defining and dealing with environmental issues so as to achieve sustainable development (Brundtland 1987, p.ix). As it was required to determine what changes were necessary, the Commission focused on perceived deficiencies in the existing global economic order; it did not develop an ideal scenario. It also paid most attention to changes which could be instigated by multinational organisations or national governments rather than by individuals or community groups. By accepting the global market economy as the foundation for achieving sustainable development the Commission placed itself clearly within the capitalist categories defined by Griffin and Corbridge. The sustainable development sought was that which would permit continued economic growth. The main theme of the Commission's recommendations was:

> If large parts of the developing world are to avert economic, social, and environmental catastrophes, it is essential that global economic growth be revitalized. In practical terms, this means more rapid economic growth in both industrial and developing countries, freer market access for the products of developing countries, lower interest rates, greater technology transfer, and significantly larger capital flows, both concessional and commercial.
>
> But many people fear that a more rapidly growing economy will apply environmental pressures that are no more sustainable than the pressures presented by growing poverty. The increased demand for energy and other non-renewable raw materials could significantly raise the price of these items relative to other goods.

> The Commission's overall assessment is that the international economy must speed up world growth while respecting the environmental constraints (World Commission on Environment and Development 1987, p.89).

Given this context for the Commission's deliberations, it has relatively little to say about the production of non-commercial fuelwood. However, two points are made that are particularly relevant to the theme of this thesis. First, recognition is given to the fact that the search for solutions to fuelwood problems must focus on local conditions.

> The communities concerned will have to work out local solutions to these problems. But such local issues mean that governments and aid and development organizations that want to help the fuelwood situation in developing countries will have to work harder to understand the role fuelwood plays in rural areas, and the social relations governing its production and use (World Commission on Environment and Development 1987, p.192).

Second, in respect to rural areas where fuelwood is regarded as a 'free good', the suggestion is made that agroforestry systems are likely to offer the best method of production.

> Forestry can also be extended into agriculture. Farmers can use agroforestry systems to produce food and fuel. ... Well-chosen crops reinforce each other and yield more food and fuel than when grown separately. ... Agroforestry has been practised by traditional farmers everywhere. The challenge today is to revive the old methods, improve them, adapt them to the new conditions, and develop new ones (World Commission on Environment and Development 1987, p.137).

The presentation of options which require locally initiated action based on the adaptation of traditional practices acknowledges that in the situations where sustainable development is most needed, to meet the basic needs of the rural poor, the market economy cannot provide appropriate mechanisms for the allocation of resources. In addition, the admission is explicitly made that governments and development agencies are, by and large, inadequately informed to provide appropriate assistance to local communities seeking solutions to local problems. If those promoting expansion of the capitalist economy as the only route to gain widespread sustainable development cannot offer meaningful assistance to those most likely to be adversely affected by economic growth, can their claims that such growth will benefit all be taken seriously? It is not possible to include a full debate of this issue here, but the point must be made that the rural poor are likely to be sceptical about the advantages of 'sustainable development' when it is presented as operating only through the market economy.

With particular reference to development on Tongatapu, the people themselves will have to decide what form of development they want and which approaches they adopt to achieve it. The development objectives included in the government's Fourth Five-Year Development Plan 1980-1985 (Central Planning Department 1981) give an indication of the development aspirations of the Tongan people. For the purpose of developing the theme of this thesis the following assumptions are made:

1. that because the stated aim to increase production and incomes is to apply over the long-term, taking short-term gains which threaten the sustainability of long-term improvements will be discouraged;
2. that effective management of the national economy includes making appropriate provisions for the production and distribution of non-commercial goods and services;
3. that the achievement of fair distribution of goods, services, and incomes, includes as a priority the satisfaction of basic needs;
4. that basic needs will be met through mechanisms which provide opportunities for gaining improvements to living conditions;
5. that, because of their roles in ensuring development is sustainable, cultural heritage and the natural environment are to be effectively and adequately protected against adverse impacts of short-term economic activities;
6. that the establishment of economic relations with foreign countries and organisations will not be allowed to bring about detrimental impacts on any section of Tongan society, on its cultural heritage, or on the natural environment.

3.3 Approaches to addressing problems of balancing fuelwood supply and consumption

The solution of fuelwood problems is a development activity, in that it contributes to the long-term well-being of a society's human population. Attempts at achieving solutions need to relate to the society's concept of and approach to development issues. Approaches to addressing fuelwood problems are briefly discussed here to elucidate this relationship.

Approaches to problems of inadequate fuelwood supplies can be grouped into two general categories: 'institutional' and 'personal'. These categories can be characterised by the perspectives they represent and by features of their operation.

The 'institutional' approach sees the provision and consumption of fuelwood as socio-economic institutions within a community or society to be dealt with on a broad scale. Quantitative data about particular aspects of supply and demand are used to characterise the nature of the fuelwood situation in the study area. The conventional technique this approach has taken to evaluate the severity of difficulties encountered in relation to fuelwood supplies has been to compare estimated fuelwood consumption with estimated tree growth increments. If the wood production figure is less than the fuelwood consumption figure, a fuelwood deficit is said to exist. If cutting of wood from the tree stock as well as the incremental growth is still inadequate to satisfy the fuelwood demand, the situation is said to be one of acute deficit (de Montalembert and Clement 1983).

The alternative 'personal' approach tends to address fuelwood problems by looking at the situation in individual households or small communities. Local factors influencing fuelwood supply and consumption are identified and at least some understanding of their interactions gained. Modelling of the inclusive environment to facilitate investigation of interacting factors is more likely to be possible with the personal approach than the institutional. However, because the personal approach is much more open to qualitative input, varied techniques for describing collated information are likely to be required.

Each approach has its advantages and disadvantages. The 'gap theory' provided by the institutional approach to fuelwood problems has helped to make people aware that a serious, and potentially catastrophic, fuelwood problem exists. However, because it generally presents information at the country and regional levels, solutions to overcome fuelwood deficits tend to have been formulated on a large scale. The expectation that centralised organisation will be able to implement local schemes to contribute towards achieving the overall aim has often not been fulfilled. Basing action simply on consideration of quantitative data about fuelwood deficits has led to the instigation of numerous social forestry projects which have not provided appropriate solutions to fuelwood shortages (Agarwal 1987; Vainio-Mattila 1988; Arnold 1987; Shiva, Bandyopadhyay, and Jayal 1985; Foley and others, Undated). Despite the problems experienced with community forestry programmes, commentators have suggested not that they should be abandoned but that 'their design and implementation should be improved' (Foley and Barnard 1984, p.23). Changes are being made largely as a result of using a more personal approach to research local conditions so that constraints which are not apparent at the broad scale can be identified. As more careful evaluations of problems affecting particular communities are carried out, information is obtained which will contribute to the categorisation of problems and thus assist descriptions at a broader scale.

> The earlier concept of community forestry is therefore being progressively refined to define the different approaches needed in order to pursue different objectives.
>
> This process continues to be hampered by gaps in our knowledge about how trees and tree products fit into particular household, farm and communal systems. Even now, this has been systematically investigated in only a very small number of situations, with much of this work still in progress. Nevertheless, it is possible to identify at least three different categories of situation - communal forestry, farm forestry for household use, and farm forestry for market - and some of the distinguishing features of each which determine how best the support process might be approached (Arnold 1987, 125-126).

Both institutional and personal approaches have their particular values, and should be utilised as complementary tools in research aimed at gaining a comprehensive understanding of a fuelwood situation. Perhaps the most constructive role an outsider can play is to combine the personal approach of individual fuelwood users with the institution perspective of their government and other large organisations, to construct an integrated model of a fuelwood problem which can form the basis of a programme to design and implement a solution. An example of such an interaction is the development of improved stoves in Sri Lanka. The need for more efficient and clean-burning stoves had been identified at an institutional level. Specialists from the Intermediate Technology Development Group worked on a personal level with villagers to develop a stove design that would be locally acceptable. The Ceylon Electricity Board was then able to provide support for the stoves to be disseminated and so provide major and widespread benefits to the socio-economic institution of fuelwood consumption. Significantly, the several years of developmental design activity involving the Intermediate Technology Development Group specialists and local stove users and potters was facilitated by a Sri Lanka non-government organisation, the Sarvodaya Shramadana movement (Navaratna 1983; Stewart 1983; Ceylon Electricity Board and Intermediate Technology Development Group (U.K.) Undated).

Hosier (1984) classifies the activities of researchers in rural energy by way of a matrix with axes labelled 'scale of observation' (single village; multi-village; and regional or national) and 'substantive framework' (wood supply/demand; energy supply/demand; and energy ecosystem). Most studies relating to any combination of these headings would include elements of both institutional and personal approaches; a regional or national analysis dependent on purely quantitative supply and demand data would be the most fully institutional; an energy ecosystem study of a single village would come closest to achieving the full potential of a personal approach. However, concentrating on energy would restrict investigation of the broad range of factors relevant to fuelwood supply and consumption. The approach developed in this thesis is an attempt to provide a framework for fully comprehensive research into fuelwood problems.

4. A DESCRIPTION OF THE RESEARCH STRATEGY AND FIELD RESEARCH METHODS

4.1 The development of a research strategy from the conceptual framework

The conceptual framework described in Chapter 1 is considered to be at least potentially applicable to a broad range of environmental research. However, it was designed specifically to guide investigations of fuelwood systems on Tongatapu. Some of the direct links between the structure of the thematic approach and the subject matter to be studied have been mentioned in Section 1.4. This chapter expands on the relationship between the conceptual framework and the research techniques employed, then describes how the field research was organised and conducted.

The approach of this study has been to focus the research on a chosen geographical location to allow detailed examination of interactions between the physical, biological, and cultural spheres of relevant systems. The theme for this work, based on the field research aims, is the adequate description of fuelwood systems in selected Tongatapu communities to facilitate the development of methods of providing sustainable supplies of fuelwood. The results of research guided by this theme could then be related to the general aim of making a contribution to the understanding of fuelwood problems.

Following preliminary research into the fuelwood situation on Tongatapu, and discussions with researchers and Tongan government officials, an outline of the field research strategy was drafted. Developing this strategy involved devising appropriate fieldwork techniques to gather information relevant to households' supplies and consumption of fuelwood. Data would have to be collected about fuelwood resources on cultivated and 'natural' land as well as about household activities relating to fuelwood use. With nearly 10 000 households in 62 village communities on Tongatapu decisions had to be made about sample selection. Listing of households to be included in the surveys could have been based on random selections of town or bush allotments. Two main disadvantages of this approach were the logistics of travelling to households randomly distributed across the island, and the lack of opportunity to learn about social interactions and environmental conditions in each household's community. The alternative approach adopted was to select six geographically distinct study areas and then to randomly select households within those areas. This pattern of fieldwork allowed enough time in each study area to obtain some understanding of characteristics of social and natural systems, and also kept travelling times to a minimum.

The selection of study areas was based on a desire for the diverse environmental conditions existing across the island to be represented. The most distinct contrast was between urban Nuku'alofa and the more remote rural villages. Given that the population of greater Nuku'alofa was approximately one third of the island's total, two of the six study areas were located there. The boundaries of the three pre-existing villages which combined to form the town were used to define the Urban Nuku'alofa study area. Residential areas contiguous with this town area together with two satellite villages, Tukutonga and Popua, were designated as the Peri-urban study area. The villages of 'Ahau, Vaotu'u, Folaha, and Lavengatonga constituted the four study areas chosen to represent Tongatapu's varied rural environments. Each of the rural villages was of medium size in terms of population so that deductions made about regional differences were based on comparisons between villages of similar sizes. This was considered more likely to yield valid conclusions than would comparisons between villages with wider variations in population numbers.

The approach taken to attain adequate descriptions of the fuelwood situation in the study areas has been to examine the natural, domestic, cultivated, commercial, and social systems within those areas. These categories were chosen as theoretical constructs to assist study of the phenomena, activities, and relationships found within the study areas. They form a vital link between the conceptual framework, the field research, and the analysis and interpretation of data. Providing each of these types of systems as a research focus acknowledges not only the breadth of phenomena affecting fuelwood systems, but also that there are different perspectives from which the study of fuelwood systems can be approached. The inclusion of natural systems is of particular significance as it requires that non-anthropocentric values be considered.

The role of the field research was to obtain the information required to meet the objectives listed in Section 1.1.1 above, and in particular to satisfy stage 3 of the thematic approach. While general information on physical, biological, and cultural characteristics of Tongatapu was available from the literature, the bulk of the detailed data about households' relationships with fuelwood had to be collected in the field. The main use for the data was to be to describe as fully as possible the fuelwood resource, supply mechanisms, domestic requirements, and consumption patterns, as they related to the natural, domestic, cultivated, commercial, and social systems in the study area. Gauging attitudes towards fuelwood and trees was another major requirement. Information less directly related to fuelwood supply and consumption mechanisms was also to be collected to supplement material gleaned from the literature to satisfy stage 2 of the thematic approach, the characterisation of local and regional environments. Fieldwork techniques to obtain these data would necessarily include observations and measurements as well as interviews with people whose activities directly influenced the fuelwood situation. Particular value was placed on the information gained from interviews because of a strong commitment that local information and attitudes are essential to the success of any programme requiring changes to residents' behaviour.

The basic strategy for the accumulation of data in each of the six study areas began with household characteristics interviews with fifteen randomly selected households. These interviews gleaned information mainly about domestic fuelwood requirements, supply mechanisms, and consumption patterns. They also elicited attitudes about trees, as the basic fuelwood resource. To satisfy the field research objectives, interview results directly related to fuelwood would have to be discussed in terms of the natural, domestic, cultivated, commercial, and social systems. Questions were therefore also included in interviews to ascertain non-fuelwood household characteristics.

A second series of interviews was conducted in each study area to obtain information about characteristics and management of bush allotments used by a sub-set of household characteristics interviewees. These interviews focused on fuelwood resources and supply as they related to the cultivated system. From the bush allotments included in these interviews, between three and six in each study area were selected for detailed surveys to gain data about the fuelwood resource and its relationship with land management techniques.

Information on the fuelwood resource on non-agricultural land was gathered through surveys of trees growing inside the town boundaries of each study area, and surveys in 'Ahau and Peri-urban Nuku'alofa of sections of coastal forest. These highlighted relationships between fuelwood activities and natural systems. A study was also made of a remnant stand of relatively undisturbed lowland tropical forest to obtain an indication of the vegetation potential of inland Tongatapu (King 1986).

A number of activities were undertaken in Nuku'alofa to glean details of commercial distribution of fuelwood. These activities included a survey of quantities of fuelwood sold at the Talamahu market in the centre of the town, interviews with fuelwood sellers, and interviews with representatives of commercial enterprises using fuelwood. Data were also collected about fuelwood use by schools.

Each of these information gathering activities in the six study areas related directly to the theme of describing the fuelwood situation on Tongatapu. Details of how these components of the fieldwork programme were undertaken are presented in the following sections.

4.2 Descriptions of field research methods

4.2.1 Household characteristics interviews

4.2.1.1 Interview schedule development

Preliminary field research in November 1984 and December 1985 included interviews with Tongatapu households about aspects of their fuelwood supply and consumption. This experience provided valuable awareness about the sorts of information which Tongan respondents would be able and willing to provide. Advice from researchers at the University of Tasmania and the University of the South Pacific, from Dr Chris Harwood of the Pacific Energy Development Programme, and from Tongan government officials was of considerable assistance in developing the schedules.

Given the breadth of information required to describe the fuelwood situation in relation to natural, domestic, cultivated, commercial, and social systems in each of the six study areas, it was desirable to build a comprehensive profile of each household interviewed. This would require a large number of questions and hence a long interview. The potential disadvantages of conducting lengthy interviews were considered during the drafting of the questions and asking for superfluous information was avoided, but it was decided to include all necessary questions to obtain the comprehensive data required. If problems arose during interviews such that the reliability of data was diminished the schedule could be reassessed and amended as necessary. A shortened version of the schedule was prepared and used for one interview in the Peri-urban study area but no advantage was perceived. Given the deficiencies in the information obtained from the shortened interview it was decided to use the full schedule for all interviews.

The general arrangement of interview questions was to begin by obtaining general information about the household, to be followed by asking more detailed questions about cooking practices, fuelwood consumption and supply, and attitudes towards trees. Only general information about land use was sought; in selected households a second interview would glean detailed information about bush allotments. The household characteristics interview was thus largely focused on facilities and activities relating to the town allotment.

A relatively high proportion of questions did not refer directly to fuelwood issues. However, they were all included because it was believed the information they requested would be significant to aspects of the household's fuelwood requirements and supplies. Considerable attention was given to the sequence of questions in an attempt to ensure that as far as possible they would follow one another in a logical fashion that would allow the interview to flow smoothly. One question that was included close to the start of the interview contrary to normal practice, was the request for information about the household's monetary income. Previous interview experience had indicated that householders on Tongatapu were less sensitive about revealing this information than expected. Interviewees were told that all responses were received in confidence, that no published information would be traceable to individual households. Precise income figures were not required; only the band within which the household's income fell was recorded. It was also felt that having given the most personal piece of information to be asked of them respondents would be more comfortable providing subsequent answers.

Questions were originally drafted and checked in English but had to be translated into Tongan before interviews could begin. The translation was carried out by Mr Dennis Tu'inukuafe, the Tongan government officer employed in the Energy Planning Unit of the Ministry of Lands, Survey and Natural Resources who was to assist with conducting the interviews. Extensive discussions took place to ensure that the precise meaning of the English version of each question was transferred to the Tongan version. Mr Tu'inukuafe was also carefully briefed on the importance of constructing questions to avoid leading the interviewee towards a particular answer. A draft schedule was prepared with both English and Tongan versions of all questions. This was reviewed by a teacher of the Tongan language who specialised in teaching Tongan to foreign visitors and who was in an excellent position to identify any subtle variations in meaning between the two versions. Comments from others working on energy issues for the Tongan government were also considered before the schedule was finalised.

Many of the codes to be used for categorising responses were listed on the schedule before the first interview was undertaken. Others were added as required, and a few were altered to avoid possible confusion with new codes. Additional material included on the schedule to support or enhance the information in the questions remained unaltered.

A copy of the household characteristics interview schedule is attached as Appendix 1.

4.2.1.2 Household selection

Fifteen household characteristics interviews were conducted in each of the six study areas and constituted the first stage of research in each area. Households to be approached for interview were selected randomly. For the four rural villages Ministry of Lands, Survey and Natural Resources plans showing the layout of town allotments were used as the basis for the selection procedure. In cases where additional town allotments had been occupied subsequent to the plan's production, amendments were made to ensure that all households in the village were included. Each town allotment within the study area was allocated a number which was duplicated on a slip of paper. As slips were drawn out of a hat the numbers were listed in order. Town allotments were visited in the order that their numbers appeared on the list. On occupied allotments where a resident was home, arrangements for an interview were made. In most cases an adult member of the household agreed to an interview being conducted straightaway. When this was not convenient appointments were made to carry out the interview at a later time. In the rural villages no householders approached refused an interview. When no adult member of a selected household was available, a note was made to revisit that household to seek an interview. The list of town allotment numbers was utilised in this way until fifteen household characteristic interviews had been completed.

The total numbers of town allotments located in Urban and Peri-urban Nuku'alofa and the greater distances between allotments precluded random selection of individual allotments. Also, it was not possible to traverse the whole area to update the available allotment plans. Two random selection techniques were adopted. In the long established Urban areas, blocks of town allotments were numbered and randomly selected in the same manner as the individual rural village allotments. On arriving at the block the first house encountered was approached for an interview. If this was not possible the next house was approached, and so on until an interview was arranged. Only on one occasion was an interview refused outright. A resident of one other household made an appointment for an interview but at the time arranged left a note to say that the interview could not take place. The most common reason for going on to another town allotment was that no adult was at home.

In some parts of Peri-urban Nuku'alofa the pattern of town allotments was well enough established for the same selection technique as used in the Urban area to be followed. In other areas the development of town allotments was so recent that plans were either non-existent or incomplete. Because Peri-urban Nuku'alofa is made up of a relatively large number of settlements covering a considerable area, five sub-districts were selected as being representative of the whole Peri-urban study area. This selection was based on the researcher's knowledge and impressions of living conditions throughout Peri-urban Nuku'alofa. Five interviews were conducted in the new settlements of Popua and Tukutonga to the east of Nuku'alofa, four in rapidly growing Sopu to the west, three in the established village of Haveluloto to the south, and three in Kolomotu'a/Longolongo on the south-western edge of Urban Nuku'alofa. Where plans of town allotments were incomplete, the alternative method of household selection was employed. This involved randomly choosing a number between 1 and 10, 'n', then walking in a predetermined direction from an arbitrarily selected starting point until the n^{th} house was reached.

4.2.1.3 Interview procedure

On arriving at a selected household an adult member of the household was asked to participate in the interview survey. The field research assistant explained the general purpose of the survey and the fact that it was being conducted in association with the Ministry of Lands, Survey and Natural Resources. Little information was given about the content of the interview but the potential interviewee was informed that the interview would be lengthy. If it was agreed that an interview could proceed it was begun at the interviewee's convenience. As few Tongans speak English fluently enough to use it to answer a long series of detailed questions, all household characteristics interviews were conducted in Tongan. All responses were immediately reported in English by the field research assistant and recorded by the researcher. Attempts were made to minimise influence on the interviewee from others present during the interview, particularly from people who were not members of their household.

Interviews followed the order of questions in the schedule, and as far as possible kept to the wording included in the schedule. The field research assistant was told of the importance of each interview being conducted in the same manner as all others. It was necessary in some cases to give the interviewee additional explanation about the meaning of a question. Care was taken to ensure that this ad-libbing did not lead the respondent towards any particular answer, and that the character of the interview was changed as little as possible. In general, the assistance given was believed to be essential in order to obtain reliable information and therefore was of considerable benefit.

Most household characteristics interviews took between one and two hours; the variation in time depended largely on the propensity of the interviewee to talk in broad terms about the issues covered by the questions. In only a few cases was an interview adjourned before completion, either for a short break or to be completed some hours later.

4.2.2 Bush allotment interviews

4.2.2.1 Bush allotment interview schedule development

As with the household characteristics interview the development of questions related to bush allotments was geared towards providing information required to achieve the objectives listed in Section 1.1 above. Decisions about the specific topics to be covered by questions were based on previous experience and advice from other researchers and Tongan government officers. A copy of the schedule is attached as Appendix 2.

4.2.2.2 Household selection for bush allotment interviews

On completion of household characteristics interviews in households which had access to at least one bush allotment, the interviewee was asked if a second interview would be possible. It was explained that this would be to obtain more detailed information about the household's use of bush allotment land. In some cases arrangements were made immediately for a second interview session, but most frequently the willingness for a bush interview to be conducted was noted for future consideration. The selection of households to be included in the bush allotment interview survey was based on the desire for the sample to be representative of the typical pattern in the study area.

A total of forty-six bush allotment interviews were completed, of which twelve were in Nuku'alofa. Where possible the person most closely involved with the management of the bush allotment was interviewed. In only one case was the bush allotment interviewee not a member of the household selected for the household characteristics interview; this situation arose because the household included in the first interview did not have any formal arrangement to use the bush allotment adjacent to their town allotment which constituted their main source of fuelwood.

4.2.2.3 Bush allotment interview procedure

The interview procedure adopted was fundamentally the same as that used for the household characteristics interviews: interviews were conducted in Tongan with all responses being immediately translated into English and recorded in code or note form. Prior to the start of an interview the number of bush allotments to which the interviewee had access was established. Information was collected for each allotment; in two cases responses referring to four bush allotments were recorded. The majority of these interviews took between 30 minutes and one hour to complete, depending on the number of allotments involved and the desire of the interviewee to provide elaborate responses.

4.2.3 Other interviews

Five sets of interviews with respondents other than the households referred to above, were undertaken to obtain indicative data about aspects of the fuelwood situation on Tongatapu.

4.2.3.1 Interviews with sellers of fuelwood

Eleven wood sellers at the Talamahu market in central Nuku'alofa were interviewed. The questions asked were designed to elicit information about:

1. the importance to the interviewee of selling fuelwood;
2. the types and amounts of fuelwood sold;
3. the sources and methods of collection of the fuelwood sold; and
4. attitudes towards current and future levels of wood supply.

4.2.3.2 Interviews with people shipping fuelwood to Tongatapu from 'Eua

Short interviews were carried out with ten people arrived at the Faua jetty in Nuku'alofa with quantities of wood from 'Eua. Fuller interviews were conducted with three people. Where possible the load of wood shipped by the interviewee was measured.

4.2.3.3 Interviews with commercial users of fuelwood

A total of fourteen interviews were conducted with commercial users of fuelwood on Tongatapu. Information was collected on:

1. the types and quantities of fuelwood used;
2. sources of fuelwood;
3. trends in fuelwood use; and
4. attitudes towards future supplies.

The businesses represented by the interviewees were seven restaurants, six take-away food stalls, and one guest house.

4.2.3.4 School interviews

Representatives of three schools on Tongatapu were interviewed using a schedule of similar structure to the households characteristics interviews. Information gathered related to the general character of the school and its facilities; cooking practices; fuelwood consumption; fuelwood supply; and attitudes towards trees.

4.2.3.5 Interviews with sellers of chainsaws

Formal interviews were carried out at four retail outlets in Nuku'alofa with a view to finding out:

1. how many and which types of chainsaws were being sold;
2. how much the chainsaws cost;
3. whether services offered included repairs, maintenance, or advice on safety aspects of chainsaw use;
4. the occupations of buyers of chainsaws; and
5. whether chainsaws were available for hire.

4.2.4 Bush allotment surveys

4.2.4.1 Introduction

This section describes the survey techniques devised to record trees on agricultural land in Tonga. This fieldwork was a fundamental component of the research programme, and was carried out during two visits: October to

November 1984, and December 1985 to September 1986. All data referred to in this thesis relate to surveys conducted in 1986. While the main purpose of the fieldwork was to record the numbers, sizes, and species of trees, when time permitted their positions were recorded, as were the boundaries delineating variations in crop combinations and different types of uncultivated land. The following notes give step-by-step descriptions of the survey procedures used.

4.2.4.2 The survey techniques

(a) The boundary survey

Reasonably accurate outline plans of bush allotments were produced from a carefully executed survey of each allotment carried out by taking bearings with a hand-held compass and by pacing distances. The survey consisted of the following steps.

(i) As much information as possible was gathered about the character of the boundary from Ministry of Lands, Survey and Natural Resources (MLSNR) records, from the bush allotment holder, or from others familiar with the site. Where possible, MLSNR survey marker stones (concrete blocks set in the ground) were located, and the numbers on the field markers checked against the numbers displayed on cadastral maps. In cases where fences, hedgerows, or other continuous boundary features were present their positions relative to the actual boundary line were ascertained. Where no linear features were evident, obvious landmarks were selected and their positions fixed in relation to the official boundary.

(ii) A precise and readily identifiable point on the boundary was selected from which to start the survey; it was usually most convenient for this to be at a corner.

(iii) A straight length of the boundary was selected as the first section to be measured, and an adequate number of markers to define this line established. On open, level ground markers at each end of the line were usually found to be adequate.

(iv) Using a hand-held compass a bearing was taken, as precisely as possible, along the boundary line from the starting point and the reading was recorded.

(v) The boundary was paced as far as the end of this first straight section, or to another convenient landmark, and the number of paces recorded.

(vi) A back-bearing was taken along the boundary to the starting point, and compared with the initial compass bearing taken from the starting point. If there was any serious discrepancy the bearings were checked.

(vii) The next straight length of boundary to be measured was identified, and a forward compass bearing from the boundary marker at the start of this second section taken.

(viii) This length was paced, the number of paces noted, and back and forward compass bearings recorded.

(ix) This process was repeated for subsequent sections of the boundary until the starting point was reached.

The accuracy of the boundary plans depended on the care taken during the field survey, the experience of the surveyor, and field conditions. Obtaining precise and accurate readings with a hand-held compass came more easily with practice, and readings to the nearest degree were consistently achieved. In dense vegetation it was necessary to establish more boundary markers, and to check back and forward bearings much more frequently than in open country. In order for the surveyors to know the length of paces taken as accurately as possible a known distance was paced a number of times to test consistency. Changes in slope, ground surface, vegetation, and weather were found to affect the length of paces; a positive effort was required to maintain a constant stride. Where obstructions prevented the pacing of a given length of boundary in a single straight line, the surveyor walked a known distance at right angles to the boundary and then continued pacing on a line parallel to the boundary until the obstruction had been overcome.

The technique of pacing to obtain measurements of distance was preferred to using a measuring tape mainly because of expediency. One person was able to complete a boundary survey by pacing in less time than it would have taken two with a tape.

There were various ways in which the compass bearings and distances could have been recorded. Once a convenient system was adopted it was adhered to rigidly to avoid confusion. When more sophisticated drawing apparatus was not available, the use of graph paper and a circular protractor greatly assisted the preparation of measured plans from field sketches and notes.

(b) The crop areas survey

Boundaries of distinctive cultivated and uncultivated areas within an allotment were recorded by the following procedure.

(i) Readily discernible, straight baselines were selected to which measurements of the areas being surveyed were related. Where these baselines were not coincident with the already surveyed allotment boundary, the positions of points on them were related to fixed points on the boundary. The number, length, and locations of baselines depended on the distance between the area to be surveyed and the allotment boundary, and on obstructions to establishing links with the boundary.

(ii) An accurately measured relationship between at least one point on the perimeter of the area being surveyed, and at least one baseline was established. In order to check the accuracy of the survey it was found to be useful to have measurements and compass bearings between several points on the area perimeter and more than one baseline.

(iii) Using the compass bearing and pacing survey technique described above, the perimeter of each area was recorded.

(c) Plotting positions of trees within bush allotments

The positions of individual trees with diameter at breast height not less than 10 cm were fixed in relation to the allotment boundary or baselines by taking compass bearings and pacing distances. The following procedure was used.

(i) A rough sketch plan was prepared of the allotment, or a section of the allotment, at a scale which provided space for recording information about individual trees.

(ii) The tree to be plotted was selected.

(iii) A symbol was drawn on the allotment sketch plan to represent the tree in approximately the correct position, and the species was noted. The tree location symbol used by the author was a small circle with a cross through it; a three-letter code was written beside each symbol to record the species.

(iv) A convenient section of boundary or baseline close to the tree was paced from a known starting point to the point where the tree was at right angles to the boundary or baseline.

(v) This position was recorded by noting the number of paces from the starting point. In the convention used, this figure was written alongside the tree location symbol on a line parallel to the boundary or baseline.

(vi) From this point a straight line to the tree was paced.

(vii) The number of paces from the boundary or baseline to the centre of the tree was recorded. In the author's convention this figure was written adjacent to the tree symbol at right angles to the boundary or baseline.

(viii) This procedure was repeated for each tree to be recorded.

As with the boundary survey, it was found here to be important to adhere strictly to the adopted convention for the recording of measurements. To avoid confusion in the plotting of trees on a measured drawing, as few baselines as possible were used, and distances were recorded in such a way as to clearly indicate from which boundary or baseline they were taken.

(d) Taking measurements of trees

Three sets of measurements were made to give information about the sizes of trees. These were: diameter at breast height (DBH); clinometer readings to allow the calculation of tree heights; and dimensions across the crowns. In general, measurements were taken of only those trees with a DBH of 10 cm or greater.

To measure the diameter at breast height (DBH) either the trunk of the tree was encircled at breast height (1.4 metres above ground level) with a diameter tape and the diameter read; or an ordinary linear tape was used to measure the girth, and the reading was divided by pi (3.142) to obtain the diameter.

If at breast height there was a branch or other protuberance which would unjustifiably exaggerate the measurement of the girth of the trunk, the tape was moved above or below the obstruction so that a measurement more indicative of the true diameter was recorded.

To obtain information to calculate the height of the tree the following procedure was used.

(i) The highest point of the tree's foliage was located visually.

(ii) From directly below the high-point of the tree, a straight line away from the tree was paced until a place was reached where the high-point was visible and (if possible) from where the angle to the top of the tree was less than 45 degrees.

(iii) The number of paces taken was recorded.

(iv) Using a clinometer, the angle of the high-point of the tree above the horizontal was ascertained.

(v) Where the ground was not level, a second clinometer reading was taken to ascertain the angle of the point on the ground vertically below the high-point, above or below the horizontal.

(vi) The clinometer readings were checked.

For ease of calculation it was found to be convenient to take clinometer readings from constant distances (for example 15 or 20 metres). However, it was more important to take readings where the high-point of the tree was clearly visible, and within the optimum angle range of the measuring device. While a clinometer is not difficult to use, it required care and practice to obtain consistently accurate results. Tree heights were calculated as follows:

$$H = (L \tan a) + e$$

where

H = the vertical height of the highest point of the tree above ground level, in metres;

a = the angle of the top of the tree above eye level, as read from the clinometer;

L = the distance between the point vertically below the highest point of the tree and the position where the clinometer reading was taken, in metres; and

e = height of eye level above ground level (taken as 1.65 metres).

For readings taken on sloping ground the equation was amended as follows:

$$H = L(\tan a' - \tan a'')$$

where

a' = the positive angle between eye level and the top of the tree; and

a'' = the negative angle between eye level and the point on the ground vertically below the top of the tree.

To measure crown dimensions the following technique was adopted.

(i) If the crown of the tree was obviously non-uniform in horizontal cross-section, the greatest dimension across the crown was located.

(ii) One end of a tape was held directly below the extremity of the foliage at one end of the line of the crown's greatest dimension.

(iii) The tape was extended along a line which ran as close to the middle of the tree as possible, to the extremity of the crown's foliage on the opposite side of the tree.

(iv) With the tape taut and horizontal the dimension between the points directly below the two extremities of the crown was recorded.

(v) With the tape extended along a line at right angles to the first line, the dimension between the extremities of foliage was noted.

In this survey extreme crown dimensions were measured. This meant that if foliage away from the line of the tape extended further than the foliage vertically above the tape, then the point on the tape at right angles to the extremity of the foliage was recorded.

4.2.5 Survey of wood sold at Talamahu market

Stocks of fuelwood for sale at the Talamahu market, Nuku'alofa, were recorded from Friday 13 December 1985 to Monday 13 January 1986, from Monday 19 May to Monday 23 June, and from Wednesday 27 August to Monday 29 September 1986. Stack volumes of split and round wood were measured, while solid volumes of logs, poles, and other large pieces of wood were either measured or estimated. The species of wood offered for sale were recorded when known, and sample bundles of split wood were weighed in order to allow estimates of weights of wood sold to be calculated. Samples of wood were collected for density and calorific value determination.

5. A DESCRIPTIVE ACCOUNT OF CHARACTERISTICS OF SIX STUDY AREAS ON TONGATAPU IN RELATION TO FUELWOOD SUPPLY AND CONSUMPTION

5.1 Introduction

This chapter describes characteristics of the six study areas that are considered significant to the theme of fuelwood supply and consumption on Tongatapu. A profile of each study area is constructed on the framework of natural, domestic, cultivated, commercial, and social systems. Aspects of each system are presented before its significance to fuelwood supply and consumption is outlined. Each study area profile is concluded by the reporting of data on the mechanisms of the fuelwood system itself.

The majority of the information included in this chapter has been gleaned from the results of the fieldwork described in Chapter 4. Some material from the literature has been used, in particular to assist description of physical and biological aspects of natural systems. Information emanating from the results of the field interviews has been utilised extensively to characterise components of the systems under review. As interview surveys each involved a maximum of fifteen households per study area they cannot be claimed to provide a comprehensive description valid for the whole community.

The number of bush allotments surveyed was much smaller than the number of households interviewed. Information from eighteen allotment surveys has been drawn on to indicate characteristic variations and similarities in the cultivated systems pertaining to the six study areas. The results of these bush allotment surveys are particularly relevant to consideration of continuing production of fuelwood. The field survey techniques were selected to facilitate the collection of as much information as possible in the time available. The information provided by the allotment boundary and crop areas survey is considered accurate enough to characterise agricultural land management by interviewees in the six study areas; these data are not intended to give a definitive description of land areas allocated to particular uses. Similarly, the brief surveys of coastal land in 'Ahau and Tukutonga were undertaken as preliminary investigations of the condition of the land and its vegetation, not as detailed studies of floral diversity or specific aspects of environmental impacts associated with fuelwood collection.

Varied degrees of detail are included in the six study area profiles. The full complement of information is presented for 'Ahau, but where a particular aspect of a system in another study area was found to be insignificantly different from that described for 'Ahau it has generally not been reported. The greatest general differences from 'Ahau were recorded in the capital town; this has led to more information being included for Peri-urban and Urban Nuku'alofa than for Vaotu'u, Folaha, and Lavengatonga.

Tree species are mostly referred to in the text by their Tongan names and in tables by three letter codes. Both are listed in Appendix 3 which also gives botanical and English names.

5.2 Profiles of the six Tongatapu study areas in terms of natural, domestic, cultivated, commercial, social, and fuelwood systems

5.2.1 'Ahau

5.2.1.1 Natural systems

(a) Physical aspects

'Ahau's geographical location on the north-west peninsula of Tongatapu has been the primary factor influencing its natural environment. The geomorphology of the peninsula has been determined by the actions of the predominant winds and seas. While the coast to the north-west of 'Ahau is sheltered enough to allow more coral growth than occurs further south, the reef on this western side of the peninsula is very much narrower than to the east. The dominant feature of the inland topography is a ridge running parallel to the windward shore and some 200 metres from it. At its maximum height due west of 'Ahau the ridge is just over 15 metres above sea level. The land slopes in a mostly regular manner from the ridge to both western and eastern shores.

(b) Biological aspects

The natural vegetation found on the two coasts predictably reflected the climatic and geological conditions. Species on the rocky west coast were among those which Thaman (1976) lists as characterising coastal littoral forest. These included: fau, *Hibiscus tiliaceus*; loupata, *Macaranga harveyana*; puataukanave, *Cordia subcordata*; tatangia, *Acacia simplicifolia*; fo'ui, *Grewia crenata*; toa, *Casuarina equisetifolia*; and *Pandanus* species. The coastal forest was confined to a narrow strip between the sea-swept rocks and cultivated bush allotments.

The sand and mud flats on the eastern shore presented somewhat different environmental conditions for plant life. A survey of a 100 metres stretch of coast at the northern end of 'Ahau village showed there to be distinct vegetation zones beyond the cultivated land. The highest zone consisted of a strip 20 to 25 metres wide of trees mostly 2 to 5 metres high. The dominant species was fau, *Hibiscus tiliaceus*, with spreading branches intermingling to create an almost impenetrable barrier. Scattered individual specimens of fau rose above the continuous canopy to a maximum height of about 7 metres. Other isolated species included toto, *Cerbera manghas*; lekileki, *Xylocarpus granatum*; ifi, *Inocarpus edulis*; and *Pandanus* species. These species are characteristic of swamp forest which occurs on hydromorphic soils intermittently flooded by heavy rain and exceptionally high tides (Thaman 1976). Below this was a tongue of sandflat which was apparently subjected to inundation from the sea much more frequently than the strip of swamp forest. Tree cover in this area was less than 1 percent, consisting solely of scattered mangrove bushes (tongo, *Rhizophora* species) no more than half a metre in height or in diameter. Between this open area and the inter-tidal reef was a spit of land supporting more trees representative of the swamp forest community. Here the dominant species was not fau but feta'anu (*Excoecaria agallocha*). The form of the tree cover was much less dense than in the strip adjacent to the bush allotment, with the canopy occupying approximately 40 percent of the area. Less frequent species on the spit were: fau, *Hibiscus tiliaceus*; lekileki, *Xylocarpus granatum*; lala, *Vitex trifolia*; milo, *Thespesia populnea*; and ifi, *Inocarpus edulis*. Herbaceous understorey species covered about another 20 percent of the land area.

(c) Cultural aspects

This brief examination of coastal vegetation illustrated very clearly that the natural ecosystems on land adjacent to 'Ahau village had been shaped not only by physical and biological factors but also very much by direct human impacts. The dominant tree species on the eastern shore, feta'anu, remained not because of some ecological competitive advantage but because its wood was of low value as fuel. Species such as lekileki and tongo were prized for their firewood and so were the first to be cut out. Pressure had been particularly heavy on this coastal land because of its proximity to the village and because access to it was not regulated (Plate 1).

The littoral forest on the western side of the peninsula had been less damaged. Part of the reason for this was undoubtedly the extra distance to carry firewood for household consumption, but also very significant was realisation that the trees growing between the beach and the bush allotments played a valuable role in protecting the farmland from salt-laden sea-spray.

(d) Significance to fuelwood supply

Coastal land was a significant source of firewood for nine of the fourteen wood using households interviewed in 'Ahau. Five of the nine households collected from the eastern shore, within 100 metres or so of their town allotment. The remaining four households collected from the liku coast on the western side of the peninsula. Of the three respondents who gave the coast as their most important collection site, one gathered firewood on the liku coast. As well as the trees growing on the coast providing firewood, driftwood was also a worthwhile source. Three households included washed up coconuts as a significant component of the driftwood used as fuel. Driftwood also included pieces of sawn timber and sialemohemohe, *Leucaena leucocephala.*

As would be expected in an area where agricultural land was at a premium, it was unusual for any sections of bush allotments to be allowed to continually support natural vegetation. The only locations where this was observed were adjacent to coasts where physical conditions were unsuited to cultivation. Here bush allotment land effectively formed part of the coastal forest. Because landholders valued such vegetation to protect their cultivated land from sea-spray and inundation, it was less likely that these trees would be seriously damaged by firewood collection. Such stands of trees under the control of an allotment holder represented a potentially sustainable source of significant quantities of firewood.

Roadsides and unmanaged pockets of land within the town area were sites for semi-natural self-regenerated vegetation which, so long as it was not over-exploited, constituted a self-renewing source of firewood. Only two interviewed households said they collected from roadsides, but four of the five interviewees who gave the town as a source of firewood said they collected from town allotments other than their own. With a high proportion of 'Ahau's town allotments being unoccupied, the vegetation which succeeded in becoming established here would be an attractive source of readily accessible firewood.

5.2.1.2 Domestic systems

(a) Household facilities

Land

'Ahau's ninety-one residential town allotments in 1986 occupied approximately 10 hectares, with a median allotment size of 970 square metres. Only about half the allotments were occupied. Whilst the uses to which town allotments were put varied from household to household, most supported some food crops and ornamental plants as well as the domestic buildings. Areas of food crops were generally surrounded by low fences to protect them against wandering pigs.

The nine households from whom detailed information about bush allotments was elicited had access to a total of twenty-one bush allotments. This represented a significantly higher number of allotments per household than had been indicated by respondents to the household characteristics interviews. This suggests that household members other than those who are actively involved in crop cultivation often are not fully aware of the household's farming activities. Indeed, individuals were quite frequently encountered who never visited their household's bush allotments.

Of the twenty-one allotments identified by bush interview respondents only one was not located on the agricultural land adjacent to the village. This allotment in Matahau, 6 to 7 km from 'Ahau, was used by a household with fourteen members whose 3 acre allotment in 'Ahau was apparently not large enough to support the production of commercial crops as well as meeting the subsistence requirements of the household. One of the bush allotments was situated on the edge of 'Ahau village and had four European style buildings which constituted the household's permanent home. Of the other twenty allotments only three had buildings on them, all of which were of traditional or modified Tongan style. The allotment in the main village area was the only one to have piped water, and only one of the others had a rainwater tank.

Buildings

Of the fifteen households participating in the household characteristics interviews, all but one had two or more buildings. This reflected the Tongan tradition of having a separate building for the kitchen. The household which occupied a single building was also the only one which never used firewood for cooking. This house was of reinforced concrete construction on two levels, and was one of only four main buildings among the fifteen households included in the survey which had walls built of concrete blocks; all others had wooden walls. All the main buildings had metal (mostly corrugated iron) roofs, glass louvre windows, and wooden entrance doors. Floors in nine houses were wholly wood and in five were completely concrete; the reinforced concrete house had a combination of both wooden and concrete floors. The main buildings belonging to all fifteen interviewed households were categorised as European or modified European in style.

Ancillary buildings were much less likely to be of European style. Of the eleven kitchen buildings used by interviewed households for which descriptions were obtained, seven were modified European in style, three were modified Tongan, and one traditional Tongan. Walling materials included metal sheet as well as wood and concrete blocks; some roofs were constructed with thatch as well as metal sheeting; most floors were earthen; and none of the kitchens had glass windows.

A survey of all the kitchens in the village revealed that 79 percent (37 of 47) were in buildings separate from the main living quarters (Table 5.1). The most common materials for kitchen wall construction were metal sheeting and prepared wood, with other walling materials being cardboard, rough wood, thatch, and concrete blocks. Nine percent of kitchens had open sides. Where windows were formed in walls 29 percent were open, and 26 percent were glazed, with the remainder having shutters made of metal sheeting, cardboard, wood, and thatch. Metal sheet was the main roofing material on 70 percent of the kitchens, and thatch was used on nearly all the remainder. The most common floor material was earth, followed by concrete and wood.

Only one of the fifteen households interviewed had toilet and personal washing facilities inside the main building. The form of separate structures to meet these requirements varied from roofless enclosures of thatch panels to a rendered concrete block building with corrugated iron roof.

Eight of the fifteen interviewees said they had made alterations to their home in the past year. The most common addition was the building of a new rainwater tank, followed by a new kitchen and a new toilet. Two households had been connected to the electricity grid. All but two respondents said they planned to make alterations, most commonly to extend the main building to accommodate washing and toilet facilities. Other plans ranged from total rebuilding to the addition of a verandah and garden paths.

When asked what alterations they would like to make to their kitchens interviewees responded with a range of desired changes. Many wanted to totally reconstruct their kitchen in the European fashion with facilities such as a sink with running water, storage cupboards and shelves, and tables and chairs being specified. Desired improvements to cooking appliances included changing to a gas stove and having a raised fireplace for the open fire and drum 'umu. Given the opportunity to own any sort of cooking stove six respondents gave gas as their favoured option, four said electric, two kerosene, two charcoal, and only one preferred to continue using wood.

TABLE 5.1

A summary of characteristics of kitchens in the village of 'Ahau in 1986

	Number of kitchens	Percentage of kitchens
Location		
Main building	10	21
Separate building	37	79
Valid cases:	47	100
Main walling material		
Thatch	5	11
Rough wood	6	13
Prepared wood	10	21
Concrete blocks	2	4
Metal sheeting	11	23
Cardboard	7	15
Open	4	9
Valid cases:	47	100
Main window/shutter material		
Glass	9	26
Thatch	1	3
Prepared wood	3	9
Metal sheeting	7	20
Cardboard	5	14
Open	10	29
Valid cases:	35	100
Main roofing material		
Thatch	13	28
Metal sheeting	33	70
Cardboard	1	2
Valid cases:	47	100
Main floor material		
Earth	23	49
Concrete/cement	16	34
Prepared wood	5	11
Rough wood	3	6
Valid cases:	47	100

Water and electricity

Water supplies were most commonly available from external standpipes and rainwater tanks; none of the fifteen interviewees said they had water piped to the main house but three had tap water in their kitchens. Eight households were connected to the mains electricity grid and two others on occasions used an extension lead to connect to a neighbour's supply.

Cooking facilities

Fourteen of the fifteen interviewees gave the open fire as their most important cooking appliance, and each of these also used an earth or drum 'umu. Kerosene stoves were used by one household as their sole cooking appliance, and by four others as a supplement to the open fire. Two households cooked with kerosene stoves in their main living houses, which was also where all electric jugs were used (Table 5.2). The most common location for the open fire was in a kitchen separate from the main building while eight of the fourteen 'umus were located outside. The drum 'umu was more convenient to use than the earth type which requires a pit to be dug in the ground, and it cooked in basically the same manner, but for some households it was not acceptable as it was a deviation from the true traditional practice.

The only other domestic woodfuel cooking appliance used by interviewees was the charcoal stove. 'Ahau women had been included in a programme of dissemination of charcoal stoves so that a member of most households knew how to make one. Of five respondents currently using a charcoal stove two claimed that cooking on this stove was quicker than on an open fire.

Transport and communications

Among the fifteen households interviewed, six owned no form of transport. Horses were owned by five households and three households owned carts but only one was in working order. Bicycles provided transport for three households, and one household used a motorcycle. Of two vans only one was roadworthy, and the only truck owned by an interviewed household had broken down.

TABLE 5.2

Numbers and percentages of interviewed households using six types of cooking appliances in 'Ahau in 1986 by appliance location

Appliance type	Appliance location							
	Main building		Separate kitchen		External		Totals	
Open fire			10	67%	4	27%	14	93%
Earth 'umu			4	27%	7	47%	11	73%
Drum 'umu			2	13%	1	7%	3	20%
Charcoal stove			5	33%			5	33%
Kerosene stove	2	13%	3	20%			5	33%
Electric jug	5	33%					5	33%
Valid cases:							15	

Average number of appliances per household: 2.53

Non-wood burning appliances as percentage of total: 13.2%

All interviewees said members of their household used the public buses. A total of nine households paid to use vans, and one used a taxi.

(b) Members of the household

Age and sex characteristics

The numbers of members in the households interviewed in 'Ahau ranged from two to fourteen, with a mean of 5.5. The 1986 census data gave the average household size as 6.6 (Tonga, Statistics Department, Undated(b)). Among interviewed households the ratio of children (under 16 years) to adults was 0.77:1, and of males to females was 0.98:1.

Occupations

Twenty-three of the thirty-six children in interviewed households attended school and three young adults were students. The most common income generating occupation was farmer, followed by clerk and fisherman. Other jobs included carpenter, engineer and police detective. Several members of interviewed households travelled to work in Nuku'alofa each day. Two farmers lived on their bush allotments a large proportion of the time. One of these worked on an allotment near Matahau, some 6 to 7 km away, but the other preferred to live in the bush just 30 minutes walk from his town allotment.

Income

Each of the fourteen interviewed households which included an employed person earned at least T$500 per year (with the possible exception of one household where the interviewee did not know how much was earned). Five of the thirteen households had an income between T$500 and T$1000, and six earned between T$1000 and T$2000 per year. Two respondents said their household's annual earned income was between T$2000 and T$5000.

Of the ten households which received remittances from overseas, two, including the only household which had no earned income, received more than T$2000. Four households received no more than T$100 per year.

(c) Domestic activities

The following are day-to-day tasks necessary for the maintenance of a typical household's lifestyle. While children and men in some households assisted with domestic chores, the bulk of the work involved in these activities was the responsibility of the women.

Food and drink preparation

The domestic activity which almost certainly took most time was the preparation of meals. From Monday to Saturday interviewed households cooked an average of 2.4 meals per day, with 1.9 being cooked on Sunday. The cooking method which was used by all fifteen of the interviewed households was haka, boiling in coconut cream. Other cooking methods followed by at least half the households interviewed were the 'umu, boiling other than haka, frying, and roasting. Nine respondents would have liked to be able to bake food; only two said they already could. The times interviewees claimed a fire or stove had to be alight to cook a haka meal varied from 10 minutes to 2 hours, with an average of 1 hour. Those households who used different types of stove indicated that the open fire took longer than a charcoal or kerosene stove. Additional time was required to prepare food prior to cooking. To cook by the haka method coconut flesh has to be scraped out of the shells, grated, and squeezed to release the juices used in cooking. This time-consuming process would have to be carried out for most meals, as would peeling and cutting up of root vegetables and fruits. Preparation of food to be cooked in the 'umu, such as for most households' main Sunday meal, would require more time and attention. It was common practice for the man of the household to start preparing the 'umu early on a Sunday morning while the woman prepared the food. The food could then be cooking while the family was at church, and be ready to eat on their return home.

The number of people for whom meals were prepared ranged from two to twenty, with averages of about six on weekdays and seven on Sundays. The preparation of hot drinks was given as an important reason for heating water by fourteen of the fifteen interviewees. The most common appliance for heating water was the open fire, with electric jugs being used by six households, kerosene stoves by five, and charcoal stoves by three.

Handicrafts

No specific questions about the production of handicrafts were included in the interviews, but women in visited households were clearly involved in weaving mats and making tapa cloth. Apart from casual observations support for this conclusion was given by eight respondents to the household characteristics interviews saying that they needed to heat water to boil pandanus leaves in preparation for mat weaving. Following field surveys in 1985 and 1987 researchers with the South Pacific Smallholder Project calculated that handicraft activities occupied between 19 and 32 percent of Tongan village women's non-leisure time. The average time spent working on handicrafts by women in the Tongatapu villages surveyed was around 7 hours per week (Gyles, Delforce, and Ika 1989).

Washing and ironing of clothes

Tongan people take considerable pride in their personal appearance, and so the washing and ironing of clothes for all members of the family is a major activity in the management of a household. The use of electric washing machines was not monitored, but observations suggested that the majority of washing was done by hand. One household regularly used hot water for laundry and two did so occasionally. 'Ahau participants in the household characteristics interviews were asked what sort of iron they used. Ten used electric irons while five used charcoal irons, with one of these five also using a benzine fuelled iron.

Child care

The time and attention needed to care for children depends not only on the number and ages of the children but also on the assistance available from other family members and neighbours. The strong family and community cohesion which is characteristic of Tongan villages usually means that a mother can obtain help with child care. The field surveys did not include monitoring time taken up by this activity. Having young children around can affect ways in which other activities are undertaken; for example, extra vigilance is required when using an open fire.

Livestock management

In common with most rural Tongan villages, 'Ahau town allotments were the main locations for the rearing of pigs and chickens. These animals were generally allowed to roam freely within the town area, restricted only by fences erected specifically to keep them out of garden areas. Householders were observed to put some time and effort into providing food, such as coconut meat, for their livestock. Of the fifteen households interviewed, only one did not mention chickens or pigs as food produced on the town allotment. Other animals given as food sources were a horse, ducks, and goats.

Gardening

Most occupied town allotments in 'Ahau supported some food plants. Except where garden areas were protected from foraging pigs these plants generally took the form of fruit trees such as mei (breadfruit, *Artocarpus altilis*).

All four households including trees in their interview responses mentioned mei; the other trees were 'apele 'initia (soursop, *Annona muricata*), mango (mango, *Mangifera indica*), telie (Indian almond, *Terminalia catappa*), and niu (coconut, *Cocos nucifera*). Crop plants included in responses were bananas (siaine and pata, *Musa sapientum*), plantains (hopa, *Musa paradisiaca*), yams ('ufi, *Dioscorea alata*), papaya (lesi, *Carica papaya*), and sugar cane (to, *Saccharum officinarum*).

Collecting firewood

Collecting firewood for domestic use was a household chore which was estimated by interviewees to take between 8 and 60 person hours per month. All but one of the fourteen 'Ahau households using firewood included an adult male among those collecting firewood; in five households adult males were the only collectors. Adult females collected wood for nine households, and children were said to be collectors in just three. Thirteen of the fourteen respondents said they spent the same or more time now on firewood collection than they did in 1985. Three of thirteen responses claimed that less time was taken now than in 1981, but eight said collecting now took longer.

Fetching water

Fetching water from a standpipe or tank was less time consuming than collecting firewood but it was a chore that was primarily the responsibility of the woman of the household. Water supply was more of a problem during periods of drought when supplies quite commonly ran short. The installation of rainwater storage tanks adjacent to homes should have considerably reduced difficulties with the provision of water.

Transporting food supplies

Bringing produce home from the bush allotment was generally undertaken by those working on the allotment. As men were almost always most actively involved in crop management it was generally an adult male member of the household who transported subsistence food crops to the town allotment. In some households women and children also went to the bush allotment on Saturdays to help gather the food required for Sundays. Food grown on the town allotment was more likely to be harvested by women who, as they did most of the cooking, could pick fruit or dig vegetables just as they were required.

The quantity of foodstuffs bought from shops appeared to vary from household to household depending on monetary income. No specific questions about shop purchases were included in the formal interviews, but observations and informal discussions suggested that all households bought supplementary food items such as salt and sugar. Shopping from the two local shops would have caused little disruption to the daily routine, but for those households with adequate cash incomes shopping excursions to Nuku'alofa appeared to occupy a significant amount of time.

(d) Energy consumption

Electricity

All eight households connected to the electricity grid used electric lights and electric irons. One household using an extension lead from a neighbouring house also operated electric lights and iron but the other did not regularly use either. One interviewee whose home was not connected to the grid said she used an electric iron in a relative's house. None of the households interviewed used electricity for cooking.

Just over half the households interviewed said they used batteries, needing to replace an average of about two and a half per week.

Kerosene

Of the nine households using kerosene for lighting, five had no other form of lighting, three used it in combination with electricity, and one also had benzine lamps. Using kerosene for cooking and heating water was less popular, with just five respondents using kerosene stoves on a regular basis.

Gas

None of the fifteen households included in the 'Ahau interviews used gas for cooking or lighting.

Woodfuels

Firewood was by far the most commonly used domestic fuel, burnt for cooking by open fire and 'umu (Table 5.2).

Six purposes for burning firewood other than cooking were given by respondents. Nine households used firewood to dry copra, and nine boiled pandanus leaves over an open fire in preparation for mat weaving. Almost as common was the preparation of scented coconut oils for which seven households burned coconut shells, charcoal, or wood. Four households used charcoal burning irons. The two other uses of fuelwood, repelling insects and drying fish, were mentioned in two and one interviews respectively.

5.2.1.3 Cultivated systems

(a) Bush allotments

Land allocation

As indicated in Section 5.2.1.2 above, the vast majority of the land cultivated by 'Ahau households was located within 2 km of the village. The topographic nature of this agricultural land has been briefly described in Section 5.2.1.1. The full width of this section of the peninsula has been sub-divided into bush allotments with the exceptions of the town area and the narrow strips of coastal vegetation. The mean size of allotments here was less than the Tongatapu average, and it was more common for individual farmers to have two small allotments registered in their name rather than one full size allotment. Local men claimed that this system allowed the fair allocation of land of inferior and superior quality.

Of the twenty-one allotments used by respondents to the bush allotment interviews, ten were registered in the name of a member of the interviewee's household. On average these allotments had been used for 24 years, twice as long as allotments accessed by agreement with holders outside the household. Ten allotments were shared with other households; of these, only two were registered in the interviewee's household. The mean allotment size was 5.3 acres but households had access to bush allotments totalling an average of 12.4 acres. Allotments shared by two or more households were on average 50 percent larger (6.5 acres) than those used by only one (4.3 acres). The locations of the six bush allotments surveyed are indicated in Figure 5.1.

Soil

The soil in the village itself and in a 300 metre strip to the north of the village is Nuku'alofa sand. This soil type is categorised as fair for food crops and coconuts but poor for cash crops (Cowie, in preparation). The patch of Sopu sand which occurs at the southern end of the village area is even less promising for crop production. On the higher land immediately behind the Nuku'alofa sand, Fahefa clay is found. On gentle slopes this rich, well-drained soil derived from moderately weathered andesitic ash is classified as good for food crops, cash crops, pasture, coconuts, and forestry. On the steeper slopes to the west of the ridge its classification falls to 'fair' for food and cash crops.

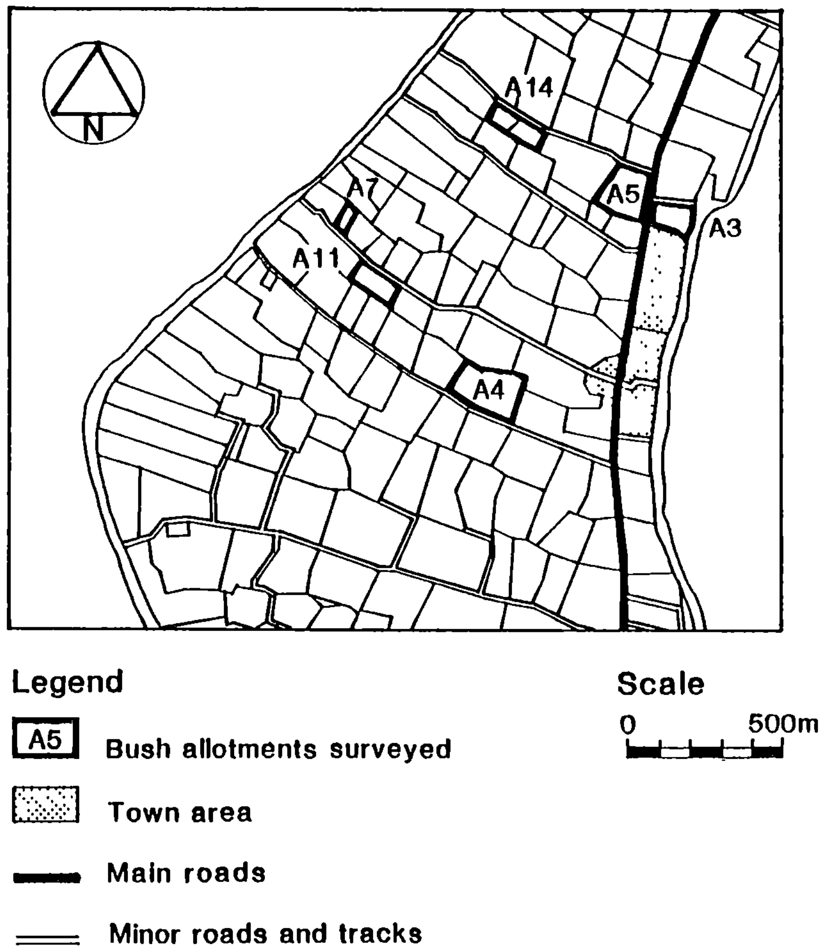
Responses to bush allotment interviews indicated that farmers were aware of significant variations in fertility both within and between bush allotments. Techniques for maintaining fertility ranged from the application of artificial fertilizers in banana plantations to ploughing and leaving land fallow. Three of the nine interviewees mentioned adding natural materials such as chicken manure, and one suggested that including beans in the fallow would lead to significant improvement.

Agricultural land management

While the use of a crop rotation system appeared to influence the proportion of land cultivated at any one time, interview results indicated that a more significant factor was whether or not commercial crops were being grown. On the five

FIGURE 5.1

Sketch map showing boundaries of 'Ahau village and surveyed bush allotments



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allotments being used at the time of the interviews to grow commercial crops 92 percent of the land was under crops. On the thirteen allotments being used for non-commercial production only 50 percent of the land area was said to be cultivated. Three (60 percent) of the five commercial allotments were reportedly being managed along traditional crop rotation lines, as were eight (62 percent) of the thirteen non-commercial allotments.

Of the six bush allotments surveyed four were said to be managed on crop rotation principles (A4, A5, A7, and A11). Each of these four was used predominantly to grow food crops. Another allotment (A14) was also managed for food production but the owner did not claim to follow traditional rotation principles. The sixth allotment (A3) was the only banana plantation and the only allotment to have less than 20 percent of its land area as fallow (Table 5.3). The majority of the 12 percent of this allotment recorded as uncultivated was covered in scrubby vegetation of coastal tree species. Such areas of land that were unsuitable for cultivation appeared to occupy significant proportions of allotments adjacent to the coasts on both sides of the peninsula. Another land use seen to reduce the area available for cultivation was the graveyard; two were

TABLE 5.3

Summary of estimated areas of cultivated, fallow, and uncultivated sections of six surveyed bush allotments used by 'Ahau households, in m^2 and as percentages of whole allotment areas

Allotment:	A3	A4	A5	A7	A11	A14	Totals
Cultivated Sections							
- m^2	10 800	19 900	4300	4700	5700	9200	54 600
- % whole	74	54	15	79	47	62	48
Fallow Sections							
- m^2	2100	14 800	23 500	1200	6200	5400	53 300
- % whole	14	41	82	21	51	36	47
Uncultivated Sections							
- m^2	1700	1800	900	0	200	300	4900
- % whole	12	5	3	0	2	2	4
Whole Allotment							
- m^2	14 700	36 500	28 700	5900	12 100	14 900	112 800
- % whole	100	100	100	100	100	100	100

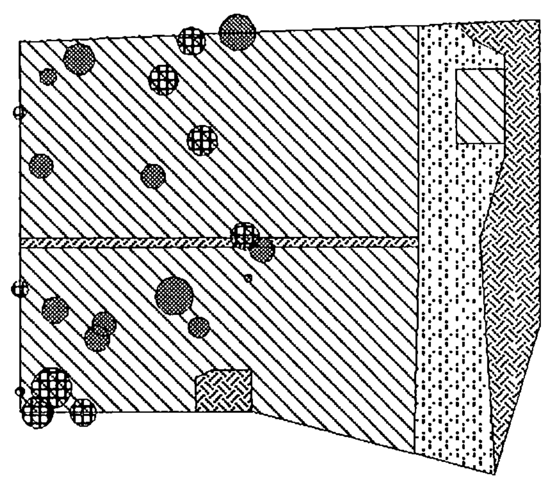
encountered on the 'Ahau allotments surveyed. The diagrams of the six allotments (Figures 5.2 to 5.7) show boundaries of areas under cultivation at the time of the survey, areas under fallow, and sections which appeared never to be cultivated. Superimposed are symbols indicating locations and relative crown areas of fruit and non-fruit trees.

The relationship between the size of an allotment and the needs of the landholder was seen to be an important determinant of the proportion of land under cultivation. One of the larger allotments surveyed, A5, had only 5 percent of its area under crops, while the smallest of the six allotments, A7, was 79 percent cultivated. In the case of the former the landholder was in secure, well-paid employment and so used just a relatively small portion of the allotment to provide favoured food crops. The smaller allotment was managed to produce food for two households with modest monetary incomes. It was the main source of food for the interviewed household and was thought to be equally significant for the second household. A large proportion of the allotment therefore had to be worked intensively. Two allotments, A4 and A11, were considered to more closely represent the typical pattern of traditional management (Plate 2). These allotments had 54 and 47 percent of their land areas under cultivation with 41 and 51 percent lying fallow. In the case of A4 the landholder lived on the bush allotment which undoubtedly increased the time spent on farming activities. Allotment A14, which was said not to be managed on crop rotation principles, had 62 percent of its area cultivated and 36 percent fallow, but only 12 percent of the total area was weeded at the time of the survey.

Crop management varied considerably, not only between farmers but also between allotments cultivated by the same household. Two of the allotments for which detailed information was collected were said to support only one crop type. However, on other allotments under the control of the same two farmers seven and four crops respectively were being cultivated. This illustrates a major difference between traditional and European styles of agriculture. The thirteen allotments on which a crop rotation system was used yielded an average of 4.6 different crop types, more than twice the average of 2.0 types grown on allotments without crop rotation. Of the seventeen crop types currently growing on the allotments under consideration, only four were present on more than 25 percent of allotments (Table 5.4). These were yams ('ufi), taro (talo), cassava

FIGURE 5.2

Diagrammatic representation of boundaries of cultivated, fallow, and uncultivated areas and individual trees with stem diameters at breast height greater than 10 cm, on bush allotment A3



LEGEND

Cultivated sections

Fallow sections

Uncultivated sections

Fruit trees

Non-fruit trees

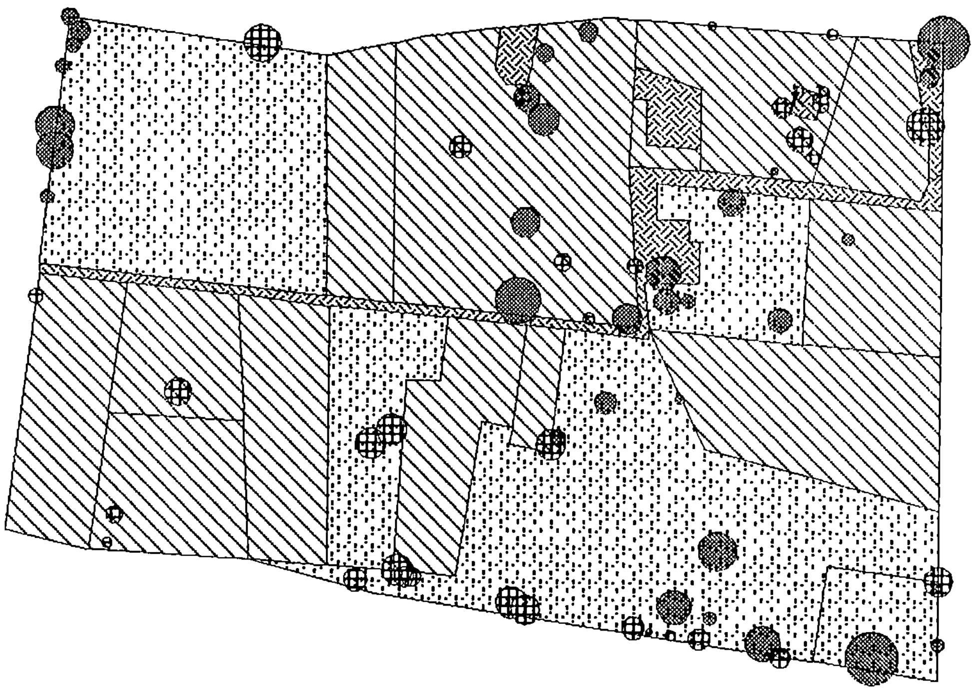
APPROXIMATE SCALE: 1:2000

0 50 metres

<u>Note</u>: The legend presented for this Figure also applies to Figures 5.3 to 5.7.

FIGURE 5.3

Diagrammatic representation of boundaries of cultivated, fallow, and uncultivated areas and individual trees with stem diameters at breast height greater than 10 cm, on bush allotment A4



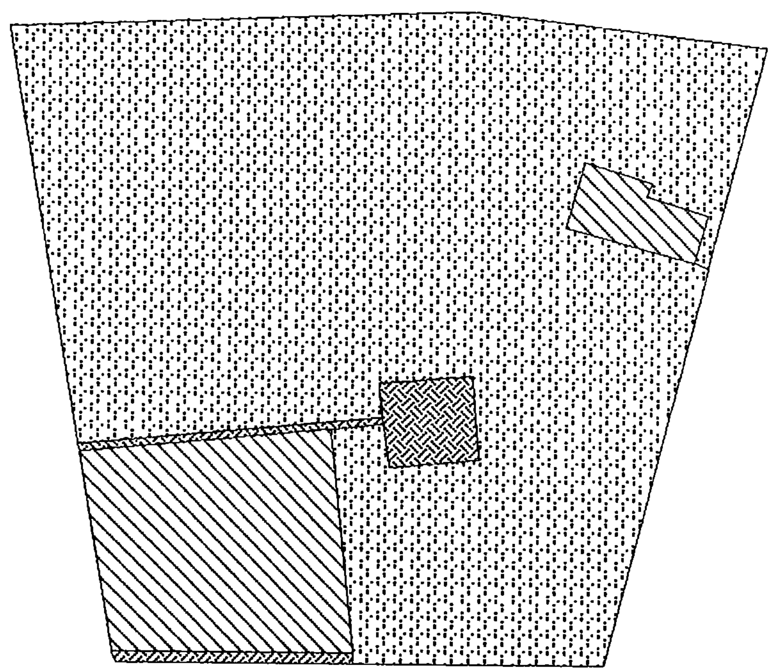
Note: For the legend to this Figure, see Figure 5.2.

(manioke), and plantain (hopa). Yams, taro, and plantain were significantly more common on allotments managed by crop rotation than on other allotments, while cassava was present on about half the allotments irrespective of management technique (Figure 5.8). The next most common crops on allotments where rotation was not practised were bananas (siaine and pata), and European style vegetables.

Each of the eight farmers practising crop rotation cultivated yams ('ufi) only during the first year of the rotation cycle. Crops most frequently accompanying

FIGURE 5.4

Diagrammatic representation of boundaries of cultivated, fallow, and uncultivated areas and individual trees with stem diameters at breast height greater than 10 cm, on bush allotment A5



Note: For the legend to this Figure, see Figure 5.2.

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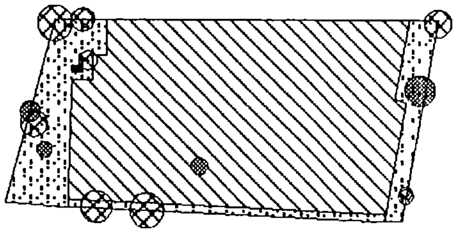
yams were plantain (hopa) and giant taro (kape). In subsequent years the predominant pattern was to grow taro (talo futuna or talo tonga) in the second and third years followed by cassava (manioke) in the third and fourth years. While plantain (hopa) continued into the second and third years, none of the interviewees included it as a fourth year crop. The average period of fallow before recommencing the rotation cycle was 1.3 years; this was the shortest fallow period recorded in any of the rural study areas. One farmer said he grew crops (yam, taro, plantain, and cassava) while the land was in fallow.

FIGURE 5.5

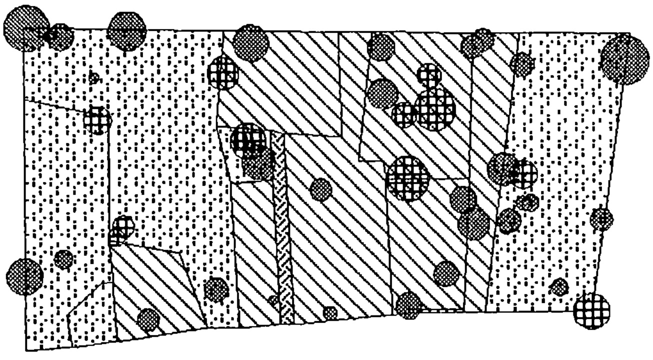
Diagrammatic representation of boundaries of cultivated, fallow, and uncultivated areas and individual trees with stem diameters at breast height greater than 10 cm, on bush allotment A7



Note: For the legend to this Figure, see Figure 5.2

FIGURE 5.6

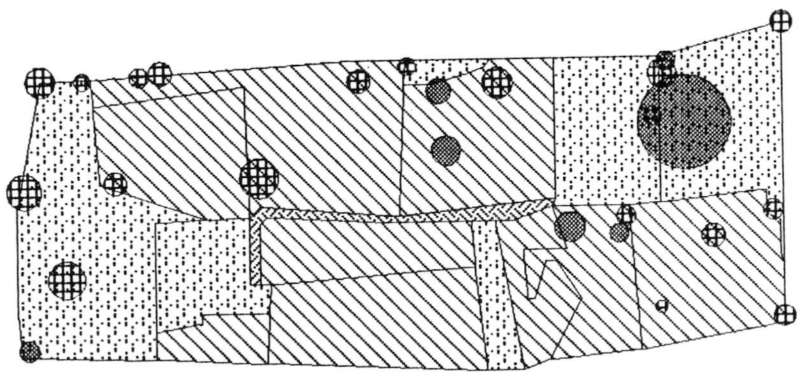
Diagrammatic representation of boundaries of cultivated, fallow, and uncultivated areas and individual trees with stem diameters at breast height greater than 10 cm, on bush allotment A11



Note: For the legend to this Figure, see Figure 5.2.

FIGURE 5.7

Diagrammatic representation of boundaries of cultivated, fallow, and uncultivated areas and individual trees with stem diameters at breast height greater than 10 cm, on bush allotment A14



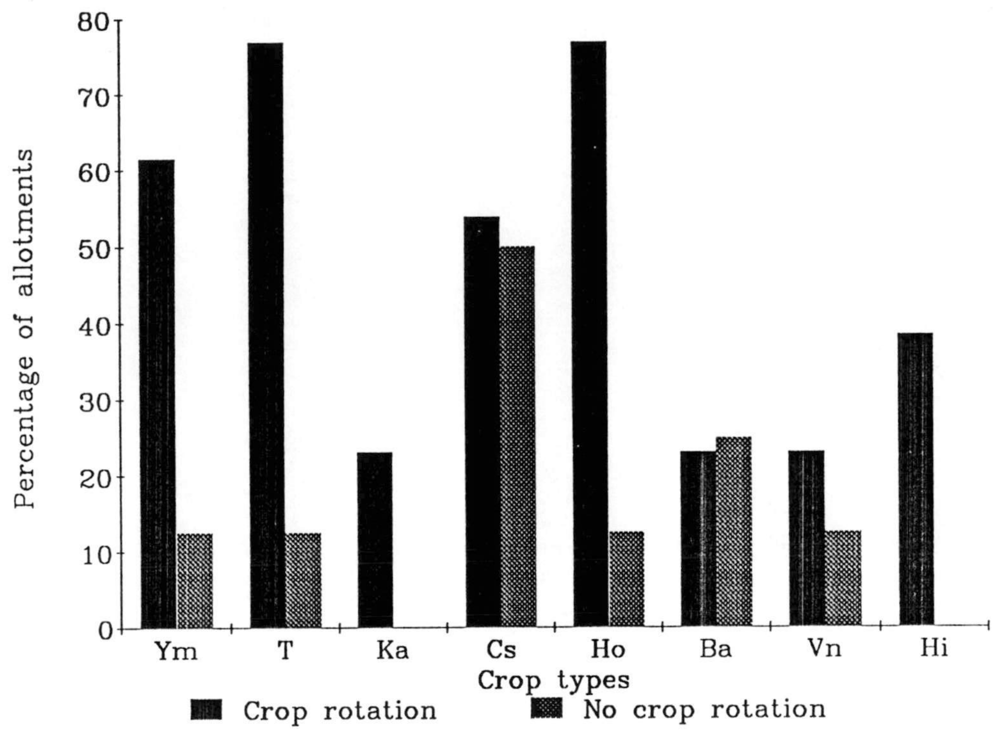
Note: For the legend to this Figure, see Figure 5.2.

Three types of agricultural equipment were used by all eight farmers: the digging spade, the hoe, and the tractor and plough. The latter was hired from either the Ministry of Agriculture or the Toloa agricultural college. Of the five respondents using chemical pesticide sprays, four said they used them only for bananas; this was a requirement of the Ministry of Agriculture for the fruit to be acceptable for export. Up to sixteen people were said to work on some allotments, but everyday management generally rested with between one and six members of the household (or households) responsible for the allotment. Cooperative groups of agricultural workers operated on eight of the seventeen allotments for which data were collected.

Four crops, cassava, yam, banana, and taro, were categorised as being most important products of cultivation on more than 20 percent of allotments. Every respondent nominated at least one of these crops as a most important product. Other important crops were plantain, vegetables, and coconuts. All of these crops were used in the household, and the majority were also products that were given

FIGURE 5.8

Percentages of bush allotments used by 'Ahau respondents to bush allotment interviews on which the most commonly mentioned types of crops were grown, by management technique



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to other family members. Estimated annual coconut production ranged from fewer than 300 to as many as 10 000 per allotment, with a mean of 3400. The average household used 32 coconuts per week (about 1600 per year) for domestic consumption. The remainder were used for copra production or sold as whole nuts. All nine bush allotment interviewees used copra dryers, fuelled with coconut residues and wood, to process copra for sale. Six also laid the coconut kernels out in the sun for part of the drying process.

TABLE 5.4

Percentages of bush allotments used by 'Ahau respondents to bush allotment interviews on which various types of crops were grown, by management technique

Crop[1.] Type	Crop Rotation Main Crop	Crop Rotation Supp. Crop	Crop Rotation Over-all	No Rotation Main Crop	No Rotation Supp. Crop	No Rotation Over-all	All Allotments Main Crop	All Allotments Supp. Crop	All Allotments Over-all
Ym	31	31	62	13		13	24	19	43
T	46	31	77	13		13	33	19	52
Ka	8	15	23				5	10	14
Cs	54		54	50		50	52		52
Ho	46	31	77	13		13	33	19	52
Ba	15	8	23	25		25	19	5	24
Pa		15	15		25	25		19	19
Pi		23	23		13	13		19	19
Sc		8	8					5	5
Vn		23	23	13		13	5	14	19
Hi		39	39					24	24
Pe		8	8					5	5
Mz	8	8	15				5	5	10
Vg				25		25	10		10
Rm				13		13	5		5
Sp	8		8				5		5
Py		8	8					5	5
Valid cases:	13	13	13	8	8	8	21	21	21

Note: 1. Tongan and English names of crop plants are listed in Appendix 4.

Trees on agricultural land

Farmers responding to questions about the benefits and nuisance values of trees on their bush allotments were unanimous in declaring that all trees were beneficial. Of the ten fruit species said to be present on interviewees' allotments none was considered to be a nuisance. Mango (*Mangifera indica*), mei (*Artocarpus edulis*), tava (*Pometia pinnata*), and moli (*Citrus* species), were each mentioned by five or more of the interviewees as being beneficial (Table 5.5). Among non-fruit trees, the one species which every respondent stated was of benefit was koka(*Bischofia javanica*). The next most favoured non-fruit trees were fau (*Hibiscus tiliaceus*) and tuitui (*Aleurites moluccana*). The most frequently mentioned benefits gained from trees were food production, provision of dyes, fuelwood supplies, and medicine (Table 5.6). The only tree mentioned solely because of its nuisance value was 'akauveli[1] (*Indigofera suffruticosa*). Two species, tavahi (*Rhus taitensis*) and talatala (*Lantana camara*), were nominated as being both a benefit and a nuisance. The reasons for these trees being classed as a nuisance were that they competed with crops, impeded hoeing, and created unwanted shade. These same disadvantages were included as influences on crops of trees in general. Positive influences on crops were given as shelter, shade for plants such as kava (*Piper methysticum*), moistening and improving the fertility of the soil, and providing windbreaks. Two of the nine interviewees said they had plans to destroy some trees; one to clear land for a new yam garden, and the other to convert over-mature coconut stems into timber.

All but two of the respondents to the bush allotment interviews had planted trees on their allotments. Six had planted mei, four mango, and two tava. Food was the dominant reason for planting. The only non-fruit trees planted were pulukamu (*Eucalyptus* species) because free seedlings were available, and lou'akau (*Pandanus* species) for handicraft material. Six of the nine farmers interviewed said they intended to plant more trees on their bush allotments. The production of food, building timber, and handicraft material were the most popular reasons, but one

1. 'Akauveli (*Indigofera suffruticosa*) is, in fact, a spindly shrub. It is included in consideration about trees because it was a significant invasive species which was commonly referred to by bush allotment interview respondents.

TABLE 5.5

Percentages of nine respondents to bush allotment interviews in 'Ahau identifying fruit and non-fruit tree species on agricultural land as being of benefit or a nuisance, and tree species protected during the clearing of fallow and weeding

Species	Benefit	Nuisance	Protect During Clearing	Protect During Weeding
Fruit trees				
AVO	11			
FEK	11			
FKP	11			
IFI	44		11	22
KUA	33			
MAN	89		67	44
MEI	78		33	33
MOL	56		44	33
Py			11	
TAV	78		33	44
VII	11			
Total numbers of fruit species	10	0	7	5
Non-fruit trees				
AKV		22		
FAU	33			
HEH			11	
HEI			11	
KOK	100		44	33
LOA	11			
LOP	11			
LOU	11			
MAI	11			
MNU	11			
NON	11			
OVA	11			
SIA	22			
TAH	11	11		
TAL	11	11		
TUI	33		11	11
Total numbers of non-fruit species	13	3	4	2
Total numbers of fruit and non-fruit species	23	3	11	7
Non-specific categories				
All fruit			44	11
Medicinal			11	

TABLE 5.6

Percentages of nine respondents to bush allotment interviews in 'Ahau giving various reasons for trees on agricultural land being a benefit and for protecting them during clearing of fallow and weeding

Reason/ Useful Product	Benefit from trees	Reason for protecting trees
Food	78	78
Fruit	22	11
Dye	67	22
Fuelwood	56	44
Medicine	22	11
Soap	11	
Oil	11	
Tapa		11
Dishwashing	11	
Income	11	
Building material	11	
Crop supports	22	
Windbreak		11

response included the generation of traditional materials for making scented oil and leis.

The surveys of six bush allotments belonging to 'Ahau interviewees showed considerable variation in the density of trees and in the species maintained on agricultural land. The six allotments surveyed ranged from approximately 0.6 to 3.6 hectares, with between 15 and 79 percent of the total area currently cultivated (Table 5.3). The number of tree species recorded ranged from eight to seventeen. On five of the six allotments non-coconut tree densities were higher on non-cultivated than cultivated sections. Numbers, measurements, and locations were consistently recorded only for those trees with diameters at breast height of 10 cm or greater. The bush survey field data presented in tables and discussed in the text of this thesis refer only to these 'large' trees except where explicit mention is made of smaller trees. The exception was the only allotment used primarily for commercial crops (A3). Here the density of trees on the cultivated section was higher than average, but no trees were growing in the fallow area which was close to the coastal boundary of the allotment (Table 5.7). The balance between fruit and non-fruit trees varied from allotment to allotment: three had more fruit than non-fruit trees on the cultivated land; two had more non-fruit trees; and one had similar numbers of each. Over the whole areas of the

TABLE 5.7

Numbers and densities of coconut, fruit, and non-fruit trees on cultivated, fallow, and uncultivated sections of six bush allotments used by 'Ahau households

	A3	A4	A5	A7	A11	A14	Totals
Cultivated Sections							
Numbers of trees							
Coconuts	161	172	64	nr	70	119	586+nr
Fruit trees	12	13	2	1	13	4	45
Non-fruit trees	12	24	1	0	5	12	54
Total numbers	185	209	67	1+nr	88	135	685+nr
Trees per hectare							
Coconuts	149	87	148	nr	118	129	107+nr
Fruit trees	11	7	5	2	23	4	8
Non-fruit trees	11	12	2	0	9	13	10
Totals per hectare	171	105	155	2+nr	155	146	125+nr
Fallow Sections							
Numbers of trees							
Coconuts	41	96	286	17	78	49	567
Fruit trees	0	19	20	3	18	4	64
Non-fruit trees	0	15	48	9	9	13	94
Total numbers	41	130	354	29	105	66	725
Trees per hectare							
Coconuts	196	65	122	137	125	91	106
Fruit trees	0	13	9	24	29	7	12
Non-fruit trees	0	10	20	73	14	24	18
Totals per hectare	196	88	151	234	168	122	136

Continued

TABLE 5.7 Continued

	A3	A4	A5	A7	A11	A14	Totals
Uncultivated Sections							
Numbers of trees							
Coconuts	22+nr	9+nr	7	na	0	5	43+nr
Fruit trees	0	3	0	0	0	1	4
Non-fruit trees	7	0	3	0	0	0	10
Total trees	29	12	10	0	0	6	57
Trees per hectare							
Coconuts	166+nr	51+nr	77	na	0	193	88+nr
Fruit trees	0	17	0	0	0	39	8
Non-fruit trees	40	0	33	0	0	0	20
Total per hectare	167	67	110	0	0	232	116
Whole Allotment							
Numbers of trees							
Coconuts	224+nr	277+nr	357	17+nr	148	173	1196+nr
Fruit trees	12	35	22	4	31	8	112
Non-fruit trees	19	39	52	9	14	23	156
Total trees	255+nr	351+nr	431	30+nr	193	204	1464+nr
Trees per hectare							
Coconuts	153+nr	76+nr	124	29+nr	122	116	106+nr
Fruit trees	8	10	8	7	26	5	10
Non-fruit trees	13	11	18	15	12	15	14
Total per hectare	174+nr	96+nr	150	51	159	137	130+nr

TABLE 5.8

Crown areas of fruit and non-fruit trees over cultivated, fallow, and uncultivated sections of five[1] bush allotments used by 'Ahau households

	A3	A4	A7	A11	A14	Totals
Cultivated Sections						
Fruit - m^2	467	456	18	535	175	1651
- % land area	4.3	2.3	0.4	9.4	1.9	3.3
Non-fruit - m^2	354	348+nr	40	369	335	1446+nr
- % land area	3.3	1.8+nr	0.9	6.5	3.6	2.9+nr
All trees - m^2	821	804+nr	59	904	510	3097+nr
- % land area	7.6	4.0+nr	1.3	15.9	5.5	6.2+nr
Fallow Sections						
Fruit - m^2	0	725	66	554	654	1999
- % land area	0	4.9	5.3	8.9	12.1	6.7
Non-fruit - m^2	0	502	151	301	317	1271
- % land area	0	3.4	12.2	4.8	5.9	4.3
All trees - m^2	0	1227	218	856	971	3272
- % land area	0	8.3	17.6	13.7	17.9	11.0
Uncultivated Sections						
Fruit - m^2	16	170	0	12	21	219
- % land area	0.9	9.6	0	5.8	8.1	5.5
Non-fruit - m^2	15+nr	54+nr	0	0	0	69+nr
- % land area	0.9+nr	3.0+nr	0	0	0	1.7+nr
All trees - m^2	31+nr	224+nr	0	12	21	288+nr
- % land area	1.8+nr	12.6+nr	0	5.8	8.1	7.2+nr
Whole Allotment						
Fruit - m^2	483	1351	85	1101	850	3870
- % land area	3.3	3.7	1.4	9.1	5.7	4.6
Non-fruit - m^2	369+nr	904+nr	192	671	653	2789+nr
- % land area	2.5+nr	2.5+nr	3.3	5.5	4.4	3.3+nr
All trees - m^2	824+nr	2256+nr	276	1772	1502	6658+nr
- % land area	5.6+nr	6.2+nr	4.7	14.6	10.1	7.9+nr

Notes: 1. Data from bush allotment A5 have been excluded from this table as information on crown areas was not collected.

allotments only one had more fruit trees than non-fruit (Table 5.8); this was the allotment whose management had been closest to traditional crop rotation practices. Four types of tree were present on all six allotments: mei, tava, fau, and koka. Of these, koka was by far the most numerous with an average density of 7.4 trees per hectare, followed by mei with 3.1, and fau with 2.4 trees per hectare. One allotment had no mango trees, but overall they occurred in similar densities to tava. The crowns of koka trees covered an estimated 2.6 percent of the area of the five allotments on which crown dimensions were recorded (Table 5.9). Mango trees covered 1.9 percent, mei 1.0 percent, and tava 0.9 percent of the total land area. While proportions of land covered by other species varied little, the crowns of mango and fau occupied higher percentages of fallow land than cultivated sections.

Significance to fuelwood supply

Bush allotments were the main sources of fuelwood for the households included in the interview survey. All fourteen fuelwood using households collected wood from bush allotments. Six respondents said their most important collection site was an allotment belonging to their own household, and four said an allotment owned by another household was their most important source of fuelwood. A wider variety of fuel types was said to be gathered from bush allotments than from any other source.

(b) Town allotments

Land allocation

Only four of fifteen householders interviewed could give an estimate of the size of their town allotment. From Ministry of Lands, Survey and Natural Resources records official sizes were found to range from 760 m^2 to more than 1600 m^2, with a median of 970 m^2. As many allotments were unoccupied, boundaries were not in every case clearly defined. A household could well have been using a area of land larger than their own allotment. Members of two 'Ahau households were registered holders of town allotments other than the ones they lived on.

TABLE 5.9

Tree densities per hectare and crown areas as percentages of land area[1], for the ten tree species most commonly found on five[2] surveyed bush allotments used by 'Ahau interviewees

Rank	Species		Cultivated	Fallow	Uncult-ivated	Whole Allotment
1.	KOK	per ha	6.2	7.4	0.0	6.3
		% area	2.4	2.9	1.5	2.6
2.	MEI	per ha	2.4	5.0	0.3	3.3
		% area	1.0	0.9	1.1	1.0
3.	FAU	per ha	1.2	5.0	0.7	2.7
		% area	0.1	1.1	0.2+nr	0.5+nr
4.	MAN	per ha	1.4	4.0	0.3	2.4
		% area	0.8	3.7	2.0	1.9
5.	TAV	per ha	2.2	2.3	0.0	2.1
		% area	0.9	0.8	0.5	0.9
6.	MOL	per ha	1.6	1.0	0.3	1.4
		% area	0.2	0.2	0.6	0.3
7=	NGA	per ha	1.0	1.0	0.0	1.0
		% area	<0.1	<0.1	0.1	<0.1
7=	VAV	per ha	1.2	0.7	0.0	1.0
		% area	0.1	<0.1	0.1	0.1
9=	IFI	per ha	0.2	1.0	0.3	0.6
		% area	0.1	0.4	1.1	0.3
9=	TOT	per ha	0.0	0.0	1.7	0.6
		% area	0.0	0.0	nr	nr

<u>Notes</u>:
1. Density figures refer to trees recorded as having stems growing in the section under consideration; crown areas include overhanging foliage from trees rooted in adjacent sections.
2. Data from bush allotment A5 have been excluded from this table as information on crown areas was not collected.

Areas of town allotments devoted to cultivation or other purposes were not recorded.

Crop management

While all but one of the fifteen interviewees obtained animal products from their town allotments only five grew crops. Most commonly cultivated were bananas, plantain, and papaya; only one household had planted root crops: taro and yam. Four interviewees included tree fruits as food products obtained from town allotments.

Trees on agricultural land

The two respondents listing the greatest number of food producing trees on their town allotments also grew food crops. One household gave breadfruit as the only food produced on the town allotment, and another which had both breadfruit and mango trees owned pigs and chicken but did not have any food crops on the town allotment. One household had no trees on their town allotment; all others said that trees were beneficial, and eleven gave food production as a reason. Twelve households had planted trees on their town allotments and fourteen said they intended to do so.

Significance to fuelwood supply

Five of fifteen interviewees said they collected fuelwood from their own town allotments; four of these households also collected from others' allotments. One household used to gather wood from town allotments but at the time of the interview collected all fuelwood from their bush allotment. Fuelwood types collected included coconut residues and fruit and non-fruit tree species. For the household with a dead eucalyptus tree on their town allotment this was their main source of fuelwood and was expected to remain so until the last of the eucalypt had been used.

PLATE 1
Degraded coastal land
adjacent to 'Ahau village

PLATE 2
A well tended traditional bush allotment near 'Ahau

5.2.1.4 Commercial systems

(a) Commercial exchange of goods and services within the study area

The greatest volume of commercial activity in 'Ahau was generated by the two shops, one privately run and one controlled by the Free Wesleyan Church. These sold groceries and minor household items including kerosene.

Services paid for within the village included transport, labouring, and the use of agricultural land. Six interviewees said they paid for transport to collect fuelwood, at the rate of T$2 to T$3 for a cart or T$5 for an open back van. Another household supplied fuel for a van rather than paying cash. One interviewee gave tobacco as payment for collecting fuelwood. Two groups of agricultural labourers were known to work on others' bush allotments for daily wages; earnings for such work were said to be T$1 per day. One interviewee gave odd jobs as a source of earned income. Farmers in two interviewed households paid for the use of bush allotments; one paid T$50 per year, the other more than T$500. None of the fifteen respondents paid for access to land to collect fuelwood.

(b) Commercial exchange outside the study area

The produce most frequently sold by 'Ahau households was coconuts. All nine bush allotment interviewees made copra, and eight sold whole nuts. Mature whole nuts could be sold to the Tonga Commodities Board to be processed in the desiccated coconut factory, but the numbers required were such that the buyers selected only the largest nuts. Both mature and green whole nuts were sold at the Talamahu market, and one of the farmers included in the interview survey took sackfuls of nuts to market each day. The copra was sold to the Tonga Commodities Board.

Seven interviewees included commercial farming among the household's income generating occupations. Apart from coconuts and copra, farmers sold: bananas and plantain; root crops such as yams, taro, and cassava; European vegetables; fruits, including pineapple and papaya; paper mulberry stems for making tapa cloth; and, in one case, vanilla. While small quantities of agricultural produce were probably sold within the study area most would have been sold at market in Nuku'alofa or exported.

Five interviewed households were dependent on farming or fishing for their primary monetary income; all but one earned less than T$1000 per year. All households including a salaried worker had annual earned incomes exceeding T$1000; most of these paid jobs were located in Nuku'alofa.

To obtain most durable goods 'Ahau residents travelled to Nuku'alofa. The town shops offered a much broader range of consumer items than the village shops could possibly stock, and could generally sell them more cheaply. For virtually all village households the majority of their commercial activity was carried out in Nuku'alofa. To obtain money, either a wage or salary earner worked in the town or the household's agricultural produce was sold there. Spending money on goods other than day-to-day supplements to their own food production was carried out in the town's shops.

(c) Support for commercial activities

The main institution providing assistance to householders in relation to money matters was the Bank of Tonga. A range of domestic banking services was available. At the time of the interviews the only Bank outlet open on each working day was in Nuku'alofa.

The Tongan Development Bank was the source of financial assistance to the business sector but there appeared to be little commercial development in 'Ahau that would attract such support. With farming being the main commercial activity in 'Ahau the government department most involved in providing advice was the Ministry of Agriculture, Fisheries, and Forests. Agricultural extension officers visited farmers on their allotments to advise about production techniques for cash crops. The Ministry schemes for the promotion of coconut replanting and growing bananas for export had the most impact on how 'Ahau farmers managed their agricultural land. For bananas to be accepted as export quality they had to be grown in accordance with the Ministry's requirements, particularly with regard to pest control. These requirements, and charges made for Ministry services, led to a reduction in the mid 1980s in the numbers of farmers growing bananas for export.

Through its ownership of one of the two shops in 'Ahau the Free Wesleyan Church was assisting the commercial distribution of goods within the village.

Some assistance with commercial fishing activities was available from the Ministry of Agriculture, Fisheries and Forests. It is not known whether any 'Ahau residents had made use of this support.

(d) Significance to fuelwood supply and consumption

The commercial activity most likely to affect fuelwood resources was the growing of cash crops. The degree of impact experienced would depend on the type of crop grown, details of the management system adopted, and the attitude of the farmer. Growing bananas to the Ministry's recommended procedure required weeds around the crop plants to be carefully controlled. While this would severely limit the regeneration of potentially valuable fuelwood species it did not require the felling of existing large trees. The prescribed cultivation technique did mean that export quality bananas could not be grown in a traditional mixed crop system which tended to have a higher proportion of trees growing on the cultivated land. For the production of several cash crops, such as water melons and European vegetables, many farmers believed it was necessary to plough the land. This practice commonly led to the clearing of trees to make the use of machinery easier. The desire to use a tractor and plough could make a farmer reluctant not only to plant new trees but also to replace senile coconuts. This perceived conflict between the growing of short-term cash crops and coconuts appears to have contributed to the Government's coconut replanting scheme having a lesser impact than hoped for. If the scheme succeeded in persuading farmers to maintain high densities of coconut trees it would significantly increase quantities of coconut residues available for use as fuel. There was also an apparent conflict between 'modern' mechanical agricultural techniques and allowing the land to lie fallow. This undoubtedly had a significant impact on fuelwood supply.

Whatever the density of coconut trees the selling of whole coconuts and copra had an impact on the amount of coconut fuel available for domestic purposes within the study area. The husk and shell of whole nuts sold to the desiccated coconut factory was either used to fire the factory's boiler or sold to townspeople. Copra drying in the village required the consumption of fuelwood, mostly coconut residues but sometimes including wood from other species. In each case the amount of fuel available for household use in 'Ahau was reduced. At the time of the interviews there was an abundance of coconut residues for use as fuel, but if very large quantities of coconuts were removed from the village the potential for shortages to occur would increase.

With increasing amounts of money circulating within the village commercial energy sources had become more significant. While many uses of electricity were supplementary to the purposes to which fuelwood was put, a few households were using it to replace wood. For example, five of the interviewed households were using electric jugs for heating water. While the vast majority of 'Ahau households used wood as their main cooking fuel the availability of kerosene stoves was changing patterns of domestic activities in a few homes. The impacts on wood supplies of the adoption of commercial fuels cannot be predicted, but scenarios can be constructed. The small degree to which commercial fuels had substituted for fuelwood in 1986 had no significant effect on the fuelwood resource. If a larger number of households shifted to the use of kerosene, gas, and electricity, the reduced pressure on wood supplies could be expected to make collection easier for those still using wood. However, if enough people were using commercial fuels for the provision of fuelwood to be seen as completely insignificant, land management practices might be adopted that would dramatically degrade the fuelwood resource. There already appeared to be a trend in this direction, with many people believing that in the near future they would be able to purchase commercial fuels.

5.2.1.5 Social systems

(a) Demographic features

In common with the five other villages on the north-western peninsula, the population of 'Ahau fell between 1976 and 1986. From 307 in 45 households in

1976 'Ahau's total numbers declined to 282 in 43 households in 1986. Although the difference in absolute numbers is fairly small, 'Ahau's fall in population of 8.1 percent contrasts with population growth over the whole of Tongatapu of 10.8 percent over the same period. It would appear that while a proportion of 'Ahau residents have been leaving the village, few outsiders have been moving in. In the author's interview survey the heads of 14 of the 15 households visited considered 'Ahau to be their home town. The exception was the Free Wesleyan Church minister who moved around the country at the direction of the Church authorities. Seven heads of households had lived on the same town allotment for more than twenty years, and eleven for more than ten years.

The overall sex ratio in 'Ahau somewhat surprisingly showed the male population (146) to be seven percent larger than the female population (136) (Tonga, Statistics Department, Undated). In the households interviewed the overall ratio was quite even: 42 females to 41 males, but adult males outnumbered adult females 26 to 21. In 1976 47 percent of 'Ahau's population was under sixteen years of age (Tonga, Kingdom of, Undated); in the interviewed households in 1986 the proportion was 43 percent.

(b) Community facilities and services

The level of basic services and amenities in 'Ahau was comparable to most other rural Tongatapu villages. These community facilities were provided by government instrumentalities, by the church, by private enterprise, and by some non-profit non-government organisations.

The government activity which had perhaps the most significant immediate impact on village life was the allocation of land. The system of registration, which was common across the country, is discussed in Chapter 2. With the decline in 'Ahau's population only about half of the town allotments designated in the village area were occupied in 1986. Some of the unoccupied plots were built on but the majority were left vacant. Bush allotments allocated to people not living in the village were less likely than town plots to be left vacant.

Government controlled bodies were responsible for the reticulated supply of both water and electricity. 'Ahau's piped water was pumped from a bore hole source in

Masilamea about 4 kilometres away. Until 1986 supplementary water supplies consisted of rainwater collected in communal tanks. During 1986 a programme of construction of rainwater tanks for individual households was undertaken. These were enthusiastically received as rainwater was generally preferred to piped water for drinking and cooking.

Access to the main electricity grid was available to all households in the village but in 1986 only eight of the fifteen households interviewed were connected.

The only formal religious meeting place in 'Ahau was the Free Wesleyan Church which, as Sunday in Tonga is devoted largely to religious activity, assumed a significant social role. Apart from being the venue for formal Sunday worship the church was central to activities which involved members of all sections of the community. These included a kava circle, a choir, a Sunday school, and debates. The role of the minister was a significant one for the village community as he was in a position to disseminate information and ideas to representatives of virtually all 'Ahau households on a regular basis.

As in other villages, 'Ahau's representative on government issues was the town officer. The district officer lived in Kolovai. The police officer living in 'Ahau was also perceived as representing the authority of the central government.

The metalled road which ran from the north-west peninsula to Nuku'alofa, and from there to the eastern Hahake district, provided 'Ahau's main link with the rest of the island. 'Ahau residents working in offices in the capital could comfortably commute daily to the capital. A total of seven buses ran between 'Ahau and Nuku'alofa; none of these were owned by 'Ahau residents. The buses were commonly used to take produce to Talamahu market for sale, and to bring purchases back home. Locally, a network of unmetalled roads provided access to all bush allotments.

Only one house in the village had a telephone installed.

(c) Social characteristics

The social structure of the village was fundamentally traditional in nature but was being increasingly influenced by more materialistic values. The town officer and his deputy were important members of the village community because of their roles of liaison with the government, and the church minister held a pivotal role. Indeed the Free Wesleyan Church, the only church in the village, was the main focus for social activity. Others enjoying higher than average social status were the police detective and an engineer working for the Tonga Electric Power Board. For both these salaried government employees, higher than average material well-being appeared to reinforce their social standing. In the case of the engineer, ownership of an almost new motor vehicle was, apart from being a convenient mode of travelling to work in Nuku'alofa, a very visible status symbol. Ownership of electrical domestic appliances also appeared to contribute to raising a household's social status.

While there was a trend towards greater individualism, the family and the church were still dominant social institutions. The holding of feasts reinforced their roles in maintaining social cohesion and stability. Continuing obligations for giving food to chiefs and nobles also sustained the traditional social hierarchy.

(d) Significance to fuelwood supply and consumption

Social relations played an important role in the control of access to some fuelwood collection sites. Rights to fuelwood on bush allotments were normally restricted to a relatively small social group approved by the landholder. Among the nine bush allotment interviewees in 'Ahau only one said that anyone could collect fuelwood on his land. Most respondents stated rights were limited to themselves and either family members or others with their permission. Such a system provided individuals with a route for obtaining wood while helping to prevent over exploitation. While the close social cohesion in the community did not lead to villagers always agreeing with one another, it did encourage respect for one anothers' rights.

The important role of feasts in social activities in the village generated a significant demand for fuelwood throughout the year.

5.2.1.6 Fuelwood systems

(a) Sources

None of the 'Ahau households included in the interview survey obtained wood from commercial sources or paid for access to the land where they collected fuelwood. All fourteen households that used fuelwood collected from bush allotments; for ten of them bush allotments represented the most important collection site. Among the ten collection sites six were the household's own allotments and four belonged to others. Coastal locations provided wood for nine households and were main collection sites for three. Town allotments constituted the major source of fuelwood for one household and supplementary sources for four others. Two households collected some wood from roadsides and one gathered coconut husk and shell from a copra dryer (Table 5.10).

Due to fuelwood collections being made on both the western and eastern shores of the peninsula there was a slightly greater variation in distance to coastal sources than to bush allotments. Distances to coastal sites ranged from less than 0.1 to 2 km, with a mean of 0.84 km and a standard deviation of 0.84 km. Distances to bush allotment collection sites also ranged from less than 0.1 to 2 km, but with a mean of 0.96 and a standard deviation of 0.58 km.

The greatest variety of fuelwood types was collected from bush allotments. Respondents listed 6 fruit tree species, 5 non-fruit species, 6 types of coconut residue, and 2 other categories ('various' and 'wood') as being collected from this source. No fruit tree species were gathered from the coast but eleven types of non-fruit tree and three coconut categories were mentioned (Table 5.11). Of the three most commonly collected species koka and tava came only from bush allotments while fau was collected primarily from coastal sites.

On the five comprehensively surveyed bush allotments koka and fau were the most numerous non-fruit trees and were clearly dominant in terms of crown area. Tava was the second most numerous fruit tree but had a lower total crown area than both mango and mei. No mature specimens of kuava, the fourth most important non-coconut fuelwood species, were recorded on any of the surveyed allotments. However, immature kuava trees with diameters at breast height of less than 10 cm were observed on three allotments. Moli, the fifth most important fuelwood types, was the fourth most numerous fruit tree but with a smaller average crown area than mei, tava, or mango.

TABLE 5.10

Orders of importance given by fourteen 'Ahau households to firewood collection sites they were using in 1986

Household Reference	B1	B2	OB	T/OT	C	R	CD
1	1						
2	1	2		3			
3	2	3		4	1		
4	4		1		3	2	
5	3		4	1	2		
6			1	3			2
7	1			2			
8	4		1		3	2	
9	1						
10	1		3		2		
11	3		4		1&2		
13	3		2		1		
14	2		1		3&4		
15	1		2		3&4		
Total numbers of households	13	2	9	5	9	2	1
Percentage of households	93	14	64	36	64	14	7

Key to Fuelwood Sources

B1	Household's own bush allotment, number 1
B2	Household's own bush allotment, number 2
OB	Bush allotment(s) belonging to other household(s)
T/OT	Own and others' town allotments
C	Coastal land
R	Roadsides
CD	Copra dryer

TABLE 5.11

Percentages of fourteen fuelwood using households interviewed in 'Ahau collecting various types of wood from five categories of sources

Species Code	Bush	Town	Coast	Road-sides	Copra dryer	Totals
Fruit Trees						
IFI	7					7
KUA	43					43
MAN	14	7				14
MEI	7					7
MOL	29			7		29
TAV	79					79
All Fruit	86	7	0	7	0	86
Non-Fruit Trees						
FAU	36		57	7		71
FET			7			7
KAS	7	7		7		14
KOK	86					86
LAL			14			14
LEK			21			21
LEP		7				7
MIL			7			7
PLK		7				7
PUA			7			7
SIA	7		14			21
TAH	14					14
TAT			7			7
TIM			14			14
TOA			36			36
TON			7			7
All Non-Fruit	86	14	64	7	0	100
Coconut Fuels						
COC	21			7		21
H&S	21	7	7		7	36
LOH	14					14
PAL	21					21
PUP	7		21			29
SHE			7			7
TOU	21					21
All Coconut	57	7	21	7	7	79
Other Types						
Various	7					7
Wood	7			7		7
All 'Other Types'	14	0	0	7	0	14
Overall	100	36	64	14	7	100

(b) Harvesting, transport, and preparation

Interview data indicated that fuelwood collection was predominantly carried out by adults, mainly male (Section 5.2.1.2.(c) above). This was linked to men spending the most time on agricultural activities. Reported patterns of collection tended to reflect the amount of time spent on agricultural work. For those households which derived a monetary income from farming, fuelwood was collected from bush allotments on an average of 14.3 times per month. For other households the average number of collections from bush allotments per month was 6.5. Collections from coastal sites averaged 15.8 per month and from town allotments averaged 8.8 per month. Estimated person hours spent per month collecting fuelwood ranged from eight to sixty with a mean of twenty-four. Sixty-two percent of respondents said they spent more time on fuelwood collection in 1986 than in 1981, and 29 percent spent more time than in 1985. Thirty-six percent spent the same or less time than in 1981 and 1985.

Only two of the fourteen households collecting fuelwood cut live trees as well as gathering dead wood. They both lopped and coppiced trees and one felled some specifically for fuelwood. Twelve respondents said they killed trees by ring-barking or burning and later used the wood as fuel. All but one included koka in the list of trees killed by ring-barking. The most commonly utilised equipment in harvesting fuelwood was the helepelu, or cane knife, used by all fourteen fuelwood users interviewed. Axes, toki, were used regularly by twelve respondents and occasionally by another. Hand saws, kili, were consistently utilised by four households, and chainsaws by two. Carrying by hand was a significant form of transport for eleven households (Plate 3) but most of these also used wheeled vehicles on occasions. The most popular vehicle was the saliote, horse and cart, utilised regularly by six and occasionally by four households (Plate 4). Two respondents said they regularly used a van to collect fuelwood, two used horses, and two buses. One sometimes hired a truck. Six households paid between T$2 and T$5 for the use of a cart, van, or truck.

Most wood taken home from the collection site was between 0.5 and 1.5 m long. Only the household which cut its wood to 0.5 m lengths prior to taking it home did not need to cut it down to a suitable size for burning. The majority of households burnt fuelwood in approximately 0.5 m lengths, but four used wood

PLATE 3

Transporting coconut fronds, palalafa, to be used as fuel

PLATE 4

The horse and cart, saliote, is commonly used to transport fuelwood

up to 1 m long. The helepelu was again the most commonly used cutting equipment, utilised by all but one of thirteen respondents. Six used axes, toki, and one used a handsaw, kili. In eleven of thirteen households adult males cut the wood to size, and adult females did so in six households. Only one respondent said children contributed to this work. Fuelwood was stored most frequently inside the kitchen; nine of the fourteen fuelwood users said they kept wood there all the time. The only alternative storage site mentioned was outside on the town allotment, where there was an almost equal chance of the wood being covered or uncovered.

While the ultimate source of the vast majority of coconut fuels was the plantations not all came directly from the bush allotments to the fire. The most commonly used coconut fuels were residues left over from other uses. Once coconut flesh had been removed for culinary purposes or fed to pigs the husks and shells were readily available for burning. Similarly the preparation of copra led to the provision of residue husks and shells, and while many of these were burnt in copra dryers some were retrieved for domestic consumption. Coconut residues brought from bush allotments specifically as fuel were transported to the town allotment only when a suitably low moisture content had been achieved. Husks were often removed from mature coconuts on the bush allotment so that the husks could be stacked to dry while the kernel and shell were taken to town. Other coconut residues commonly used as fuel were palalafa (frond stems), loholoho (flower spathes), toume (flower spathe sheaths), and pupu (coconuts cut green for drinking). Stems of senile coconut palms were sometimes cut up for fuelwood, and one of the fifteen households interviewed obtained offcut slabs of coconut stemwood from a sawmill. Preparation of most coconut residues was said to involve either breaking by hand or chopping with a knife.

(c) Consumption patterns

The predominant use for fuelwood in households interviewed in 'Ahau was cooking, with fourteen of fifteen interviewees saying their main cooking appliance was the open fire. All fourteen also burnt wood in either an earth or a drum 'umu. Only four supplemented their wood-burning cooking appliances with kerosene stoves. Estimates of the time that the fire was alight ranged from 10 minutes to 2 hours, but the low estimate was considered to be an exaggeration.

Eight interviewees suggested times between thirty and sixty minutes, five said longer than an hour, and only two estimated less than half an hour. On average six people were cooked for on weekdays, and six households prepared food for extra numbers on Sundays.

Twelve of the fourteen fuelwood using households included coconut residues among their five most important fuelwood types; the remaining two households used them as supplementary fuels. The dominant non-coconut fuelwood species were koka, fau, tava, and kuava, important fuelwood types for ten, eight, eight, and seven households respectively. Of the other seven species listed by between one and three respondents, only two, moli and mei, were fruit trees. Supplementary species not mentioned as important fuelwood types included coastal, inland forest, fruit, and ornamental trees.

Koka and tava figured among the top three fuelwoods preferred for use on the open fire and in the 'umu. They ranked equal second to kuava for the open fire, and equal first for the 'umu with moli coming third. The main desirable characteristic cited for good open fire fuelwoods was that they were kakaha, that is they burnt vigorously giving off a good heat. Other comments about particular species were that they produced little smoke, were easy to dry, abundant, easy to prepare, that they burned for a long time, and that the charcoal produced could be burnt again. Similar advantages were attributed to fuelwood species preferred for use in the 'umu, but with greater emphasis on the benefits of charcoal generating heat for a long time.

Four respondents mentioned a total of six species no longer available for fuel. Of these, three were fruit trees, including kuava which seven other households had given as one of their five most important fuelwood types. Four of these unobtainable fuelwoods, moli, toi, kuava, and ahi, would have been preferred to species currently available.

Based on interviewees' volume estimates the average household in 'Ahau consumed a total of 9.8 tonnes of air-dry fuelwood per year. This was close to the average for the rural study areas and slightly higher than the Tongatapu average. An estimated 6.8 tonnes of this total was non-coconut wood and 2.9 tonnes was coconut residues. Eleven of the fourteen fuelwood users said their consumption of wood varied throughout the year. All used at least an extra cart-load of wood each time they prepared a feast. Three households regularly prepared three or more feasts annually. Four respondents said they used significantly less fuelwood during the rainy season because the wood was too wet to burn.

5.2.2 Vaotu'u

5.2.2.1 Natural systems

(a) Physical aspects

The village of Vaotu'u is separated from the southern coast by a 700 metre strip of land occupied by bush allotments. Through this strip passes a ridge 15 to 20 metres above sea level running parallel to the shore. From here the land slopes gradually down to the leeward coast some 5 kilometres to the north-north-east. The southern coast adjacent to Vaotu'u is open to the full force of the prevailing winds and sea currents. With restricted coral growth the limestone terraces are relatively narrow. These terraces are the site of the blow holes that provide one of Tongatapu's major tourist attractions.

(b) Biological aspects

The land around Vaotu'u village is believed to have been originally covered with tropical lowland forest (Thaman 1976). While the continuous forest cover has been replaced by agricultural communities dominated by coconut plantations, individual specimens of forest species were still evident in 1986. These included malolo (*Glochidion* spp.), masi'ata (*Ficus scabra*), tavahi (*Rhus taitensis*), and te'ete'emanu (*Ervatamia orientalis*). Fau (*Hibiscus tiliaceus*), a species found on the margins of inland forest as well as in coastal forest, was found to be common on town allotments as well as on farmland. Species characteristic of the coastal littoral forest which were identified on farmland included fao (*Ochrosia oppositifolia*) and futu (*Barringtonia asiatica*).

(c) Cultural aspects

The main impact of human activities on the ecological communities of this area was the clearing of the tropical lowland forest to provide land for coconut plantations. There are no remnants of the original vegetation close to Vaotu'u which are large enough to sustain the characteristics of the pre-existing communities. As in 'Ahau the local people, particularly farmers with allotments close to the coast, understood the value of the littoral forest as protection for crops. The sections of the coast most frequented by sight-seers visiting the blow holes were likely to be subjected to minor degradation which could affect the long term stability of the ecosystem.

(d) Significance to fuelwood supply

The types of fuelwood collected from inland sites around Vaotu'u reflect the elimination of the tropical lowland forest. The only fuelwood species which was designated by Thaman as a dominant tropical lowland forest species was tavahi (*Rhus taitensis*). Fau (*Hibiscus tiliaceus*) was collected from bush allotments, but that was a coastal species as well as representative of the margins of inland forest. The coastal vegetation between the exposed limestone terraces and the cultivated land was said by three interviewees to be an important source of fuelwood; the species collected are discussed in Section 5.2.2.6 below. The coast appeared to be a less significant site for the collection of fuelwood for Vaotu'u households than was the case in 'Ahau.

5.2.2.2 Domestic systems

Characteristics of domestic systems were similar to those reported for 'Ahau, with the following exceptions.

(a) Household facilities

Land

The town area of Vaotu'u was approximately 15 hectares (about one and a half times the area of 'Ahau village) and included eighty-three town allotments. In

1986 Vaotu'u supported sixty-nine households (Tonga, Statistics Department, Undated) so fewer allotments were unoccupied than in 'Ahau.

The average number of bush allotments to which householders had access appeared to be lower than in 'Ahau; eight bush allotment interview respondents had access to a total of fourteen allotments, an average of 1.8. However, each of these allotments was at least 8 acres in area, so the average area of agricultural land to which households had access was 14.3 acres, nearly 2 acres more than in 'Ahau. In similar fashion to 'Ahau the fourteen allotments were located within about 2 kilometres of the town area.

Buildings

The pattern of building utilisation was significantly different in Vaotu'u to 'Ahau. Five of the fifteen households interviewed had only one building, and a total of eight located their kitchens within the main house. The only non-European style main building in the interviewed households was the traditional Tongan fale built by a newly married couple. Kitchens, washrooms, and toilets not included in the main building were of traditional or modified Tongan style.

Water and electricity

Ten of the fifteen households interviewed had water piped into the main house; the other five had external standpipes. Only six households had rainwater tanks. Eleven interviewees said their main buildings were connected to the electricity grid. None of the separate kitchens were served by water pipes or electricity.

Cooking facilities

In Vaotu'u the most significant variations from the 'Ahau pattern of cooking facilities were that a higher proportion of households used non-wood appliances, and cooking facilities were more likely to be located inside the main house (Table 5.12). Also the drum 'umu was used by 40 percent of households compared to just 20 percent in 'Ahau.

TABLE 5.12

Numbers and percentages of interviewed households using six types of cooking appliances in Vaotu'u in 1986 by appliance location

Appliance type	Appliance location							
	Main building		Separate kitchen		External		Totals	
Open fire	1	7%	5	33%	7	47%	13	87%
Earth 'umu					8	53%	8	53%
Drum 'umu	2	13%	3	20%	1	7%	6	40%
Homemade woodstove	1	7%					1	7%
Charcoal stove	3	20%					3	20%
Kerosene stove	7	47%					7	47%
Gas stove	1	7%					1	7%
Valid cases:							15	

Average number of appliances per household: 2.6

Non-wood burning appliances as percentage of total: 20.5%

Transport and communications

Twice as many interviewed households in Vaotu'u owned horses as in 'Ahau: ten and five respectively. At the time of the interviews none of the Vaotu'u households included van or truck owners, compared to three in 'Ahau.

(b) Members of the household

Occupations

The proportion of children in interviewed households attending school was lower than in 'Ahau, suggesting the children were probably younger. Farming again dominated adult occupations but no interviewees said their households included fishermen/women. Two categories of employment not mentioned in 'Ahau were construction worker and factory worker.

Income

Interview responses suggested a greater range of earned monetary income in Vaotu'u than in 'Ahau. While five households were said to earn more than T$2000 per year one household which received money only from the sale of copra claimed to earn less than T$250.

(c) Domestic activities

Food and drink preparation

An average of 2.7 cooked meals were prepared per day between Monday and Saturday, and 2.3 meals on Sundays.

Gardening

The only town allotment trees said to provide food were mei (*Artocarpus altilis*), mentioned by twelve respondents, moli (*Citrus* species), and mango (*Mangifera indica*).

(d) Energy consumption

Electricity

All eleven interviewed households connected to the electricity grid used electric lights and all but two used electric irons. Two households used electric irons in relatives' homes.

Kerosene

Thirteen of the households interviewed used kerosene for lighting; nine combined their use of kerosene with electric lights.

Gas

One interviewed household owned a gas stove but used it as a supplementary cooking appliance to the open fire.

Woodfuels

As well as a higher proportion of households burning wood in a drum 'umu than in 'Ahau, twelve of thirteen Vaotu'u respondents said they burnt woody coconut waste, mostly shell, to produce coconut oil; only half of 'Ahau's interviewees did so. A slightly higher percentage of Vaotu'u respondents used a wood fire to boil pandanus leaves.

5.2.2.3 Cultivated systems

(a) Bush allotments

Land allocation

With the exception of the narrow strip of rather degraded coastal forest immediately inland from the exposed limestone terraces, the majority of the land surrounding Vaotu'u had been sub-divided into agricultural allotments.. All fourteen bush allotments referred to in interview responses were said to be between 8 and 8.5 acres (3.24 and 3.44 hectares) in area. The three allotments for which survey information is presented were located between Vaotu'u village and the liku coast (Figure 5.9).

Soil

Soil conditions on the bush allotments around Vaotu'u are similar to those on the higher ground above 'Ahau. The Fahefa clay soil extends from the western peninsula in a broadening band along the southern side of the island as far as the Fanga 'Uta lagoon. On the slopes adjacent to the coast, the rolling phase[2] of the

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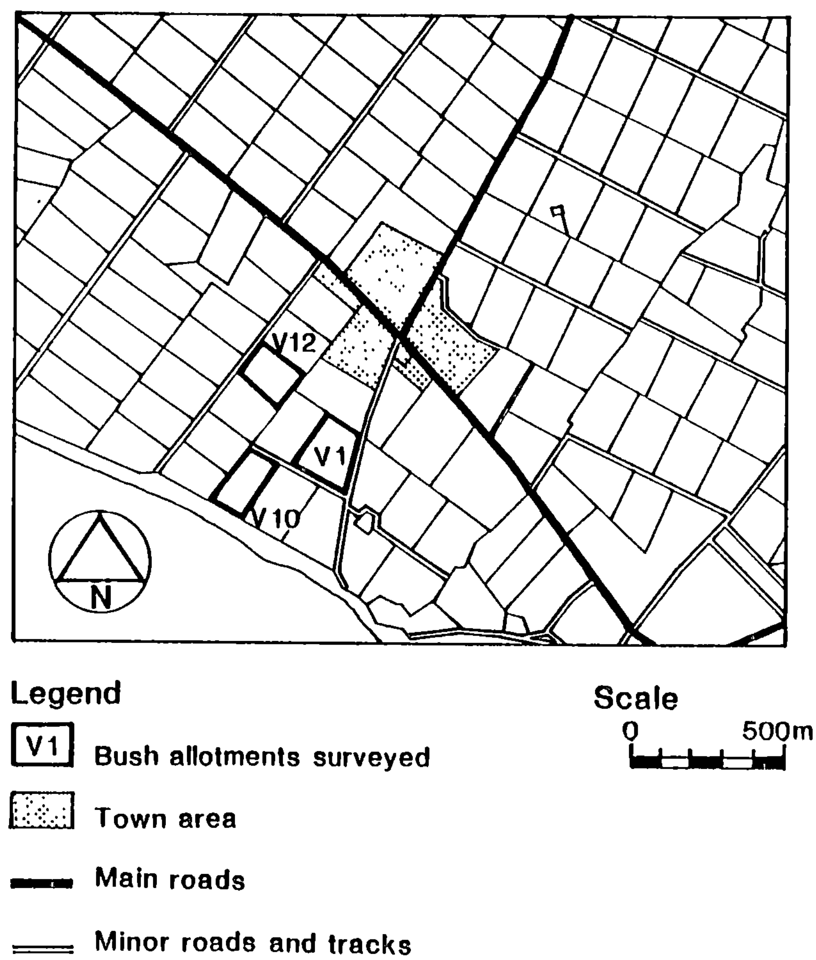
2. Cowie uses the term 'rolling phase' to identify soils located on slopes steep enough to affect their susceptibility to erosion.

FIGURE 5.9

Sketch map showing boundaries of Vaotu'u village and surveyed bush allotments



soil type presents some limitations to cultivation, particularly food and cash crops (Cowie, in preparation).

In responses to bush allotment interviews the soil on twelve of the fourteen allotments used by the eight respondents was said to be 'very fertile'. In the remaining two cases the soil was given as 'fertile'. Six farmers said they had improved the fertility of the soil, by use of fallow periods, fertilisers, ploughing, and growing cassava.

Agricultural land management

Eight of the interview respondents' allotments were growing crops at the time of the interviews. Of these, three were being used for commercial production and five primarily for non-commercial production. The proportion of the non-commercial land being cultivated was the same as in 'Ahau, 50 percent, but the proportion of commercial land under crops was much lower than in 'Ahau, just 60 percent. However, due to the larger allotment size, the average area cultivated for commercial purposes in Vaotu'u was nearly 50 percent larger than in 'Ahau: 4.8 acres compared to 3.3 acres. Similarly, the average area cultivated for non-commercial crop production was considerably larger at 3.7 compared to 2.3 acres.

Total areas of the three allotments surveyed were similar, but percentage areas cultivated ranged from zero to 79 percent (Table 5.13).

All three of the commercial allotments produced bananas and one was used to grow yams for sale. All eight cultivated allotments supported at least three food crops. Taro was the only crop growing on all allotments but in all but one case it was a supplementary crop. The most common main crop was cassava which was present on half the allotments (Table 5.14). Crop rotation systems were being used to manage all but one of these eight allotments. The data obtained show no significant difference between the crop combinations on the rotation and non-rotation allotments.

The types of manual equipment used in cultivation were generally similar to that used in 'Ahau, but with the addition of the European style spade. Only three of the seven respondents with crops on their allotments said they used a tractor and plough, compared to all eight of the 'Ahau farmers interviewed. Two said they sprayed pesticides on their banana crops, but two others stated they controlled pests by burning infested plants. The number of people working on an allotment ranged from one to thirty, with an average of eight. Cooperatives of farm workers contributed to the cultivation of four allotments.

Yams were the most important crop for five of the eight farmers, and along with bananas were the product most commonly sold. Cassava and taro, which in

TABLE 5.13

Summary of areas of cultivated, fallow, and uncultivated sections of three surveyed bush allotments used by households interviewed in Vaotu'u, in m^2 and as percentages of whole allotment areas

Allotment:	V1	V10	V12	Totals
Cultivated Sections				
- m^2	0	6700	25 600	32 300
- % whole	0	20	79	33
Fallow Sections				
- m^2	33 900	5400	6900	46 200
- % whole	100	16	21	47
Uncultivated Sections				
- m^2	0	20 700	0	20 700
- % whole	0	63	0	21
Whole Allotment				
- m^2	33 900	32 800	32 500	99 200
- % whole	100	100	100	100

'Ahau had been equally as important as yams and bananas, gained only one vote each from Vaotu'u respondents as most important crops. Seven of the eight interviewees sold whole coconuts to the Tonga Commodities Board but only three produced significant quantities of copra.

Trees on agricultural land

Each of the eight interviewees named at least five trees present on their bush allotment. The number of trees species said to be beneficial ranged from one to all trees on the allotment. The trees most commonly mentioned as being beneficial were similar to those named in 'Ahau except for <u>moli</u> being nominated by only one interviewee (Table 5.15). Provision of food was again the most commonly

TABLE 5.14

Percentages of bush allotments used by Vaotu'u respondents to bush allotment interviews on which various types of crops were grown, by management technique

Crop Type	Crop Rotation			No Rotation			All Allotments		
	Main Crop	Supp. Crop	Over-all	Main Crop	Supp. Crop	Over-all	Main Crop	Supp. Crop	Over-all
Ym	14	71	86	100		100	25	63	88
T	14	100	100		100	100	13	100	100
Ka		29	29		100	100		38	38
Cs	57	43	100				50	38	88
Ho	14	71	86				13	63	75
Ba	43	43	86		100	100	38	50	88
Pa		14	14					13	13
Hi		14	14					13	13
Sp		14	14					13	13
Gn		14	14					13	13
Valid cases:	7	7	7	1	1	1	8	8	8

cited benefit of trees, and fuelwood was significant, but only one Vaotu'u respondent mentioned dye. Only one tree, 'akauveli was claimed to be a nuisance (Table 5.16).

Among the five interviewees who said trees blocked sunlight from cultivated land one also said they were useful for providing air to crops. Two other adverse influences were the taking of soil fertility and possible damage to crops in high winds. Two farmers thought trees had no influence on crops. One interviewee had plans to cut down coconut stems to provide timber for house renovation and one would probably destroy trees during land clearance.

All but two of the eight Vaotu'u respondents said they had planted trees, for food, handicraft materials, windbreak, and for the next generation. Four intended to plant trees within the coming year, mainly for timber production.

Of the three bush allotments surveyed the density of non-coconut trees was marginally highest on the one which was entirely fallow, allotment V1 (Table 5.17). While the numbers of non-coconut trees per hectare on the three allotments ranged from sixteen to twenty-one, the proportion of land covered by the crowns of trees on V1 was six times the proportion for the one other allotment for which full data were recorded, and more than five times the cultivated and fallow section of the third allotment, V10 (Table 5.18). Approximately two-thirds of the area of this allotment was uncultivated and vegetated by coastal trees and shrubs. This gave rise to a distinct difference in the tree species recorded on this allotment compared to the other two which were further from the sea. More than 60 percent of the trees on V10 (which was adjacent to the coast) were <u>fau</u> or <u>futu</u>, in contrast to V1 and V12 which were dominated by <u>koka</u> (Figure 5.9). On V1 and V10 non-fruit trees dominated both the tree numbers and crown area data, but on V12, which had a more normal ratio of cultivated to fallow and uncultivated land, the crown areas were more evenly divided between fruit and non-fruit trees. While the average densities of <u>koka</u> and <u>fau</u> on the Vaotu'u allotments surveyed were similar to densities in 'Ahau, <u>mei</u> trees were much less abundant; <u>mango</u> was the most frequently recorded fruit tree (Table 5.19).

Significance to fuelwood supply

Among the Vaotu'u survey households, bush allotments were even more dominant as sources of fuelwood than in 'Ahau. For twelve of the fourteen households using fuelwood bush allotments were their main collection site. Twenty-one of the twenty-seven bush allotments sites mentioned belonged to the fuelwood collecting household.

TABLE 5.15

Percentages of eight respondents to bush allotment interviews in Vaotu'u identifying fruit and non-fruit tree species on agricultural land as being of benefit or a nuisance, and tree species protected during the clearing of fallow and weeding

Species	Benefit	Nuisance During Clearing	Protect During Weeding	Protect
Fruit trees				
AVO	13			
IFI	38			
KUA	50			13
MAN	75		13	
MEI	50		25	13
MOL	13			
TAV	38		13	
VII			13	13
Total numbers of fruit species	7	0	4	3
Non-fruit trees				
AKV	13	13		
FAO	25			
FAU	25			13
FUT	13		13	
HEH				13
KOK	63		25	13
LOA	13			
LOU	13			
MAL	13			
MAS	13			
MOH	13			
MOO	13			
NGA	13			
NON	13			
OKE	13			
TAH	25			
TAL				13
TUI	13			
None				
Total numbers of non-fruit species	16	1	2	4
Total numbers of fruit and non-fruit species	23	1	6	7
Non-specific categories				
Medicinal			13	

TABLE 5.16

Percentages of eight respondents to bush allotment interviews in Vaotu'u giving various reasons for trees on agricultural land being a benefit and for protecting them during clearing of fallow and weeding

Reason/ Useful Product	Benefit from trees	Reason for protecting trees
Food	88	63
Dye	13	13
Fuelwood	38	13
Medicine	25	25
Soap	13	
Income		25
Building material	25	
Fencing	13	13
Prevent soil erosion	13	
Rope fibre	13	
Copra	13	13
Sea defence		13
Household		13
Drink		13

(b) Town allotments

Land allocation

Twelve of the fifteen Vaotu'u interviewees could not estimate the size of their household's town allotment. A Ministry of Lands, Survey and Natural Resources town plan showed that sub-division was undertaken with the aim of providing households with approximately 0.16 ha (1 rood 24 poles, or 0.4 acre) of land. A few larger allotments of up to two-thirds of a hectare were shown on the 1972 plan. Two interviewees said members of their households held other town allotments.

TABLE 5.17

Numbers and densities of coconut, fruit, and non-fruit trees on cultivated, fallow, and uncultivated sections of three bush allotments used by Vaotu'u households

	V1	V10	V12	Totals
Cultivated Sections				
Numbers of trees				
Coconuts	na	113	nr	113+nr
Fruit trees	na	1	16	17
Non-fruit trees	na	2	33	35
Total numbers	na	116	49+nr	165+nr
Trees per hectare				
Coconuts	na	169	nr	35+nr
Fruit trees	na	1	6	5
Non-fruit trees	na	3	13	11
Total numbers	na	173	19+nr	51+nr
Fallow Sections				
Numbers of trees				
Coconuts	475	88	nr	563+nr
Fruit trees	13	1	3	17
Non-fruit trees	59	8	8	75
Total numbers	547	97	11+nr	655+nr
Trees per hectare				
Coconuts	140	164	nr	122+nr
Fruit trees	4	2	4	4
Non-fruit trees	17	15	12	16
Total numbers	161	181	16+nr	142+nr

Continued

TABLE 5.17 Continued

	V1	V10	V12	Totals
Uncultivated Sections				
Numbers of trees				
Coconuts	na	nr	na	nr
Fruit trees	na	0	na	0
Non-fruit trees	na	39	na	39
Total numbers	na	39+nr	na	39+nr
Trees per hectare				
Coconuts	na	nr	na	nr
Fruit trees	na	0	na	0
Non-fruit trees	na	19	na	19
Total numbers	na	19+nr	na	19+nr
Whole Allotment				
Numbers of trees				
Coconuts	475	201+nr	489	1155+nr
Fruit trees	13	2	19	34
Non-fruit trees	59	49	41	149
Total numbers	547	253+nr	548	1338
Trees per hectare				
Coconuts	140	167 [1.]	150	147 [1.]
Fruit trees	4	1	6	3
Non-fruit trees	17	15	13	15
Total numbers	161	210 [1.]	169	171 [1.]

Notes: 1. Excluding Uncultivated Section of V10

TABLE 5.18

Crown areas of fruit and non-fruit trees over cultivated, fallow, and uncultivated sections of three bush allotments used by Vaotu'u households

	V1	V10	V12	Totals
Cultivated Sections				
Fruit - m^2	na	22	196	217
- % land area	na	0.3	0.8	0.7
Non-fruit - m^2	na	37	259	297
- % land area	na	0.6	1.0	0.9
All trees - m^2	na	59	455	514
- % land area	na	0.9	1.8	1.6
Fallow Sections				
Fruit - m^2	649	8	39	696
- % land area	1.9	0.1	0.6	1.5
Non-fruit - m^2	2949	473	54	3476
- % land area	8.7	8.8	0.8	7.5
All trees - m^2	3598	481	93	4172
- % land area	10.6	9.0	1.3	9.0
Uncultivated Sections				
Fruit - m^2	na	0	na	0
- % land area	na	0	na	0
Non-fruit - m^2	na	71+nr	na	71+nr
- % land area	na	0.3+nr	na	0.3+nr
All trees - m^2	na	71+nr	na	71+nr
- % land area	na	0.3+nr	na	0.3+nr
Whole Allotment				
Fruit - m^2	649	30	234	914
- % land area	1.9	0.1	0.7	0.9
Non-fruit - m^2	2949	581+nr	314	3844+nr
- % land area	8.7	1.8+nr	1.0	3.9+nr
All trees - m^2	3598	610+nr	548	4757+nr
- % land area	10.6	1.9+nr	1.7	4.8+nr

TABLE 5.19

Tree densities per hectare and crown areas as percentages of land area[1]., for the eleven tree species most commonly found on three surveyed bush allotments used by Vaotu'u interviewees

Rank	Species		Cultivated	Fallow	Uncult-ivated	Whole Allotment
1.	KOK	per ha	8.7	9.7	0.0	7.4
		% area	0.7	3.5	0.0	1.9
2.	FAU	per ha	0.0	1.5	6.8	2.1
		% area	0.0	2.1	nr	1.1+nr
3.	FUT	per ha	0.0	0.6	6.3	1.6
		% area	0.0	0.2	nr	0.1+nr
4.	MAN	per ha	1.2	2.2	0.0	1.4
		% area	0.2	1.1	0.0	0.6
5.	LOU	per ha	0.6	0.9	0.4	0.7
		% area	0.1	0.7	nr	0.4+nr
6=	SII	per ha	0.0	0.2	2.4	0.6
		% area	0.0	<0.1	nr	<0.1+nr
6=	TAH	per ha	0.0	1.3	0.0	0.6
		% area	0.0	0.5	0.0	0.2
6=	MOL	per ha	0.9	0.6	0.0	0.6
		% area	0.1	0.1	0.0	0.1
9=	FAO	per ha	0.0	0.0	1.8	0.5
		% area	0.0	0.0	nr	nr
9=	TUI	per ha	0.3	0.9	0.0	0.5
		% area	<0.1	0.3	0.0	0.1
9=	MEI	per ha	1.2	0.2	0.0	0.5
		% area	0.1	<0.1	0.0	<0.1

Notes: 1. Density figures refer to trees recorded as having stems growing in the section under consideration; crown areas include overhanging foliage from trees rooted in adjacent sections.

Soil

The soil in the town area of Vaotu'u is the same Fahefa clay found on the surrounding agricultural land. Cowie (in preparation) described it as good for all forms of cultivation.

Crop management

Only four of the fifteen households interviewed in Vaotu'u grew food crops on their town allotments. The most common source of food products were fruit trees and livestock. All but one of the interviewees said they obtained food products from trees growing on their town allotments.

Trees on agricultural land

Households' fruit trees included mei on twelve interviewees' allotments, mango trees on two, and a moli tree on one allotment. All interviewees said that trees on their town allotments were beneficial, mainly for food production and for the shade they provided. Twelve households had planted trees on their town allotments, mostly fruit and ornamental trees, but some for other uses such as handicraft material production and for fencing. Of the nine interviewees who had plans to plant more trees eight said they would plant mei, and three wanted traditional trees for cultural uses.

5.2.2.4 Commercial systems

Commercial exchange outside the study area

Only four of eight bush allotment interviewees in Vaotu'u sold copra, compared to all nine respondents in 'Ahau. Seven of the eight sold whole coconuts, mostly to the Tonga Commodities Board. The one interviewee who gained no monetary income from coconuts, even though the two allotments he had access to produced between 20 000 and 40 000 nuts per year, had recently returned from working overseas.

Seven of the fifteen household characteristics interviewees said at least one of the household's bush allotments was used mainly for commercial production. The three commercial farmers included in the bush allotment interviewees sold bananas, yams, and peanuts. A total of eleven interviewees gave the growing of agricultural crops as an income earning occupation.

5.2.2.5 Social systems

(a) Demographic features

Between 1976 and 1986 the total population of Vaotu'u declined by 11 percent from 523 to 465 persons. This decline came about as a result of a 21 percent drop in the male population, from 262 to 207, while female numbers stayed reasonably constant. The number of households dropped from 77 to 69 so that the average household size changed only marginally, from 6.79 to 6.74. The female to male balance in the author's interviewed households was 42 to 43 including 26 adult females to 23 adult males. Adults outnumbered children (under sixteen years) by 49 to 36.

Heads of the Vaotu'u households interviewed had lived on their current town allotments for between less than one year and more than fifty years. Vaotu'u was the home town of all fifteen heads of household.

(b) Community facilities and services

Vaotu'u was served by grid electricity and reticulated water supplies. Eleven of the fifteen households interviewed were connected to the electricity grid, and nine had water piped to their main houses. Approximately twenty households in the village had telephones in 1986.

There were four churches in the village: Catholic, Free Wesleyan, Free Church of Tonga, and the Church of Jesus Christ of Latter Day Saints (Mormon). The number of shops operating in Vaotu'u appeared to change quite rapidly, but at the time of the author's interviews there were five privately owned shops in business. None of the five buses that linked the village with Nuku'alofa were owned by village residents, but five vans used for passenger transport were owned within Vaotu'u.

(c) Social characteristics

Four aspects of social status were clearly apparent within the Vaotu'u community. These were related to: the traditional chiefly hierarchy, government appointments, church membership, and the accumulation of material wealth. As in other villages with increasing involvement in commercial activity, traditional features of the society appeared to be gradually overtaken by social relations based on materialistic values. While the influence of the Tongan churches tended to be to reinforce traditional values, membership of the American Church of Jesus Christ of Latter Day Saints was seen as being of assistance in the accumulation of material wealth.

There were several cooperative working groups in Vaotu'u: four or five shared bush allotments, four labouring groups, and two women's handicraft groups.

5.2.2.6 Fuelwood systems

(a) Sources

Bush allotments were main sources for twelve of the fourteen fuelwood using households interviewed in Vaotu'u. Of a total of thirty-nine collection sites mentioned by respondents twenty-seven were bush allotments, five were town allotments, and just three coastal. Copra dryers provided fuel for four households and were the most important source for one (Table 5.20).

While the mean distance to bush allotment collection sites, 0.95 km, was almost exactly the same as in 'Ahau the furthest allotment was nearly twice as far from the town, approximately 3.5 km. All town allotment collection sites were less than 1 km from the home. Estimated distances to coastal sites averaged 1.5 km.

Fuelwood types collected from bush allotments were very similar to those listed in 'Ahau, but five of the six coastal species gathered by Vaotu'u households had not been cited in 'Ahau.

TABLE 5.20

Percentages of fourteen fuelwood using households interviewed in Vaotu'u collecting various types of wood from five categories of sources

Species Code	Bush	Town	Coast	Road-sides	Copra dryer	Totals
Fruit Trees						
KUA	71					71
MAN	50					50
MOL	43					43
TAV	64					64
All Fruit	93	0	0	0	0	93
Non-Fruit Trees						
FAO			7			7
FAU	36	7	7			43
HEI	7					7
KOK	100	7				100
KOT			7			7
MAT			7			7
SIA	7					7
TAH	29					29
TAT			7			7
TIM		7				7
TOH			7			7
All Non-Fruit	100	14	14	0	0	100
Coconut Fuels						
COC	50	14				57
H&S	14	21			29	50
HUS	7	21				21
LOH	21					21
PAL	36	7				36
PUP		7				7
SHE	7	7				7
TOU	14	7				14
All Coconut	79	36	0	0	29	86
Other Types						
Other		7				7
Dry wood	7	7				14
Scraps		7				7
All 'Other Types'	7	21	0	0	0	28
Overall	100	36	14	0	28	100
Valid cases:						14

On the surveyed bush allotments belonging to Vaotu'u residents mango was the only fruit tree to come close to the dominant koka and fau in terms of numeric density and crown area. Of the two fruit species most significant for fuel production, kuava and tava, trees with diameters at breast height greater than 10 cm were recorded on only one allotment each.

(b) Harvesting, transport, and preparation

The mean frequency of fuelwood collection from bush allotments was considerably lower in Vaotu'u than in 'Ahau. Households farming commercially collected 3.0 times per month while others obtained fuelwood from their bush allotments on average approximately once every seven weeks. Collections from town allotments were made 9.7 times per month and 2.3 times per month from the coast. Estimates of time spent on fuelwood collection ranged from one to fifty person hours per month, with a mean of 12.5, just over half the mean estimate in 'Ahau. A quarter of respondents thought they spent more time in 1986 on collecting wood than they had done in 1985, and a third said they were spending more time than in 1981.

While none of the fourteen respondents said they cut live wood for use as fuel, ten killed trees by burning and five by ring-barking. Two claimed that no trees were killed by these methods and one did not know. The most significant difference in the use of cutting equipment was that five households regularly used chainsaws and three used them occasionally. Only two 'Ahau respondents had said they used chainsaws. All fuelwood using Vaotu'u households transported wood by horse and cart, although one did so only occasionally. Four regularly used vans and two occasionally. Eight respondents said their households normally carried fuelwood by hand while a ninth sometimes did. Six households paid between T$2 and T$4 per load for transport, equivalent to between 17 and 75 cents per month.

Six households storing fuelwood on their town allotments left it uncovered but three others covered it. Three stored fuelwood in the kitchen, one in a separate store, and one in the main building.

All fourteen households used coconut fuel brought directly from bush allotments; ten used culinary residues; seven burned husks and shells left over from feeding pigs; a total of nine used residues collected from copra dryers. Of four households saying coconut fuels needed preparation three said they had to be dried and two stated they needed to be chopped up.

(c) Consumption patterns

As in 'Ahau fourteen of fifteen interviewees said woodfuels constituted their main energy source for cooking but two gave alternatives to the open fire as their main appliances. One household mostly used a charcoal stove and another had a homemade wood-burning stove. Two households used charcoal stoves as supplementary appliances. All eight earth 'umus mentioned were sited outside while only one of the drum 'umus owned by the other six fuelwood using households was located outdoors. Four households used kerosene stoves and one a gas stove as supplementary cooking appliances. On average 5.1 people were cooked for on weekdays and 5.5 on Sundays.

All fourteen fuelwood users interviewed in Vaotu'u used coconut fuels; eleven included them among their five most important fuelwood types. Among non-coconut species koka (*Bischofia javanica*) was dominant, being mentioned as a most important fuelwood by all fourteen wood users. The only coastal species mentioned was fau. Species said to be no longer available which were not mentioned in 'Ahau included inland forest species tavahi (*Rhus taitensis*), ngatata (*Elattostachys falcata*), and fo'ui (*Grewia crenata*), and coastal species futu (*Barringtonia asiatica*) and toa (*Casuarina/Allocasuarina* spp.).

Kuava and moli gained five mentions each as preferred open fire fuels with koka ranked third. Opinions about the best 'umu fuel were remarkably consistent: thirteen respondents included koka. Next came moli, mentioned by five interviewees, then kuava and tava, each gaining three mentions. Six responses listed a total of eleven species as being unavailable or hard to find. The fuelwood type most commonly referred to in this respect was moli, which four households would have preferred to readily available species.

Calculations based on interviewees' fuelwood consumption estimates suggest that the average Vaotu'u household used slightly less fuelwood than in the other rural study areas. The average household total of 9.2 tonnes per year was 4 percent lower than the rural study area mean, but the same as the Urban Nuku'alofa average. It included 6.3 tonnes of non-coconut wood and 2.9 tonnes of coconut residues.

5.2.3 Folaha

5.2.3.1 Natural systems

(a) Physical aspects

Folaha is situated on the southern side of the Fanga Kakau lagoon; no part of the village is more than 500 metres from the shore. Only two small sections of the village area are more than 5 metres above sea level. The western section of the village beside the lagoon lies so low that it apparently is frequently inundated. Land to the north-east which is sub-divided into bush allotments includes permanently flooded areas. Immediately to the south of Folaha, a tongue of low-lying land is too wet to support agriculture. The higher ground beyond this is eminently suited to cultivation. The strip of wetland broadens westward into extensive swamps adjacent to the Fanga 'Uta lagoon.

(b) Biological aspects

The dominant natural plant communities in the area surrounding Folaha are mangrove swamp, dominated by *Rhizophora* and *Bruquiera* species, and swamp forest (Thaman 1976). Species recorded on a waterlogged section of a bush allotment to the north-east of the village included eleven species said by Thaman to be characteristic of swamp forest. The overwhelmingly dominant species on the tongue of low-lying land just south of Folaha was kuava (*Psidium guajava*). This study did not include detailed surveys of vegetation away from the agricultural land.

(c) Cultural aspects

The vegetation fringing the lagoon near Folaha has been subjected to high levels of human pressure; where the village meets the lagoon virtually all the natural vegetation has been cleared. Tongo, mangrove, is particularly valuable for numerous uses, including building material, dye for tapa cloth, and firewood. Wood from other swamp forest trees also possesses characteristics which make it attractive for exploitation. The cutting of these preferred species has led to dramatic changes in vegetation communities. Kuava is an invasive introduced species which took over the strip of land south of Folaha after the natural vegetation had been severely degraded. While there was some local concern that reduction of the mangrove forest would be detrimental to fish stocks, small amounts of tongo were still being cut. This continued despite legislative prohibition.

(d) Significance to fuelwood supply

Seven of fifteen interviewees said their households collected fuelwood from mangrove swamps, with six of these also mentioning other coastal collection sites. There was some indication that collection of mangrove wood from sites close to Folaha was declining. One household no longer brought fuelwood from the coast, and another travelled by boat to the mangrove areas of Nukunukumotu island on the northern side of the lagoon to gather fuel. Seven respondents included species from mangrove and swamp forests among fuelwood types which were no longer available. Kuava (*Psidium guajava*) was the most commonly specified important fuelwood type, which suggests that this introduced invasive species was tending to replace the diminishing supply of fuelwood from native forest trees.

5.2.3.2 Domestic systems

(a) Household facilities

Land

One hundred and sixty-five residential town allotments were counted within Folaha's town boundaries. The 1986 census recorded one hundred and fifteen households (Tonga, Statistics Department, Undated). While the proportion of occupied allotments was higher than in 'Ahau, there was still a considerable area of unoccupied land within the town boundaries.

In a similar fashion to Vaotu'u, the average number of bush allotments to which interviewees had access was lower than 'Ahau (1.9 compared to 2.3), but the average area available was larger (15.1 acres compared to 12.4). All bush allotments used by interviewees were less than 3 kilometres from their homes.

Buildings

While all main buildings were European or modified European in style a much higher proportion of the kitchen buildings were of Tongan style than was the case in 'Ahau.

Water and electricity

Five interviewed households had piped water available in their main house; none of the 'Ahau households had this.

Cooking facilities

While the pattern of wood burning appliance ownership was similar to that in 'Ahau, twice as many households interviewed in Folaha had non-wood burning cooking stoves. These ten households owned three gas stoves, two electric, and six kerosene stoves (Table 5.21).

(b) Members of the household

Age and sex characteristics

While the overall ratios of males to females and adults to children in interviewed households in Folaha were similar to those in 'Ahau, the sex ratio among adults was quite different. With twenty-two adult males to thirty-one adult females the Folaha ratio was 0.71:1 compared to 1.24:1 in 'Ahau.

TABLE 5.21

Numbers and percentages of interviewed households using six types of cooking appliances in Folaha in 1986 by appliance location

Appliance type	Appliance location							
	Main building		Separate kitchen		External		Totals	
Open fire			15	100%			15	100%
Earth 'umu			1	7%	9	60%	10	67%
Drum 'umu			2	13%	3	20%	5	33%
Charcoal stove			1	7%			1	7%
Kerosene stove	5	33%	1	7%	1	7%	6	40%
Electric stove	1	7%	1	7%			2	13%
Gas stove	3	20%					3	20%
Valid cases:							15	100%

Average number of appliances per household: 2.8

Non-wood burning appliances as percentage of total: 26.2%

Occupations

The range of occupations was generally similar to 'Ahau except that four interviewed households obtained income from handicrafts, which had not been mentioned in 'Ahau.

Income

The range of household incomes was broader in Folaha than among interviewed households in 'Ahau. One respondent claimed an income of less than T$250 per year while five of fifteen households earned more than T$2000.

(c) Domestic activities

Food and drink preparation

Responses to Folaha interviews indicated more meals were cooked per day here than in 'Ahau: 2.7 on weekdays and 2.4 on Sundays, compared to 2.4 and 1.9 in 'Ahau.

Handicrafts

From observation and informal discussions the impression was gained that women in Folaha spent more time on making handicrafts than did women in 'Ahau. This was supported by the inclusion in interview responses of handicraft as an income earning occupation. At the time of the interview surveys there were three women's handicraft cooperative working groups in the village. No data were collected to quantify time spent on handicraft activities.

Collecting firewood

The pattern of age and sex of fuelwood collectors in Folaha was similar to 'Ahau except for one household in which all wood was gathered by children. While in 'Ahau most interviewees said more time was spent in 1986 on fuelwood collection than one or five years previous, nine Folaha respondents said they spent less time than in 1985 and ten spent less time than in 1981.

(d) Energy consumption

Electricity

The only significant variation in use of electricity from the pattern shown by interviewed households in 'Ahau was that two households in Folaha owned electric cooking stoves.

Kerosene

One interviewed household used a kerosene stove as its main cooking appliance. Four households had kerosene stoves for supplementary cooking.

Gas

Three Folaha interviewees said their households used gas stoves for cooking, and for two they were the main cooking appliance.

Woodfuels

The open wood fire was the main cooking method for twelve of the fifteen Folaha households interviewed (compared to fourteen in 'Ahau). Only one Folaha household used a charcoal stove. The pattern of non-cooking uses of fuelwood in Folaha appeared to be somewhat different to 'Ahau: more households used woody fuels to make coconut oil (ten compared to seven), while fewer (three) Folaha respondents said they burnt wood to dry copra (compared to nine in 'Ahau).

5.2.3.3 Cultivated systems

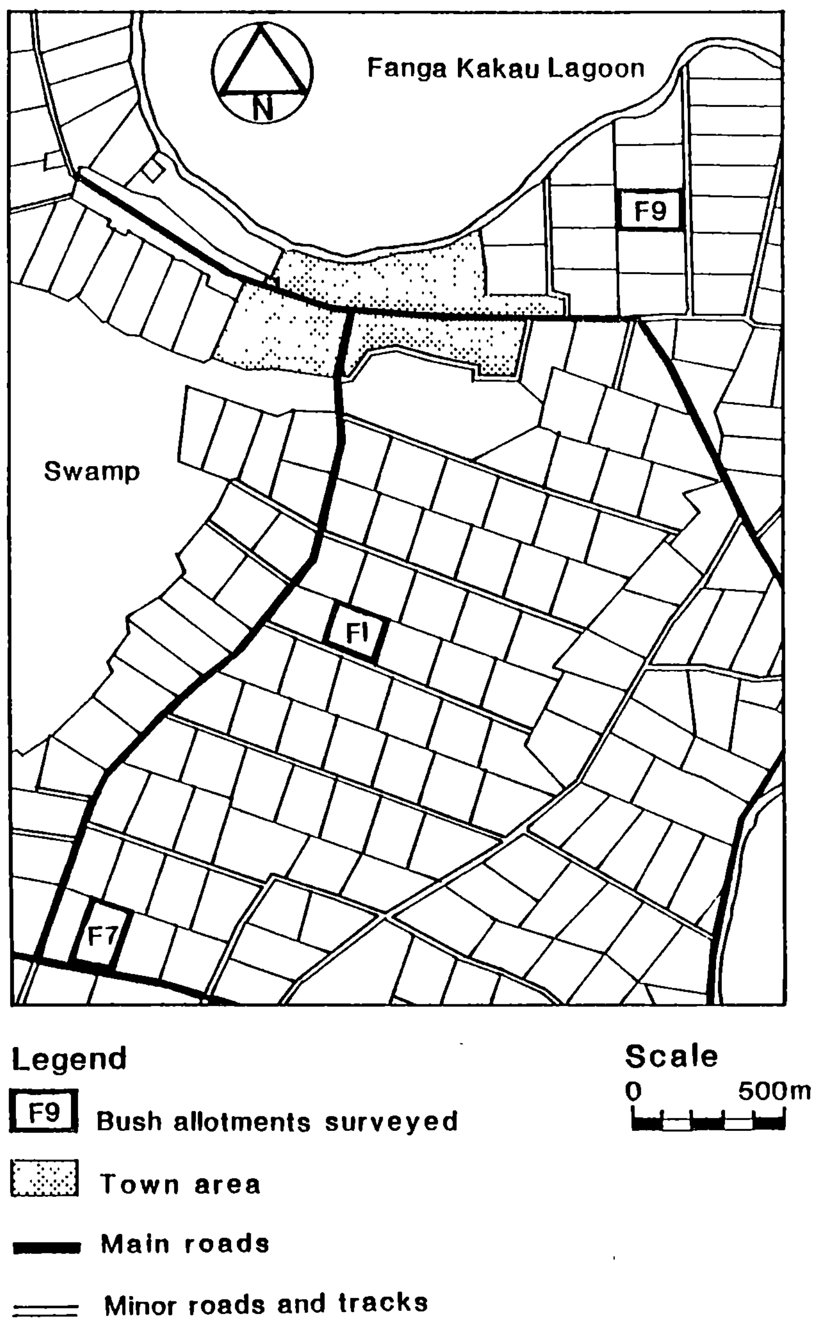
(a) Bush allotments

Land allocation

The average distance from Folaha interviewees' town allotments to their bush allotments was just over twice the distance recorded for 'Ahau. This indicates a shortage of cultivable land close to the village. Obvious contributing factors were the location of a large area of wetland to the south of Folaha, and the demand for land by residents of the adjacent village of Nukuhetulu. The locations of the three surveyed bush allotments are shown in Figure 5.10.

FIGURE 5.10

Sketch map showing boundaries of Folaha village and surveyed bush allotments



Only one third (five of fifteen) of Folaha interviewees' allotments were shared with other farmers, compared to just under a half (ten of twenty-one) of 'Ahau's. The average area of bush allotments to which Folaha households had access, 15 acres (6 hectares), was the highest of the rural villages.

Soil

The vast majority of agricultural land around Folaha has Vaini clay soils. The three phases of this soil in this area are all rated as good for food crops but on the steeper slopes cultivation is likely to lead to erosion (Cowie, in preparation). Some allotments adjacent to the wetland south of Folaha could include some areas of Sopu loam which is categorised as fair for food crops. The Sopu sand of the swamp to the south-west is considered fair for coconuts but poor for food and commercial crops, pasture, and forestry.

Twenty percent of Folaha interviewees' allotments were said to be very fertile; this proportion was the lowest of all six study areas. Seven of the fifteen allotments were described as fertile; the remaining five were 'just fertile', 'not very fertile', 'fertile after fallow', or 'probably fertile'. All four respondents who said they had improved soil fertility had used fallow to do so.

Agricultural land management

Of the fifteen allotments for which information was received, eleven had crops growing on them. All of these cultivated allotments were said to be managed by crop rotation techniques primarily for the production of non-commercial crops. The average size of bush allotment, 6 acres, was midway between the average sizes in 'Ahau and Vaotu'u, while the proportion of cultivated allotment land currently under crops, 60 percent, was slightly higher than in the other two study areas. The three surveyed allotments were all larger than the Folaha average, and while two had average proportions of their total areas cultivated, 91 percent of allotment F1 was under cultivation at the time of the survey (Table 5.22).

Fewer than four crops had been planted on only two allotments. Responses listed an average of 2.5 main crops and 3.6 supplementary crops per allotment. The most commonly grown crops were the same as found in 'Ahau with two

TABLE 5.22

Summary of areas of cultivated, fallow, and uncultivated sections of three surveyed bush allotments used by Folaha households, in m^2 and as percentages of whole allotment areas

Allotment:	F1	F7	F9	Totals
Cultivated Sections				
- m^2	30 600	19 100	21 900	71 500
- % whole	91	59	68	73
Fallow Sections				
- m^2	1200	11 800	10 000	23 100
- % whole	4	37	31	23
Uncultivated Sections				
- m^2	1700	1500	500	3700
- % whole	5	5	2	4
Whole Allotment				
- m^2	33 500	32 400	32 400	98 200
- % whole	100	100	100	100

significant variations. Kape, a traditional companion to yams in the first year of cropping, was said to be grown on 55 percent of Folaha allotments compared to just 14 percent in 'Ahau. Bananas were included as crops on 24 percent of 'Ahau allotments but were grown on only 9 percent in Folaha (Table 5.23). Average fallow time in Folaha was 2.4 years compared to 1.3 years in 'Ahau.

Fewer farmers in Folaha used the tractor and plough for cultivation: six of eight compared to all eight in 'Ahau. Chemical sprays were used by four respondents on yams, vegetables, and water melons, rather than on bananas. Yams were included as a most important agricultural product by all Folaha farmers. Twelve other crops were mentioned as important or commercial agricultural products. Responses received on the number of coconuts produced per allotment per year gave an average of 8100, more than twice the 'Ahau average. This higher yield cannot be explained solely by the larger size of Folaha's allotments; at the same

TABLE 5.23

Percentages of bush allotments used by Folaha respondents to bush allotment interviews on which various types of crops were grown, by management technique

Crop Type	Crop Rotation			No Rotation			All Allotments		
	Main Crop	Supp. Crop	Over-all	Main Crop	Supp. Crop	Over-all	Main Crop	Supp. Crop	Over-all
Ym	55	45	100				55	45	100
T	55	45	100				55	45	100
Ka	9	45	55				9	45	55
Cs	45	36	82				45	36	82
Ho	18	55	73				18	55	73
Ba	9		9				9		9
Pa		27	27					27	27
Pi		9	9					9	9
Hi	18	18	36				18	18	36
Pe		9	9					9	9
Mz		9	9					9	9
Vg		9	9					9	9
Sp	18	9	27				18	9	27
Tm		9	9					9	9
Valid cases:	11	11	11	0	0	0	11	11	11

production rate per unit area the expected Folaha figure would be 5150. Three households used wood fuelled dryers to process their coconuts into copra for sale.

Trees on agricultural land

Folaha respondents listed between two and nine trees as present on their bush allotments. Their main benefit was said to be food production, mentioned by seven of the eight farmers (Table 5.24). No tree species were given as being a nuisance. All interviewees offering definite responses said they protected self-regenerated species when clearing fallow or weeding (Table 5.25). Of the seven respondents who thought trees had an influence on crops, five said there were detrimental influences while three mentioned benefits. Only one farmer planned to cut down any trees; in this case old coconut stems for building timber. Six had planted trees, for reasons ranging from food production to providing shade. Three of the four interviewees planning to plant trees in the coming year favoured timber species.

Of the three Folaha bush allotments surveyed the one with the highest proportion of cultivated land supported the highest density of non-coconut trees. Here fruit trees were clearly favoured, with a density of twelve trees per hectare compared to seven non-fruit trees per hectare, giving total numbers on the allotment of thirty-nine and twenty-three respectively (Table 5.26). This same allotment (F1) had the highest percentages of tree crown cover over each category of land (Table 5.27). On allotment F7 only nine trees with a diameter at breast height of greater than 10 cm were recorded; seven of these were fruit trees. Of the forty non-coconut trees growing on the allotment F9 twenty-three (58 percent) were non-fruit species, and fifteen of these were koka. Overall, koka was the most common tree species on the three allotments, but fruit trees were strongly represented among the twelve most frequently recorded species (Table 5.28).

Significance to fuelwood supply

For ten of the fifteen interviewed households one of their own bush allotments was their main fuelwood collection site, and for two, other bush allotments were most important. In all, twenty-four of forty-five collection sites were said to be

TABLE 5.24

Percentages of eight respondents to bush allotment interviews in Folaha giving various reasons for trees on agricultural land being a benefit and for protecting them during clearing of fallow and weeding

Reason/ Useful Product	Benefit from trees	Reason for protecting trees
Food	88	88
Fruit	13	
Dye	38	38
Fuelwood	50	13
Income	13	13
Building material	25	
Baskets	13	
Drink		13
Improve soil		13
Fodder		13
Don't know		13

bush allotments. Twenty-one different types of fuelwood were gathered on bush allotments, including nine types of coconut fuel.

(b) Town allotments

Land allocation

Compared to other study areas a relatively high proportion of Folaha interviewees offered an estimate of the area covered by their town allotment. The sizes given by the eleven households ranged from about 0.1 ha (1 rood) to approximately 1.6 ha (4 acres). Six responses between 0.16 and 0.2 ha were stated with a degree of precision which suggested that the respondent knew the official size of the allotment.

TABLE 5.25

Percentages of eight respondents to bush allotment interviews in Folaha identifying fruit and non-fruit tree species on agricultural land as being of benefit or a nuisance, and tree species protected during the clearing of fallow and weeding

Species	Benefit	Nuisance	Protect During Clearing	Protect During Weeding
Fruit trees				
AVO	25			13
IFI	38		25	
KUA	13			
MAN	63		25	25
MEI	25		13	13
MOL	13		13	38
Py			13	13
TAV	13		13	13
TEL			13	
VII	38		13	
Total numbers of fruit species	8	0	8	6
Non-fruit trees				
FKV	13			
KOK	38		25	38
LOU	25			
TAH	25			
TOI	13			
Total numbers of non-fruit species	5	0	1	1
Total numbers of fruit and non-fruit species	13	0	9	7
Non-specific categories				
All fruit	25			
Food trees			13	13
Don't know			13	13

TABLE 5.26

Numbers and densities of coconut, fruit, and non-fruit trees on cultivated, fallow, and uncultivated sections of three bush allotments used by Folaha households

	F1	F7	F9	Totals
Cultivated Sections				
Numbers of trees				
Coconuts	332	119	261	712
Fruit trees	25+(5)[1.]	1+(1)	8+(2)	34+(8)
Non-fruit trees	15+(2)	0	9+(1)	24+(3)
Total numbers	372+(7)	120+(1)	278+(3)	770+(11)
Trees per hectare				
Coconuts	108	62	119	100
Fruit trees	8+(2)	1+(1)	4+(1)	5+(1)
Non-fruit trees	5+(1)	0	4+(<1)	3+(<1)
Total numbers	122+(2)	63+(1)	127+(1)	108+(2)
Fallow Sections				
Numbers of trees				
Coconuts	6	92	114	212
Fruit trees	3+(1)	4+(1)	8	15+(2)
Non-fruit trees	5+(1)[2.]	2	14+(1)	21+(2)
Total numbers	14+(2)	98+(1)	136+(1)	248+(4)
Trees per hectare				
Coconuts	49	78	114	92
Fruit trees	25+(8)	3+(1)	8	6+(1)
Non-fruit trees	41+(8)	2	14+(1)	9+(1)
Total numbers	115+(16)	83+(1)	136+(1)	107+(2)

Continued

TABLE 5.26. Continued

	F1	F7	F9	Totals
Uncultivated Sections				
Numbers of trees				
Coconuts	3	5	0	8
Fruit trees	11+(1)	2+(4)	1	14+(5)
Non-fruit trees	3	0	0	3
Total numbers	17+(1)	7+(4)	1	25+(5)
Trees per hectare				
Coconuts	18	34	0	22
Fruit trees	65+(6)	14+(27)	20	38+(14)
Non-fruit trees	18	0	0	8
Total numbers	100+(6)	48+(27)	20	68+(14)
Whole Allotment				
Numbers of trees				
Coconuts	341	216	375	932
Fruit trees	39	7	17	63
Non-fruit trees	23+(1)2.	2	23	48+(1)2.
Total numbers	403+(1)2.	225	415	1043+(1)2.
Trees per hectare				
Coconuts	102	67	116	95
Fruit trees	12	2	5	6
Non-fruit trees	7+(<1)	1	7	5+(<1)
Total numbers	120+(<1)	69	128	106+(<1)

Notes: 1. Figures in brackets generally refer to boundary trees which have been counted in the data for other sections.

2. This bracketed figure refers to a tree whose crown overhung the allotment but whose stem was located outside the allotment.

TABLE 5.27

Crown areas of fruit and non-fruit trees over cultivated, fallow, and uncultivated sections of three bush allotments used by Folaha households

	F1	F7	F9	Totals
Cultivated Sections				
Fruit - m^2	787	18	290	1095
- % land area	2.6	0.1	1.3	1.5
Non-fruit - m^2	344	0	232	576
- % land area	1.1	0	1.1	0.8
All trees - m^2	1131	18	522	1671
- % land area	3.7	0.1	2.4	2.3
Fallow Sections				
Fruit - m^2	207	158	314	679
- % land area	17.0	1.3	3.1	2.9
Non-fruit - m^2	133	54	470	657
- % land area	10.9	0.5	4.7	2.8
All trees - m^2	340	212	784	1335
- % land area	27.8	1.8	7.8	5.8
Uncultivated Sections				
Fruit - m^2	494	234	37	765
- % land area	29.0	16.0	7.4	20.9
Non-fruit - m^2	403	0	0	403
- % land area	23.6	0	0	11.0
All trees - m^2	897	234	37	1168
- % land area	52.6	16.0	7.4	31.9
Whole Allotment				
Fruit - m^2	1487	410	641	2538
- % land area	4.4	1.3	2.0	2.6
Non-fruit - m^2	880	54	702	1636
- % land area	2.6	0.2	2.2	1.7
All trees - m^2	2368	463	1343	4174
- % land area	7.1	1.4	4.1	4.2

TABLE 5.28

Tree densities per hectare and crown areas as percentages of land area[1], for the twelve tree species most commonly found on three surveyed bush allotments used by Folaha interviewees

Rank	Species		Cultivated	Fallow	Uncult-ivated	Whole Allotment
1.	KOK	per ha	2.1	4.8	8.2	3.0
		% area	0.6	2.1	11.0	1.3
2.	MEI	per ha	2.4	0.9	2.7	2.0
		% area	0.7	0.3	1.4	0.6
3.	MAN	per ha	0.7	1.3	27.3	1.8
		% area	0.3	1.1	12.5	1.0
4.	FAU	per ha	0.8	2.2	0.0	1.1
		% area	0.2	0.4	0.0	0.2
5=	AVO	per ha	0.6	1.3	0.0	0.7
		% area	0.2	0.4	0.1	0.2
5=	IFI	per ha	0.3	1.7	2.7	0.7
		% area	0.1	0.8	2.0	0.3
7.	TAV	per ha	0.3	0.9	2.7	0.5
		% area	0.1	0.3	2.4	0.2
8.	MOL	per ha	0.3	0.0	2.7	0.3
		% area	<0.1	0.0	1.0	0.1
9=	VII	per ha	0.3	0.0	0.0	0.2
		% area	0.2	0.0	1.4	0.2
9=	LOP	per ha	0.0	0.9	0.0	0.2
		% area	0.0	0.2	0.0	0.1
9=	OKE	per ha	0.3	0.0	0.0	0.2
		% area	<0.1	0.0	0.0	<0.1
9=	TAH	per ha	0.0	0.9	0.0	0.2
		% area	<0.1	0.1	0.0	<0.1

Notes: 1. Density figures refer to trees recorded as having stems growing in the section under consideration; crown areas include overhanging foliage from trees rooted in adjacent sections.

Soil

The soil in the village is the same Vaini clay that covers most of the nearby agricultural land.

Crop management

All eight of the fifteen households interviewed which grew food crops on their town allotments also kept livestock which would have to be controlled to avoid damage to the crops. Crops grown by these households were bananas, plantain, papaya, sugar cane, and edible hibiscus; none of them grew root crops. Twelve households obtained food products from fruit trees.

Trees on agricultural land

As in other study areas mei was the fruit tree most commonly found on town allotments. Mango was mentioned by two interviewees, and moli by one. All respondents thought the trees on their town allotments were of benefit, but one added that some were a nuisance. Fifteen different reasons were offered for these trees being beneficial. Twelve interviewees said their households had planted trees on their town allotments, and eleven claimed to have definite intentions to plant trees in the future. In both cases fruit trees were most frequently cited.

Significance to fuelwood supply

Seven households collected fuelwood from their own or others' town allotments. As well as coconut residues and scraps of timber seven tree species were mentioned. Three households collected wood more frequently from town allotments than from any other source.

5.2.3.4 Commercial systems

(a) Commercial exchange of goods and services within the study area

None of the fifteen interviewed households in Folaha paid cash for the use of agricultural land, but two gave produce to land-holders. Ten households paid for the use of carts, vans, and a truck to transport fuelwood. Average amounts spent per month on transport ranged from 50 cents to T$15. Two households paid cash for labourers assisting in the collection of wood.

(b) Commercial exchange outside the study area

None of the bush allotments referred to in the interviews were said to be used mainly for commercial production. However, five of the eight respondents to bush allotment interviews sold agricultural produce, including bananas and plantain, traditional root crops, and European vegetables. Three of eight farmers interviewed said they made copra, and five sold whole nuts to the Tonga Commodities Board.

5.2.3.5 Social systems

(a) Demographic features

Folaha's population fell by 4.3 percent from 738 in 1976 to 706 in 1986. As in Vaotu'u this change represented a decline in the number of males while the female population remained stable. With the number of households rising from 114 to 115, average household size fell from 6.47 to 6.14. Among the fifteen interview survey households the average size was 5.87, with 53 adults and 35 children, 42 males and 46 females. The adult sex ratio of 31 females to 22 males supports the assertion that men left the village between 1976 and 1986.

(b) Community facilities and services

Reticulated electricity and water supplies were available throughout Folaha. Telephone lines were installed during 1986; three houses had 'phones at the time of the interviews.

The same four churches as in Vaotu'u were represented in Folaha. Four shops were operating in the village when the interviews were conducted. Of the four buses serving Folaha one was owned by a village resident. There were no passenger vans operating in Folaha.

(c) Social characteristics

Cooperative work appeared to be a strong force for social cohesion in Folaha. There were five men's and three women's working groups. Day-to-day social interaction commonly extended beyond the study area boundaries, to include the adjacent village of Nukuhetulu.

5.2.3.6 Fuelwood systems

(a) Sources

Most important fuelwood collection sites were located on bush allotments for twelve Folaha interview respondents and on coastal land for two. One household collected most fuelwood from copra dryers. All households collected at least some of their wood from agricultural land; among the total of forty-five collection sites mentioned by interviewees, twenty-four were bush allotments. Each of the seven households using coastal collection sites obtained fuelwood from the mangrove forest. Members of at least one household travelled by boat across the lagoon to collect fuelwood from islands which were still lined by extensive mangrove swamps. Town allotments were supplementary fuelwood sources for seven of the fifteen households.

Bush allotment fuelwood collection sites were in general considerably further from the village than was the case in 'Ahau. The average distance was 3.3 km, with the range extending to 16 km and a standard deviation of 4.1 km. Town sites mentioned were all less than 0.1 km from homes but coastal sources of fuelwood were up to 5 km away, with a mean of 1.6 km and a standard deviation of 1.8 km.

The most commonly collected fuelwood type, koka, was mostly obtained from bush allotments but one household obtained it from town allotments and one from coastal sites (Table 5.29). Fuelwood types collected from coastal sites were dominated by tongo, mangrove species *Rhizophora mangle, Rhizophora mucronata,* and *Bruguiera gymnorrhiza.*

The dominant tree species on the three surveyed bush allotments was koka, which ranked second to kuava among the most important non-coconut

TABLE 5.29

Percentages of fifteen fuelwood using households interviewed in Folaha collecting various types of wood from five categories of sources

Species Code	Bush	Town	Coast	Road-sides	Copra dryer	Totals
Fruit Trees						
AVO	7					7
FEK	7					7
IFI	13	7				20
KUA	73	7				73
MAN	13	7				20
MOL	20					20
TAV	47	13	7			60
All Fruit	87	27	7	0	0	93
Non-Fruit Trees						
FAU	47	7	13			53
FOU			7			7
HAN			7			7
KOK	80	7	7			87
LAL			7			7
LEK			7			7
SIA	13	7				13
TAH	40					40
TAL	7					7
TIM		7				7
TON			40			40
All Non-Fruit	87	20	40	0	0	93
Coconut Fuels						
COC	20	13				33
H&S	20	20			13	47
HUS	7	7			7	20
LOH	7					7
NIU	7					7
PAL	20	7				27
PUP	7					7
SHE	7	13				20
TOU	13	7				20
All Coconut	47	40	0	0	13	73
Other Types						
Scraps		7				7
Unknown spp.		7				7
Unspecified			7			7
All 'Other Types'		13	7	0	0	20
Overall	100	47	47	0	13	100
Valid cases:						15

fuelwoods. Only one kuava tree with a DBH greater than 10 cm was recorded on the surveyed allotments but smaller kuava trees were found on two allotments. The most common fruit trees were mei and mango, with mango covering the greater area. More than half the mango trees were located on uncultivated land, but seventeen of the twenty mei trees were recorded on cultivated plots. Tava, a numerous fruit tree on 'Ahau allotments, was found in Folaha less frequently than avoka and ifi, both of which were of less significance as fuel.

(b) Harvesting, transport, and preparation

Fuelwood collections from bush allotments were made much less frequently than in 'Ahau. Households using allotments for commercial farming brought fuelwood from them on average 3.9 times per month, and non-commercial farming households made 1.3 collections per month. Collections from coastal sites averaged 2.9 per month and from town allotments 10.5 per month. Estimates of time spent on fuelwood collection ranged from less than 2 hours to about 50 hours per month, with a mean of 14.4 person hours. All respondents said they spent about the same or less time on collection in 1986 compared to 1985, and in only three households did collection take more time than in 1981.

One household cut live wood from tongo and lekileki trees. Six respondents said they ring-barked trees and eight killed trees by burning. Species killed in this way included a range of both fruit and non-fruit trees. The most common way of transporting fuelwood was by van, used regularly by nine households and occasionally by three. Nine households carried fuelwood by hand, five used horses, three transported wood by truck, and two by boat. Horses and carts were regularly employed by five households and on occasions by three. Nine interviewees paid between T$2 and T$15 per load for transport.

All fifteen households stored fuelwood in their kitchens, and thirteen kept some there all the time. One stored wood all the time in the main building and one kept it outside and uncovered. Three others kept wood outside some of the time.

Coconut residues from cooking uses were used as fuel by all fifteen households and twelve used husks and shells left over from feeding pigs. Nine collected residues from copra dryers and thirteen respondents brought coconut residues directly from bush allotments. One household bought a van-load of husks from the Tonga Commodities Board every six months and another bought a truck-load of shells once a year.

(c) Consumption patterns

Twelve of the fifteen Folaha interviewees said their main cooking appliance was the open fire. Two of the other three households mostly used gas stoves and one used kerosene; each of these three used an open fire as their secondary appliance. Ten households used earth 'umu and five cooked in drum 'umus. Two used electric stoves as supplementary appliances.

Four of the five most important non-coconut fuelwood types in Folaha were also important in 'Ahau; these were kuava, koka, fau, and moli. The exception was sialemohemohe. Tava was not as important in Folaha as in 'Ahau and Vaotu'u, but tongo, which was not mentioned in any other rural study area, was listed as important by six Folaha households. A total of sixteen non-coconut species were considered to be important fuelwood types in Folaha, five more than in 'Ahau.

Tongo was the preferred fuelwood for open fire use and second to kuava for burning in the 'umu. Other favoured species were koka, moli, and sialemohemohe. Eleven respondents listed a total of sixteen species which they considered to be no longer available to them. Of these, seven were swamp forest species which, with one exception, would have been preferred to available fuelwood types.

According to respondents' estimates the average amount of wood burned per year in a Folaha household was average for the rural study areas. 6.5 tonnes of wood plus 3.0 tonnes of coconut residues gave a total of 9.5 tonnes of fuelwood consumed per household per year. Eight interviewees said their use of wood varied throughout the year, but only five attributed this variation to feasts. Extra fuel requirements were estimated at up to one truck load.

5.2.4 Lavengatonga

5.2.4.1 Natural systems

(a) Physical aspects

At 35 to 40 metres above sea level, Lavengatonga is located at the highest elevation of the six study areas. Situated within a kilometre of the south-east coast the village has little protection from the prevailing winds. As in Vaotu'u, but in contrast to the other two rural villages studied, no town allotments are at risk form inundation by sea water. The slope of the land to the east of Lavengatonga gradually steepens until it falls away to the sandy shoreline. On the other side of the village the slope is almost imperceptible as the elevation evenly declines over the 7 kilometres to the central lagoon.

(b) Biological aspects

On the coast adjacent to Lavengatonga the plant communities immediately behind the beaches were found to be characteristic of the coastal littoral forest described by Thaman (1976). Inland from this coastal forest two exotic species were quick to invade any cleared land: sialemohemohe (*Leucaena leucocephala*), and pula (*Solanum verbascifolium*). Sialemohemohe in particular formed dense monospecific stands. In 1985 sialemohemohe had been attacked by the leucaena psyllid *Heteropsylla cubana*, a sap-sucking insect which spread across the Pacific in less than two years (Fakalata 1986). The severe impact on the leucaena stands appeared, in 1986, to have given an opportunity for pula to become dominant. With the exception of a handful of town allotments, trees were very sparsely distributed throughout the village area.

(c) Cultural aspects

Human activity has had a major impact on the natural, self-regenerating, vegetation of the area around Lavengatonga. The original introduction of sialemohemohe was the result of Spanish voyages of exploration some 400 years ago (Fakalata 1986). The clearing of increasingly large areas of indigenous forest cover provided ideal conditions for the invasive leucaena to establish extensive single species stands. Under traditional agricultural management techniques based on a crop rotation system sialemohemohe was likely to be the dominant colonizer of fallow land. The adoption of monocultural cultivation methods has been accompanied by considerable difficulties in preventing leucaena from invading crop fields. As leucaena readily coppices from cut stumps, local farmers found they had to dig out the roots to have any chance of stopping the growth of sialemohemohe.

The coastal littoral forest is vulnerable to various human impacts, but its location at the base of sea cliffs, albeit mostly gently sloping, has protected it from large scale collection of fuelwood. Among the fifteen households interviewed in Lavengatonga none gathered wood from the coast. Although no detailed study of the coastal vegetation was undertaken, the appearance of coastal forest adjacent to the vehicular track leading to the beach from the northern end of the village suggested some collection of fuelwood had taken place. In locations where the slope behind the beach did not prevent cultivation some crops had been grown. Such occurrences punctuated the ribbon of coastal forest. Another land use which had reduced, although not completely cleared, beachside vegetation was a tourist development utilising 'Oholei beach and a natural cave in the limestone cliffs. Recreational use of the beach by local people as well as foreign tourists affected the forest ecosystem by disturbing natural regeneration and by the casual removal of wood for picnic fires.

(d) Significance to fuelwood supply

As none of the Lavengatonga interviewees included the coast among their fuelwood collection sites, it would appear that the coastal forest was not in 1986 a significant source of fuel. In contrast, leuceana is clearly the species most commonly used as fuelwood.

5.2.4.2 Domestic systems

(a) Household facilities

Land

A total of one hundred and seventeen town allotments were recorded within the village of Lavengatonga. 1986 census data suggest there were fifty-four households living there. This proportion of allotments to resident households, at 2.2:1, was higher than for any of the other three rural villages studied. Unoccupied allotments were generally not fenced off, so that while pigs and chicken were free to move around the village this land could not be used for crop production.

Buildings

Three of the main buildings used by interviewed households in Lavengatonga were Tongan in style, two of them being constructed of thatch in the traditional manner. None of 'Ahau's main buildings had been of traditional materials. The majority of kitchen buildings in Lavengatonga were either of thatch construction or built of a combination of materials to resemble the traditional form.

Water and electricity

Two of the fifteen interviewed households had water piped to the main house or kitchen. Of the others who used external standpipes, three households had to go to neighbours' allotments to collect water. No households in Lavengatonga had mains electricity in 1986 as the grid had not been extended to their village at that time.

Cooking facilities

Non-wood burning stoves constituted only 6 percent of the cooking appliances used by the fifteen households interviewed in Lavengatonga, compared to 13 percent in 'Ahau (Table 5.30). The average number of appliances per household, 2.1, was the lowest of the four rural study areas. Lavengatonga was the only village where no interviewee said they used a charcoal stove.

TABLE 5.30

Numbers and percentages of interviewed households using six types of cooking appliances in Lavengatonga in 1986 by appliance location

Appliance type	**Appliance location**							
	Main building		Separate kitchen		External		Totals	
Open fire			13	87%	2	13%	15	100%
Earth '<u>umu</u>			3	20%	8	53%	11	73%
Drum '<u>umu</u>			1	7%	3	20%	4	27%
Kerosene stove	1	7%					1	7%
Gas stove	1	7%					1	7%

Valid cases: 15

Average number of appliances per household: 2.1

Non-wood burning appliances as percentage of total: 6.3%

Transport and communications

Ownership of transport facilities in Lavengatonga was similar to 'Ahau but a higher proportion of interviewees, thirteen of fifteen, said their households paid to travel in open back trucks.

(b) Members of the household

Age and sex characteristics

Among the sample households the ratio of adult males to adult females was, at 0.68:1, even lower than in Folaha. The proportion of children in the sample population was the highest among the four rural villages with 0.81 children per adult.

Occupations

As in 'Ahau the most common commercial activity was farming, but neither of the other two dominant occupations in 'Ahau, clerk and fisherman, figured at all in the Lavengatonga survey. Two households here said they had no income generating work. Five households earned money from handicrafts, and one from traditional dancing at the tourist entertainment establishment on the beach. Other occupations not encountered in other villages were machinist, laundry worker, and church treasurer.

Income

The two households without occupations had no earned income, and two respondents could not estimate the household's income level. Two interviewees gave annual earned incomes as more than T$1000 and more than T$2000 respectively. All others said less than T$1000.

Seven of the fifteen Lavengatonga households claimed to receive no remittances from overseas; this was the highest number of any of the four study villages. One interviewee's household was said to be sent about T$50 per year, another about $100. The remaining five respondents estimated receiving between T$400 and T$2000 annually.

(c) Domestic activities

Food and drink preparation

With no electricity available in Lavengatonga all households heated water with their main cooking appliances: thirteen open fires, one kerosene stove, and one gas stove. This would have been more time consuming than using an electric jug.

Handicrafts

While no specific data were recorded about handicraft production, the emergence of handicrafts as a significant source of income in Lavengatonga suggests that it was a time-consuming activity.

(d) Energy consumption

Electricity

Lavengatonga was the only one of the four study villages which was not linked to the electricity grid.

Kerosene

Only one of the fifteen interviewed households used a kerosene stove but it was said to be the main cooking appliance for this household. All fifteen interviewees said their households used kerosene to fuel lamps. Eight also used benzine for lighting.

Woodfuels

All fifteen Lavengatonga households included in the survey burnt wood as a cooking fuel, both in open fires and 'umus. All but one respondent said woodburning appliances were used to heat water, to make hot drinks, to boil pandanus leaves, for personal washing, dishwashing, and laundry. Eleven households used coconut shell as fuel to make coconut oil.

5.2.4.3 Cultivated systems

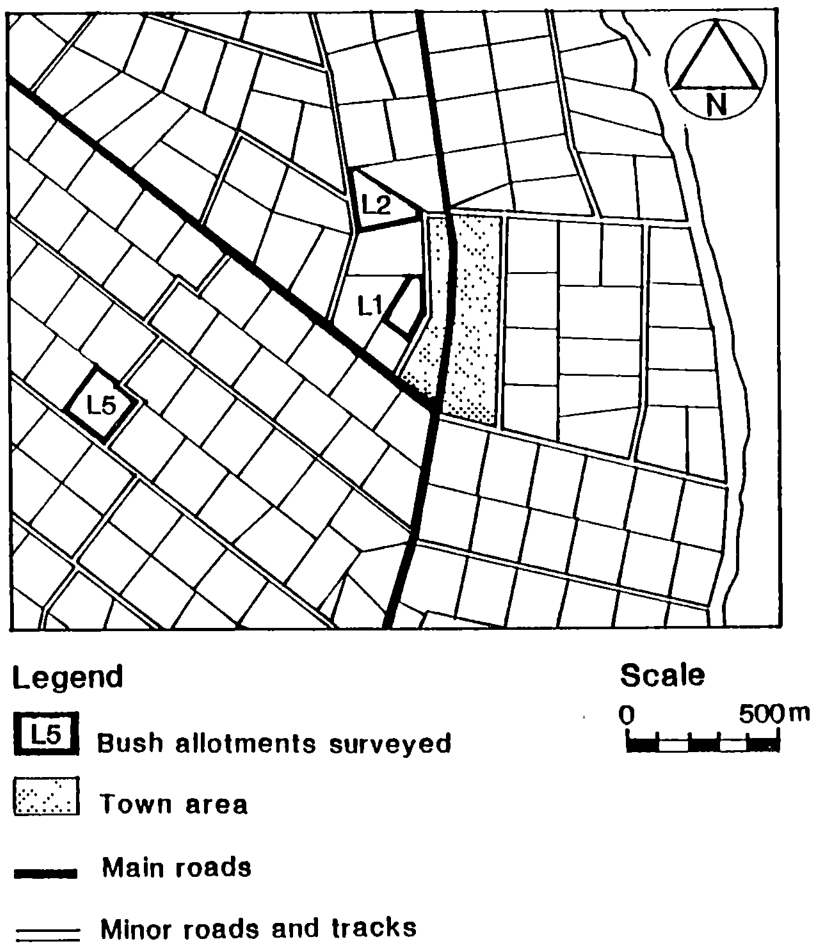
(a) Bush allotments

Land allocation

Lavengatonga interviewees' bush allotments were located an average of 1.3 kilometres from their homes; a shorter distance than in Folaha but further than in 'Ahau and Vaotu'u. This average excludes the land on 'Eua being cultivated by one interviewee. The locations of surveyed Lavengatonga allotments referred to in the text are indicated in Figure 5.11. The mean allotment size of 7 acres (2.8 hectares) was about one third larger than the 'Ahau average and 1 acre less than the averages in Vaotu'u and Folaha. At 14.9 acres (6 hectares) the area accessible to the average respondent was very close to the highest figure, recorded in

FIGURE 5.11

Sketch map showing boundaries of Lavengatonga village and surveyed bush allotments



Folaha. The proportion of allotments registered in the user's household, six of seventeen, was the lowest of the rural villages.

Soil

The Vaini and Lapaha clay soils of the agricultural land behind Lavengatonga, have all been categorised as good for food crops except for shallow Vaini clay in depressions which is rated as fair (Cowie, in preparation). Eleven allotments were considered by their users to be very fertile, three as fertile, one as not very fertile, and two were described as only partly fertile or very fertile. While one farmer thought ploughing improved fertility the majority said they had improved their soil by fallowing. Another suggestion was to leave agricultural wastes to rot.

Agricultural land management

All seventeen of the bush allotments accessible to Lavengatonga interviewees were under cultivation at the time of the interviews. Of the available area on the seven producing commercial crops 93 percent was cultivated. The comparable proportion under crops on the non-commercial allotments was 59 percent. In absolute terms the average area cultivated for non-commercial crops, 3.9 acres, was only 13 percent less than the average area used for commercial production. The three surveyed bush allotments ranged in total area from 4 to 13 acres (1.7 to 5.4 hectares) and were 23 to 99 percent cultivated (Table 5.31).

The only allotment said to support just one crop was dedicated to vanilla production and was the only one not managed on a crop rotation system. Most commonly cited main crops were cassava, taro, and yams (Table 5.32). Plantains and bananas figured prominently among the supplementary crops, with hopa being the most popular and pata and bananas rating third and fourth. Yams were grown as a supplementary crop by half the farmers interviewed and were overall the most widely grown crop. The range of produce sold appeared to be broader than in the other rural study areas. Included were: yams, cassava, taro, sweet potato, bananas, vanilla, taro leaves, and papaya. Fallow times included in the crop rotation ranged from nil to five years, with an average of 2.1 years.

Hand tools used in Lavengatonga were similar to the other villages. Two respondents used a tractor and plough. Four farmers used chemical sprays on yams, sweet potato, and bananas. Cooperative groups worked on eleven of the thirteen allotments currently being cultivated.

Those farmers who specified which were their most important products mentioned a total of six crops. Responses for five allotments were that all crops could be considered to be most important; one interviewee said all food crops

TABLE 5.31

Summary of areas of cultivated, fallow, and uncultivated sections of three surveyed bush allotments used by Lavengatonga households, in m^2 and as percentages of whole allotment areas

Allotment:	L1	L2	L5	Totals
Cultivated Sections				
- m^2	16 800	7800	25 700	50 300
- % whole	99	23	48	48
Fallow Sections				
- m^2	100	24 700	26 800	51 600
- % whole	1	74	50	49
Uncultivated Sections				
- m^2	0	900	1600	2500
- % whole	0	3	3	2
Whole Allotment				
- m^2	17 000	33 300	54 100	104 400
- % whole	100	100	100	100

constituted the most important products. Yams were the produce most commonly sold, followed by hiapo (paper mulberry) stems and taro.

Trees on agricultural land

All respondents named at least four tree species present on their bush allotments. Seven of the nine interviewees said all these species were beneficial, for a broad range of reasons (Table 5.33). One farmer said that koka and lopa were a nuisance because they regenerated quickly and took up cultivation space (Table 5.34). These trees had also been covered by the same farmer's previous response that all trees on his land were beneficial. The only other nuisance tree was sialemohemohe, which was disliked by one respondent because it spread rapidly.

TABLE 5.32

Percentages of bush allotments used by Lavengatonga respondents to bush allotment interviews on which various types of crops were grown, by management technique

Crop Type	Crop Rotation Main Crop	Crop Rotation Supp. Crop	Crop Rotation Over-all	No Rotation Main Crop	No Rotation Supp. Crop	No Rotation Over-all	All Allotments Main Crop	All Allotments Supp. Crop	All Allotments Over-all
Ym	31	50	81				29	47	76
T	38	31	69				35	29	65
Ka		13	13					12	12
Cs	50	13	63				47	12	59
Ho		75	75					71	71
Ba	6	31	38				6	29	35
Pa		44	44					41	41
Pi		6	6					6	6
Vn		13	13	100		100		18	18
Hi	6	25	31				6	24	29
Mz		6	6					6	6
Sp		6	6					6	6
Kv		6	6					6	6
Valid cases:	16	16	16	1	1	1	17	17	17

TABLE 5.33

Percentages of nine respondents to bush allotment interviews in Lavengatonga giving various reasons for trees on agricultural land being a benefit and for protecting them during clearing of fallow and weeding

Reason/ Useful Product	Benefit from trees	Reason for protecting trees
Food	78	67
Dye	22	22
Fuelwood	56	11
Medicine	56	33
Oil	11	22
Income		11
Building material	44	
Fencing	22	
Incense	11	
Handicraft	11	
Canoe	11	
Numerous	11	
Cult. decoration	11	
Improve soil		11
Insect repellant		11

One self-regenerating species protected by three of the Lavengatonga respondents, ahi (sandalwood), had not been mentioned in this context in any other study area. This is significant for two reasons: ahi is an important traditional source of an ingredient for scented oils, and sandalwood is potentially a valuable export commodity.

Eight of the nine interviewees perceived that trees had an influence on crops. Five cited detrimental effects such as trees block the sun and the soil is more fertile after big trees have been felled. Three saw beneficial influences: trees provide windbreaks and koka and ifi improve soil fertility. Three farmers planned to clear trees to make way for cultivation. Six respondents had planted trees in the past, between 1965 and 1986, mostly to provide food but also for timber, handicraft material, and to support vanilla vines. Production of building timber figured more strongly in the reasons given by respondents for planning to plant trees in the coming year.

TABLE 5.34

Percentages of nine respondents to bush allotment interviews in Lavengatonga identifying fruit and non-fruit tree species on agricultural land as being of benefit or a nuisance, and tree species protected during the clearing of fallow and weeding

Species	Benefit	Nuisance	Protect During Clearing	Protect During Weeding
Fruit trees				
AVO	22			
FEK	11			
IFI	56			11
KUA	22			
LEM	11			
MAN	78		11	22
MEI	67			11
MOL	44			11
TAV	56		22	56
VII	11			
Total numbers of fruit species	10	0	2	5
Non-fruit trees				
AHI	22		33	33
FAU	11			
FIK	22			
HEI	22			
KOF	11			
KOK	78	11	11	11
LOA	11			
LOP	11	11		
LOU	11			
NON	33			
OKE	22			
PIP	11			
PUK	11			
PUL	11			
SIA	67	11		
TAH	33			
TUI	11			
Total numbers of non-fruit species	17	3	2	2
Total numbers of fruit and non-fruit species	27	3	4	7

Continued

TABLE 5.34 Continued

Species	Benefit	Nuisance	Protect During Clearing	Protect During Weeding
Non-specific categories				
All trees				11
All big trees			11	
All except SIA and PUL			11	
All fruit			22	
Food trees			11	
Unnamed spp.	11			

The densities of non-coconut trees on the entire areas of the three Lavengatonga bush allotments surveyed were very similar: seventeen, sixteen, and fourteen trees per hectare (Table 5.35). Densities on the cultivated portions showed a broader spread: from nine to eighteen trees per hectare. While full sets of data were not recorded on two of the allotments, the proportions of land areas covered by tree crowns have been estimated to be within the range monitored in the other rural study areas (Table 5.36). Lavengatonga was the only rural study area where the most frequently encountered tree on the surveyed bush allotments was not koka; here tava was most common, with 2.7 trees per hectare, followed by koka, mei and vavae (Table 5.37). However, koka was the most common species on cultivated land.

Significance to fuelwood supply

All fifteen Lavengatonga respondents gave bush allotments as their main fuelwood collection site; eleven of these belonged to the interviewed household. Of the total of thirty-two collection sites mentioned by interviewees twenty-five were bush allotments. Twenty-one of twenty-seven types of fuelwood collected came from bush allotments.

TABLE 5.35

Numbers and densities of coconut, fruit, and non-fruit trees on cultivated, fallow, and uncultivated sections of three bush allotments used by Lavengatonga households

	L1	L2	L5	Totals
Cultivated Sections				
Numbers of trees				
Coconuts	158	nr	278	436+nr
Fruit trees	14	4	17	35
Non-fruit trees	16	3+(1)[1.]	22	41+(1)
Total numbers	188	7+(1) +nr	317	512+(1) +nr
Trees per hectare				
Coconuts	94	nr	108	103[2.]
Fruit trees	8	5	7	7
Non-fruit trees	10	4+(1)	9	8
Total numbers	112	9+(1) +nr	123	102+nr
Fallow Sections				
Numbers of trees				
Coconuts	0	nr	217	217+nr
Fruit trees	0	31	10	41
Non-fruit trees	0	15	27	42
Total numbers	0	46+nr	254	300+nr
Trees per hectare				
Coconuts	0	nr	81	81[2.]
Fruit trees	0	13	4	8
Non-fruit trees	0	6	10	8
Total numbers	0	19+nr	95	58+nr

Continued

TABLE 5.35 Continued

	L1	L2	L5	Totals
Uncultivated Sections				
Numbers of trees				
Coconuts	na	nr	0	0+nr
Fruit trees	na	0	0	0
Non-fruit trees	na	0	0	0
Total numbers	na	0	0	0+nr
Trees per hectare				
Coconuts	na	nr	0	0+nr
Fruit trees	na	0	0	0
Non-fruit trees	na	0	0	0
Total numbers	na	0	0	0+nr
Whole Allotment				
Numbers of trees				
Coconuts	158	227+nr	495	880+nr
Fruit trees	14	36[3.]	27	77[3.]
Non-fruit trees	16	18	49	83
Total numbers	188	281[3.]+nr	571	1040[3.]+nr
Trees per hectare				
Coconuts	93	51+nr	92	84+nr
Fruit trees	8	11	5	7
Non-fruit trees	9	5	9	8
Total numbers	111	85+nr	106	100+nr

Notes:
1. Figures in brackets refer to boundary trees which have been counted in data for other sections.
2. Calculated from data for allotments L1 and L5 only.
3. Includes one tree whose location within the allotment was not recorded.

TABLE 5.36

Crown areas of fruit and non-fruit trees over cultivated, fallow, and uncultivated sections of three bush allotments used by Lavengatonga households

	L1	L2	L5	Totals
Cultivated Sections				
Fruit - m^2	397	122	491+nr	1010+nr
- % land area	2.4	1.6	1.9+nr	2.0+nr
Non-fruit - m^2	116	66	808+nr	991+nr
- % land area	0.7	0.9	3.1+nr	2.0+nr
All trees - m^2	513	188	1300+nr	2001+nr
- % land area	3.1	2.4	5.1+nr	4.0+nr
Fallow Sections				
Fruit - m^2	0	1122	201+nr	1323+nr
- % land area	0	4.5	0.7+nr	2.6+nr
Non-fruit - m^2	0	307+nr	105+nr	412+nr
- % land area	0	1.2+nr	0.4+nr	0.8+nr
All trees - m^2	0	1429+nr	306+nr	1735+nr
- % land area	0	5.8+nr	1.1+nr	3.4+nr
Uncultivated Sections				
Fruit - m^2	0	0	0	0
- % land area	0	0	0	0
Non-fruit - m^2	0	0	0	0
- % land area	0	0	0	0
All trees - m^2	0	0	0	0
- % land area	0	0	0	0
Whole Allotment				
Fruit - m^2	397	1252[1.]	491+nr	2341+nr
- % land area	2.3	3.8	0.9+nr	2.2+nr
Non-fruit - m^2	116	374+nr	913+nr	1403+nr
- % land area	0.7	1.2+nr	1.7+nr	1.3+nr
All trees - m^2	513	1626+nr	1605+nr	3744+nr
- % land area	3.0	4.9+nr	3.0+nr	3.6+nr

Notes: 1. Includes the crown area of one fruit tree whose location was not recorded and which therefore is not include in the Cultivated and Fallow Sections data above.

TABLE 5.37

Tree densities per hectare and crown areas as percentages of land area[1], for the ten tree species most commonly found on three surveyed bush allotments used by Lavengatonga interviewees

Rank	Species		Cultivated	Fallow	Uncult-ivated	Whole Allotment
1.	TAV	per ha	3.0	2.5	0.0	2.7
		% area	0.9	0.9	0.0	0.9
2.	KOK	per ha	3.4	1.4	0.0	2.3
		% area	1.8	nr	0.0	0.9
3=	MEI	per ha	0.4	2.5	0.0	1.4
		% area	0.2	0.8	0.0	0.5
3=	VAV	per ha	2.2	0.8	0.0	1.4
		% area	0.2	nr	0.0	0.1+nr
5.	MAN	per ha	1.4	1.4	0.0	1.3
		% area	0.4	0.7	0.0	0.5
6.	TUI	per ha	1.4	1.0	0.0	1.1
		% area	0.2	0.1+nr	0.0	0.2
7.	MOL	per ha	1.4	0.4	0.0	0.9
		% area	0.4	0.1	0.0	0.2
8=	FOU	per ha	0.2	1.0	0.0	0.6
		% area	0.1	<0.1+nr	0.0	<0.1+nr
8=	LOU	per ha	0.8	0.4	0.0	0.6
		% area	0.2	0.1+nr	0.0	0.1+nr
8=	PUL	per ha	0.2	1.0	0.0	0.6
		% area	<0.1	0.3	0.0	0.2

Notes: 1. Density figures refer to trees recorded as having stems growing in the section under consideration; crown areas include overhanging foliage from trees rooted in adjacent sections.

(b) Town allotments

Land allocation

Estimates of town allotment sizes given by six interviewees ranged from about 750 m^2 (30 poles) to 1.6 ha (4 acres).

Soil

The soil type present throughout the town area of Lavengatonga has been classed as Lapaha clay, which is considered to be good for all forms of cultivation.

Crop management

Of seven households which grew food crops on their town allotments two were cultivating taro, cassava, and yams. Both were among the twelve allotments supporting livestock. Ten allotments had fruit trees providing food products.

Trees on agricultural land

Mei was again the most frequent town allotment tree, but the six other fruit species mentioned by interviewees represented a wider range of trees than given in other rural study areas. Fourteen of the fifteen households had planted trees but only eleven planned to plant them in the future.

Significance to fuelwood supply

Six households collected coconut residues, sialemohemohe, mei, and scraps of wood of unknown species from town allotments.

5.2.4.4 Commercial systems

(a) Commercial exchange of goods and services within the study area

Two Lavengatonga households interviewed gave produce as payment for the use of bush allotments. None paid for assistance in collecting fuelwood, but six paid cash for transporting it. One bush allotment interview respondent sold whole coconuts within the village.

A member of one interviewed household was employed within the study area as a traditional dancer at a beachside tourist entertainment venue.

(b) Commercial exchange outside the study area

Five of nine bush allotment interviewees sold traditional root crops, bananas, vanilla, taro leaves, and papaya. Six of the fifteen households included in the survey had at least one bush allotment whose general use was the production of commercial crops. Eleven respondents included farming as an income generating occupation. Three of the nine farmers interviewed sold whole coconuts to the Tonga Commodities Board and one sold them in the market. None made copra.

(c) Support for commercial activities

General assistance available in Lavengatonga was similar to that available in other rural study areas.

(d) Significance to fuelwood supply and consumption

Effects of commercial activity on fuelwood supplies were similar to elsewhere in rural Tongatapu. The lack of reticulated electricity presented a barrier to changing from wood to alternative fuels.

5.2.4.5 Social systems

(a) Demographic features

Lavengatonga experienced a significant change between 1976 and 1986 not only in total population but also in household size. The number of male residents fell by 20.0 percent from 180 to 144, while the village population dropped by 13.1 percent from 351 to 305. With the number of households increasing from fifty to fifty-four the average household size fell from 7.02 to 5.65. In the fifteen households interviewed the overall proportion of males, 44 of 103, was lower than that given by the 1986 census data, and the proportion of adult males was lower still: 23 of 57. As in other study areas there were more adults than children in the sample households.

(b) Community facilities and services

The village was served by reticulated water supplies but in 1986 the electricity grid did not extend to Lavengatonga. There were no telephones in the village. There were two shops in the village and two established churches: Free Wesleyan and Catholic. The Church of Jesus Christ of Latter Day Saints had begun development of a mission complex. Lavengatonga was served by only two regular bus services per day.

(c) Social characteristics

As elsewhere the churches appeared to present the main opportunities for social interaction among groups of villagers, with the role of the town officer in liaison between the village and the government offering a village-wide focus.

5.2.4.6 Fuelwood systems

(a) Sources

Collection sites in Lavengatonga were dominated by bush allotments; all respondents said they were their most important sources of fuelwood. Six households also collected from town allotments. Lavengatonga was the only study area where no households said they collected wood from coastal sites (Table 5.38).

Distances to bush allotments ranged up to 4 km with a mean of 1.2 km and standard deviation of 0.8 km. All town collection sites were within 0.1 km.

Bush allotments provided fuelwood from four fruit trees and ten non-fruit trees as well as six types of coconut residue. All fifteen households collected sialemohemohe from bush allotments but only one found it on town allotments. The only other non-coconut fuelwood gathered from town sites was mei.

The most numerous tree species recorded on surveyed bush allotments was tava, followed by koka, mei, vavae, and mango (Table 5.37). Most significant of these in terms of fuelwood supply was mei which was an important fuelwood species for two households.

(b) Harvesting, transport, and preparation

Interviewed Lavengatonga households using bush allotments for commercial farming collected fuelwood from their allotments less frequently than households not farming commercial crops. This went against the trend found in other rural study areas. Commercial farmers collected on average 5.1 times per month while non-commercial farmers collected 6.3 times per month. Collections from town allotments were made on average 12.7 times per month. The mean estimated time spent on fuelwood collection was 22.5 hours per month, similar to 'Ahau, but the range of estimates in Lavengatonga was broader, from one to one hundred hours. Seven of the fifteen respondents said they spent more time collecting wood in 1986 than in 1985, and six more than in 1981.

Five households gathered live wood for fuel, either by felling or uprooting sialemohemohe, or by lopping pula and koka. Two households killed koka by ring-barking, and seven burned sialemohemohe, koka, vavae, mei, and coconut stems. The practice of uprooting sialemohemohe necessitated the addition of spades to the conventional array of fuelwood harvesting equipment of cane knifes, axes, and handsaws. Twelve households regularly carried their fuelwood by hand and one did so occasionally. Thirteen used horses and carts, six transported by van, and one by truck. Five of the van users paid T$2 or T$3 per load and one household paid T$5 for the truck.

Twelve households stored fuelwood in their kitchens all the time and three kept it outside and uncovered. Three respondents said they sometimes stored fuelwood uncovered on their bush allotments. Four households stored their fuelwood for between one week and three months between harvesting and burning.

TABLE 5.38

Percentages of fifteen fuelwood using households interviewed in Lavengatonga collecting various types of wood from five categories of sources

Species Code	Bush	Town	Coast	Road-sides	Copra dryer	Totals
Fruit Trees						
KUA	13					13
MAN	7					7
MEI		7				7
MOL	7					7
TAV	7					7
All Fruit	27	7	0	0	0	33
Non-Fruit Trees						
FAO	7					7
FAU	13					13
FIL	7					7
FOU	13					13
KOK	27					27
LOP	7					7
NGT	7					7
PUL	47					47
SIA	100	7				100
TOI	7					7
All Non-Fruit	100	7	0	0	0	100
Coconut Fuels						
COC	7					7
H&S	7	7				13
HUS		13				13
LOH	7					7
NIU	7					7
PAL	27	7				33
PUP		7				7
PUU		27				27
SHE		20				20
TOU	13					13
All Coconut	40	40	0	0	0	60
Other Types						
Dry Wood	7					7
Scraps		20				20
All 'Other Types'	7	20	0	0	0	27
Overall	100	40	0	0	0	100
Valid Cases:						15

Fourteen households used coconut residues left over from culinary purposes and from feeding pigs. Eight brought coconut fuels directly from bush allotments and five collected husks and shells from copra dryers. One household did not use any coconut fuels.

(c) Consumption patterns

The open fire was the main cooking appliance for thirteen of the fifteen households interviewed; the other two used a kerosene and a gas stove. These two were the only non-wood appliances utilised by the Lavengatonga sample households. Estimates of the time a cooking fire was alight ranged from 20 minutes to 2 hours, with a relatively high mean of 1 hour 20 minutes. Average numbers of people cooked for were 6.6 on weekdays and 6.8 on Sundays.

The greatest dominance of a single species in fuelwood use occurred in Lavengatonga. Fourteen of the fifteen households gave sialemohemohe as their most important fuelwood type, and the fifteenth gave it as third most important after coconut husk and shell. The only other non-coconut species to be an important fuelwood source for more than three Lavengatonga households was pula. Nominations for the best fuel for the open fire and for the 'umu were totally dominated by sialemohemohe, with no other type being suggested. Six other tree species were classed as important fuelwood sources by no more than three households each. Of these, filimoto (*Xylosma orbiculatum*), ngatata (*Elattostachys falcata*), and fo'ui (*Grewia crenata*) are characteristic of tropical lowland forest (Thaman 1976). The other three species mentioned were koka, mei, and kuava, all commonly found throughout the island. Six households mentioned ten fuelwood types as no longer being available.

Calculations based on interviewees' estimates suggest average fuelwood consumption in Lavengatonga was 7.8 tonnes of wood and 2.1 tonnes of coconut residues per household per year. Among rural study areas these estimates were the highest and lowest respectively. Six respondents said they used at least a cart load of extra fuelwood at particular times of the year when they prepared feasts.

5.2.5 Peri-urban Nuku'alofa

5.2.5.1 Natural systems

(a) Physical aspects

The dominant features of the physical environment of Peri-urban Nuku'alofa are the proximity to the sea, and the low elevation of the land. The Peri-urban extension of Nuku'alofa to the west of the town centre occupies very low-lying land which before development was swamp and marshland. Some of this land has been satisfactorily reclaimed but much is still subject to periodic flooding. None of this area is higher than 5 metres above sea level.

The new settlements that have been established to the east of Nuku'alofa are divorced from the central built-up area. Tukutonga is located on the narrow strip of raised land between the seafront and mangrove swamp. Popua occupies reclaimed swamp and adjacent land half to one kilometre inland. The higher land, above the 5 metre contour, between Popua and the town centre is mostly occupied by bush allotments. Tukutonga in particular is exposed to north and north-easterly winds.

The Peri-urban fringe south of Nuku'alofa town centre is part of the overall built-up area which extends to the edge of the Fanga 'Uta Lagoon. Land elevations here do not reach 5 metres above sea level but large scale flooding is less likely here than around the swamp areas to the north.

(b) Biological aspects

The dominant natural plant communities on the low-lying land next to the sea coast are mangrove and swamp forest. Before reclamation began, pockets of wetland extended a kilometre or more inland from the sea shore on both the western and eastern sides of the town. While some significant areas of mangrove swamp remained in 1986 it appeared to be heavily degraded from the natural condition. The more elevated sections of land near the seashore would have originally supported coastal littoral forest but little of this remained. The shores of the inland lagoon under natural conditions would have been lined with mangrove swamp but by 1986 only patches survived.

Both the seaward and inland lagoons in their natural condition were rich habitats for a variety of shellfish and scale-fish.

(c) Cultural aspects

The natural characteristics of the areas occupied by Peri-urban settlements have been extensively changed by human activities. Clearing of vegetation on the higher sections of land to make way for residential development and bush allotments was followed by clearing and filling of swamps to allow house construction to continue. The collection of building timber and firewood has contributed greatly to the degradation of remnants of mangrove and swamp forests. Lack of any effective control over cutting has exacerbated the impacts of the local communities on their natural environment. Recognition of environmental problems with regard to the destruction of mangroves on the Fanga 'Uta lagoon were acknowledged in the government's 1980-1985 Development Plan, but the only action called for was a monitoring programme (Tonga, Central Planning Department 1981).

Non-residential developments that diminish the potential for natural plant communities to thrive in the Peri-urban area include limestone quarries, small scale manufacturing and processing industries, tourist hotels, an oil storage depot, and Nuku'alofa's main rubbish tip, as well as agricultural management of much of the cultivable land. Commercial cutting of fuelwood occurs in Sopu on the western side of Nuku'alofa and probably also in the remnants of coastal forest to the east. No detailed descriptions of these cutting activities or information on the quantities taken are available.

(d) Significance to fuelwood supply

The coastal and mangrove forest areas are significant sources of fuelwood for people living in Popua and Tukutonga to the east of Nuku'alofa. Households living to the west and south of the central built-up area appeared to be more likely to collect fuelwood from agricultural land.

5.2.5.2 Domestic systems

(a) Household facilities

Land

Of the fifteen households interviewed in Peri-urban Nuku'alofa five did not have their town allotments formally registered with the government. Of these, one household had a government lease and another had customary tenure over more than twenty years which provided some security. The other three households had each occupied their town allotments for 5 years or more but, while they had some claim to continued use of the land, they had no legal security.

Six of the fifteen Peri-urban households interviewed had no access to a bush allotment to cultivate food crops. Of the twelve allotments available to the other nine households two were in Ha'apai and one on 'Eua. Of the nine allotments on Tongatapu only one was registered in the name of a member of the interviewed household. One allotment was within half a kilometre of the interviewee's home, but the others were between 5 and 18 kilometres away. The land area available for cultivation ranged from one to sixteen acres.

Buildings

Five of the fifteen Peri-urban households interviewed had kitchens located within the main building; two had separate kitchens as well. One household did not have a kitchen; in the other nine cases kitchens were separate from the main living houses. Five households had washing and toilet facilities within the main house. All main buildings except one were European or modified European in style, the one exception being modified Tongan. Construction materials were generally dressed timber for walls, sheet metal for roofs, and concrete or wooden boards for floors. Two thirds of the houses visited had glass windows and one third had glass panels in their entrance doors. Alternative materials utilised by a minority of households were concrete blocks, rough timber, metal sheet, and cardboard for walls, plastic sheeting for roofing, and coconut leaves for flooring. Separate kitchens and other ancillary buildings were most likely to be modified

Tongan in style, with earth floors, and walls and roofs of whatever suitable materials were available.

Only five interviewees said they had made alterations to their homes within the previous year, compared to twelve who had plans to do so.

Water and electricity

Nine households had piped water compared to twelve with external standpipes and five with rainwater tanks. Two households (one in Tukutonga and one in Popua) did not have their own water supply. Eight households were connected to the electricity grid. The ten households using batteries replaced an average of about three per week.

Cooking facilities

All fifteen households said they used at least one wood burning cooking appliance, with eleven giving the open fire as their most important cooking facility. A total of six households cooked with kerosene stoves, two had gas stoves, and one used an electric toaster (Table 5.39). These nine non-wood appliances represented a relatively high 24.3 percent of the total number of cooking appliances used in the fifteen households. Six households used drum 'umu located outdoors and two households used them inside a kitchen. Eight households used earth 'umus, all of which were located outdoors. None of the respondents mentioned using charcoal or electric stoves.

Transport and communications

Six of the fifteen Peri-urban households interviewed owned no form of transport. Seven households had bicycles but one of these was not roadworthy. Of the two cars and one van owned by three households only one car was in working order. Of two households owning horses one also had a cart. One interviewee said his household owned a boat.

All fourteen households giving responses said they used buses, and ten paid for taxis or minimokes. Three used passenger vans.

TABLE 5.39

Numbers and percentages of interviewed households using six types of cooking appliances in Peri-urban Nuku'alofa in 1986 by appliance location

Appliance type	**Appliance location**							
	Main building		Separate kitchen		External		Totals	
Open fire			8	57%	4	29%	12	86%
Earth 'umu					8	57%	8	57%
Drum 'umu			2	14%	6	43%	8	57%
Kerosene stove	6	43%					6	43%
Gas stove	2	14%					2	14%
Electric toaster	1	7%					1	7%
Valid cases:							14	

Average number of appliances per household: 2.5

Non-wood burning appliances as percentage of total: 24.3%

(b) Members of the household

Age and sex characteristics

The sexes in the sample households were very evenly matched, fifty-four males to fifty-two females. There were forty-four children to sixty adults. The 1986 census data indicate 446 males to 392 females in Popua and Tukutonga. Data for Sopu to the west were combined with Kolomotu'a which showed a slightly large number of females, as did Haveluloto, the most southerly of the communities included in the Peri-urban study area.

Occupations

Twenty nine of the forty-four children in the fifteen Peri-urban households were at school, and seven young adults also attended educational institutions. Only one household included a commercial farmer. Four received an income from teaching and a similar number from fishing. Members of three households worked as clerks and three households earned money by selling handicrafts. Other occupations included baker, carpenter, shopkeeper, hospital sister, and factory worker. One interviewee said no member of the household had an income earning occupation.

Income

Apart from the one household which had no earned income the lowest income among Peri-urban households was in excess of T$500. Six households earned more than T$5000 per year, with two claiming total household incomes over T$8000. Six interviewees said they never received remittances from overseas, and one only very rarely. For seven households amounts received annually ranged from T$300 to more than T$1000, and one respondent said remittances totalled more than T$5000 per year.

(c) Domestic activities

Food and drink preparation

Numbers of meals cooked per day averaged 2.7 Monday to Friday, 2.6 on Saturdays, and 1.8 on Sundays. All households used the haka cooking method; estimated cooking times ranged from 20 minutes to 2 hours. The next most popular cooking method was the 'umu which only one household did not use. Twelve respondents said they fried food, seven boiled (other than haka), and five roasted. Four households had adequate facilities for baking regularly; all but two of the other households interviewed said baking was the one cooking method they would like to be able to use which they currently could not.

Handicrafts

Interview responses showing that handicraft sales were an important source of income for three households indicate that some members of those households must have spent considerable periods of time making handicraft items. These three were among nine households which used open fires to boil pandanus leaves to prepare material for weaving mats.

Washing and ironing of clothes

Two of the fifteen Peri-urban households interviewed regularly heated water for laundry purposes while five did so only occasionally. Seven households used electric irons, four used charcoal, and three benzine irons. Only one interviewee said no iron was used.

Livestock management

Only one interviewed household did not include either pigs or chicken when asked what types of food their town allotment produced. Given that Peri-urban Nuku'alofa is more densely populated than the rural villages it is expected that householders are not so prepared to allow their livestock to wander without restriction. It can be assumed, therefore, that more time and effort is spent keeping pigs and chicken under control. Responses from seven households indicating that they kept pigs on town allotments used to grow food crops suggests that the animals were physically restrained from damaging the crops.

Gardening

The average number of non-tree crops grown on town allotments in Peri-urban Nuku'alofa was twice the average for 'Ahau. This suggests more time was spent tending dooryard gardens here than in the rural villages. This characteristic is to be expected given the lower average number of bush allotments to which households had access.

Collecting firewood

While all fifteen Peri-urban households interviewed at some time used firewood only thirteen collected wood on a regular basis; one household bought wood, and another used fuelwood so rarely that the interviewee could not give specific sources. In nine of the households that did use wood burning appliances regularly wood was collected by just one person: in seven cases an adult male, in two cases an adult female. In three households children assisted with wood collection and one household had help from an adult male from outside the household. Estimated hours spent per month on collecting fuelwood ranged from one to twenty. Three interviewees said they spent less time collecting at the time of the interview than one year previous, five said their households spent about the same time, and four thought they spent longer.

Transporting food supplies

For many Peri-urban households the pattern of obtaining day to day food supplies would have been very different to households in the rural villages. While many had productive food gardens on their town allotments these would not have been adequate to meet all their requirements. Particularly among those households who did not have access to bush allotments to grow crops high proportions of food supplies would have been bought in town stores or at the Talamahu market. From the heightened activity observed at the market on Saturdays it appeared that the common rural practice of bringing the main load of food home from the bush allotment on Saturdays had been replaced in Nuku'alofa by a trip to the market. Those who could afford to pay for a taxi or minimoke would generally do so in order to be able to transport a week's supply of food, and often firewood as well. The main alternative was to struggle with baskets of food on crowded buses.

(d) Energy consumption

Electricity

All eight of the fifteen Peri-urban households interviewed which were connected to the electricity grid used electric lighting. Seven used electricity for ironing but only two had electric jugs and one owned a toaster.

Kerosene

Kerosene was the main cooking fuel for two households and four used kerosene stoves as supplementary cooking appliances. Five of these households used their kerosene stoves for heating water. All seven households not connected to the electricity grid operated kerosene lamps, as did two households also using electric lighting.

Benzine

A total of four households used benzine as supplementary lighting fuel, and three ran benzine irons.

Gas

The two Peri-urban households who owned gas stoves used them as their main cooking appliances and also for heating water.

Woodfuels

The open fire was the main cooking appliance for eleven of the fifteen Peri-urban households interviewed and a supplementary appliance for two households. All fifteen households used the open fire on some occasions to heat water. All fifteen households used 'umus, eight using the traditional earth variety and a similar number using drum 'umus. Wood was the only cooking fuel utilised by seven of the fifteen households. No interviewees reported ownership of charcoal stoves but four households used charcoal irons.

Nine of the eleven households using firewood for non-cooking purposes used it to boil pandanus leaves; six made coconut oil; and one household used wood fires to dry fish and to repel insects.

5.2.5.3 Cultivated systems

(a) Bush allotments

Land allocation

Each of the six Peri-urban bush allotment interview respondents had access to a single allotment. Of these the only one that was registered in the name of a member of the user's household had been used for over fifty years. The other five had been used by the interviewed households for an average of 4.9 years. The four allotments whose distance from the town allotment was estimated by the interviewees were between 0.3 and 6 kilometres away. One of the other two was near the south coast about 10 kilometres from Nuku'alofa; the other was close to the airport, some 20 kilometres away. The approximate locations of three surveyed allotments, PU2, PU5, and PU15, are shown in Figure 5.12.

Soil

The area around Nuku'alofa is characterised by a patchwork of soil types. Nuku'alofa sand is found in a band along the coastline. Behind this lie patches of mostly Sopu loam and Nuku'alofa sand together with some Vaini and Fatai clay. The Sopu, Nuku'alofa, and Fatai soils are all classed as fair for food crops; only the Vaini clay is rated as good. A small area of steeper slopes on the eastern extremity of the built up area is blanketed with Lapaha clay which is considered good for all types of cultivation. The agricultural land to the west of the capital is largely on a mixture of Fahefa and Fatai soils which Cowie categorises as fair to good for food crops. All these soil types are subject to some nutrient limitations, particularly under continuous cropping (Cowie, in preparation).

The allotments used by two of the six Peri-urban interviewees were located on the southern side of the island where more constant soil conditions prevailed. Overall, farmers living in Peri-urban Nuku'alofa would be working with the full variety of soil types present on Tongatapu.

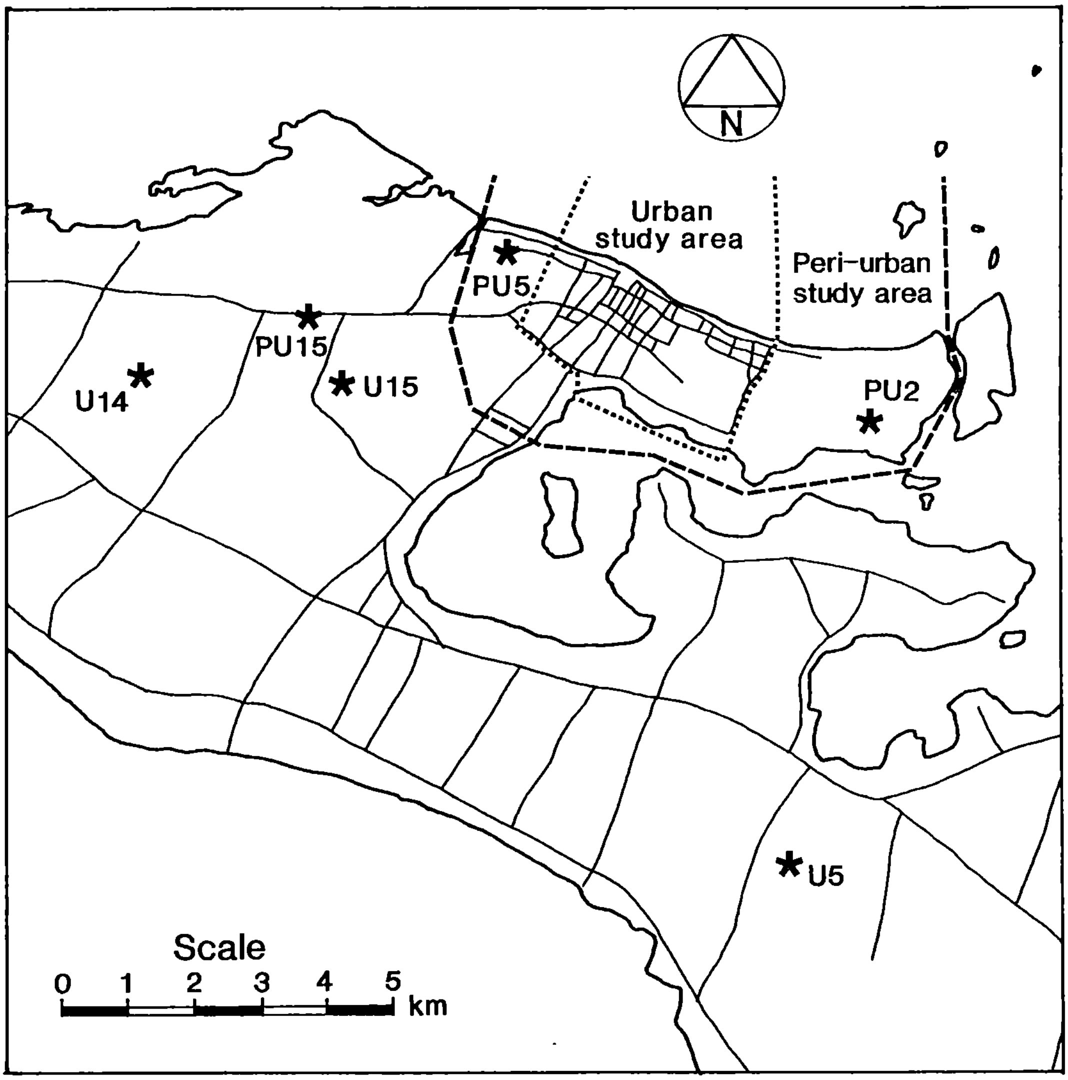
Interview respondents' assessments of the fertility of the soil on their allotments ranged from 'very fertile' to 'fertile when it rains'. Four said they had been able to improve fertility, mostly by ploughing.

Agricultural land management

Of the six allotments covered by the bush allotment interviews in Peri-urban Nuku'alofa only one was used primarily for commercial cropping. In contrast to the trend in the rural study areas a smaller proportion of the available land was cultivated on the commercial allotment than on the non-commercial ones. On only one of the five non-commercial Peri-urban allotments was the cultivated area said to be less than the total land area to which the interviewed household had access. On the commercial allotment 2.4 ha (75 percent) of 3.2 ha was under crops,

FIGURE 5.12

Sketch map of central Tongatapu showing approximate boundaries of Peri-urban and Urban study areas and locations of surveyed bush allotments used by Peri-urban and Urban interviewees



Legend

★ Bush allotment used by interviewed household while an average of 1.6 ha (83 percent) of 1.9 ha was cultivated on the non-commercial land. Areas for three surveyed bush allotments are given in Table 5.40.

The three Peri-urban farmers who used a crop rotation system managed their allotments primarily for non-commercial production, although one did sell some produce. All three gave root crops (cassava, taro, yams) as main crops, and bananas and plantains as supplementary crops (Table 5.41). Two of the three not following crop rotation methods grew bananas as a main crop with supplementary root crops. The sixth respondent practised an intermediate

TABLE 5.40

Summary of areas of cultivated, fallow, and uncultivated sections of three bush allotments used by Peri-urban households, in m^2 and as percentages of whole allotment areas

Allotment:	PU2	PU5	PU15[1]	Totals
Cultivated Sections				
- m^2	6500	21 900	nr	28 400+nr
- % whole	19	44	nr	29+nr
Fallow Sections				
- m^2	24 000	28 100	0	52 100
- % whole	72	56	0	53
Uncultivated Sections				
- m^2	3000	0	nr	3000+nr
- % whole	9	0	nr	3+nr
Whole Allotment				
- m^2	33 500	50 100	15 000	98 600
- % whole	100	100	100	100

Notes: 1. Data for this allotment relate to the area surveyed (45 percent of the total allotment area).

management system which alternated between yam cultivation and fallow. The average fallow period was 1.9 years.

Four Peri-urban farmers hired tractors and ploughs as well as using hand tools to cultivate their land. Three used chemical sprays to reduce the impact on crops of pests and diseases. No farm workers' cooperatives operated on any of the six allotments included in the Peri-urban survey, but one allotment holder employed agricultural labourers. The other five allotments were managed solely by members of the interviewee's household or family.

Products considered to be most important included traditional root crops, bananas, and European vegetables. All types of produce grown on the allotment cultivated by paid employees were sold, as well as being used by the household. One allotment produced bananas for sale and the European vegetables grown on another were sold. Three allotments were used solely for food crops to be consumed by the household. Coconuts from just two allotments were sold to the Commodities Board, and only one respondent said some copra was made.

Trees on agricultural land

The number of tree species growing on bush allotments included in the Peri-urban survey varied considerably. One respondent's allotment was said to support only fau and one unidentified species, while two interviewees listed eleven tree species. Three thought all trees were beneficial while the others named between one and three species to be of benefit. The six Peri-urban interviewees mentioned a broad range of benefits, but in contrast to responses in other study areas food produce did not assume predominant significance (Table 5.42).

Three respondents considered four named tree species and one unidentified species to be a nuisance, because they competed with crops, took soil fertility, and occupied space which should be cultivated. All but two of the trees protected during clearing and weeding were fruit trees valued for their food products (Table 5.43). Four interviewees said trees had detrimental influences on crops, and two planned to destroy trees to make way for crops and to reduce shading. Three

TABLE 5.41

Percentages of bush allotments used by Peri-urban Nuku'alofa respondents to bush allotment interviews on which various types of crops were grown, by management technique

Crop Type	**Crop Rotation**			**No Rotation**			**All Allotments**		
	Main Crop	Supp. Crop	Over-all	Main Crop	Supp. Crop	Over-all	Main Crop	Supp. Crop	Over-all
Ym	33	33	67	33		33	33	17	50
T	67	33	100	33	67	100	50	50	100
Ka		33	33					17	17
Cs	100		100		67	67	50	33	83
Ho		67	67	33		33	17	33	50
Ba		67	67	67		67	33	33	67
Pa		33	33	33		33	17	17	33
Mz		67	67					33	33
Vg	33		33				33		33
Py		33	33					17	17
Valid cases:	3	3	3	3	3	3	6	6	6

farmers had planted trees for food production. Another said he had not planted trees because he did not own the land. Two respondents intended to plant coconuts in the coming year, and two said they would plant pines for building timber, lou'akau for handicraft material, and fruit trees for food.

TABLE 5.42

Percentages of six respondents to bush allotment interviews in Peri-urban Nuku'alofa giving various reasons for trees on agricultural land being a benefit and for protecting them during clearing of fallow and weeding

Reason/ Useful Product	Benefit from trees	Reason for protecting trees
Food	33	67
Fruit	17	
Dye	33	17
Fuelwood	50	33
Medicine	50	33
Soap	17	
Oil	17	
Building material	33	17
Crop supports	17	
Drink	17	
Handicraft	17	
Culinary	17	33
Rope	17	

Data on densities and crown areas of trees on the bush allotments surveyed are presented in Tables 5.44 and 5.45. On the two Peri-urban allotments for which full survey data were recorded, the most abundant tree was feta'anu; this was due to a relatively large stand of these trees on the fallow portion of one allotment, PU5. The next most frequently found tree species was koka, followed by tava, mango, and fau (Table 5.46). Unlike feta'anu these four species were significant on bush allotments in all study areas, but none were found on the PU5 allotment where feta'anu was dominant. The distinct difference of vegetation type between the two allotments was related to their locations. PU5 was sited on the western edge of Nuku'alofa close to the coast, while PU15 was situated inland some 5 km west of the town.

TABLE 5.43

Percentages of six respondents to bush allotment interviews in Peri-urban Nuku'alofa identifying fruit and non-fruit tree species on agricultural land as being of benefit or a nuisance, and tree species protected during the clearing of fallow and weeding

Species	Benefit	Nuisance During Clearing	Protect During Weeding	Protect
Fruit trees				
FEK	17			
KUA	33			
LEM			17	33
MAN	33		17	17
MEI	17		17	33
MOL	50		17	50
Py			17	17
TEL	17			
VII	17			
Total numbers of fruit species	7	0	5	5
Non-fruit trees				
AKV		17		
FAU	50			
FOU		17		
FTU	17			
KOK	50		17	17
LEP	17			
LOP	-	17		
MNG	17			
MSA	17			
NON	17			
OKE	17			
SIA	17			
SII			17	17
TAH	33	17		
TOI	17			
TUI	17			
Total numbers of non-fruit species	12	4	2	2
Total numbers of fruit and non-fruit species	19	4	7	7
Non-specific categories				
Fruit			33	17
Unidentified		17		
None		50	33	17

TABLE 5.44

Numbers and densities of coconut, fruit, and non-fruit trees on cultivated, fallow, and uncultivated sections of three bush allotments used by Peri-urban households

	PU2	PU5	PU15 [1.]	Totals
Cultivated Sections				
Numbers of trees				
Coconuts	nr	nr	nr	nr
Fruit trees	nr	0	33	33+nr
Non-fruit trees	nr	9	34	43+nr
Total numbers	nr	9+nr	67+nr	76+nr
Trees per hectare				
Coconuts	nr	nr	nr	nr
Fruit trees	nr	0	nr	nr
Non-fruit trees	nr	4	nr	nr
Total numbers	nr	4+nr	nr	nr
Fallow Sections				
Numbers of trees				
Coconuts	nr	nr	na	nr
Fruit trees	nr	0	na	nr
Non-fruit trees	15+nr	102	na	117+nr
Total numbers	15+nr	102+nr	na	117+nr
Trees per hectare				
Coconuts	nr	nr	na	nr
Fruit trees	nr	0	na	nr
Non-fruit trees	6+nr	36	na	22+nr
Total numbers	6+nr	36+nr	na	22+nr

Continued

TABLE 5.44 Continued

	PU2	PU5	PU15 [1]	Totals
Uncultivated Sections				
Numbers of trees				
Coconuts	nr	na	nr	nr
Fruit trees	nr	na	7	7+nr
Non-fruit trees	nr	na	21	21+nr
Total numbers	nr	na	28	28+nr
Trees per hectare				
Coconuts	nr	na	nr	nr
Fruit trees	nr	na	nr	nr
Non-fruit trees	nr	na	nr	nr
Total numbers	nr	na	nr	nr
Whole Allotment				
Numbers of trees				
Coconuts	nr	454	140+nr	594+nr
Fruit trees	nr	0	40	40+nr
Non-fruit trees	15+nr	111	54	180+nr
Total numbers	15+nr	565	234+nr	814+nr
Trees per hectare				
Coconuts	nr	91	93+nr	60+nr
Fruit trees	nr	0	27	4+nr
Non-fruit trees	4+nr	22	36	18+nr
Total numbers	4+nr	113	156+nr	83+nr

Notes: 1. Data for this allotment relate to the area surveyed (45 percent of the total allotment area).

TABLE 5.45

Crown areas of fruit and non-fruit trees over cultivated, fallow, and uncultivated sections of three bush allotments used by Peri-urban households

	PU2	PU5	PU15	Totals
Cultivated Sections				
Fruit - m^2	nr	0	1490	1490+nr
- % land area	nr	0.0	nr	nr
Non-fruit - m^2	nr	107	1371+nr	1478+nr
- % land area	nr	0.5	nr	nr
All trees - m^2	nr	107	2861+nr	2968+nr
- % land area	nr	0.5	nr	nr
Fallow Sections				
Fruit - m^2	nr	0	na	nr
- % land area	nr	0	na	nr
Non-fruit - m^2	nr	86+nr	na	86+nr
- % land area	nr	0.3+nr	na	0.2+nr
All trees - m^2	nr	86+nr	na	86+nr
- % land area	nr	0.3+nr	na	0.2+nr
Uncultivated Sections				
Fruit - m^2	nr	na	437	437+nr
- % land area	nr	na	nr	nr
Non-fruit - m^2	nr	na	1034	1034+nr
- % land area	nr	na	nr	nr
All trees - m^2	nr	na	1471	1471+nr
- % land area	nr	na	nr	nr
Whole Allotment				
Fruit - m^2	nr	0	1927	1927+nr
- % land area	nr	0	12.8	2.0+nr
Non-fruit - m^2	nr	193+nr	2404+nr	2597+nr
- % land area	nr	0.4+nr	16.0+nr	2.6+nr
All trees - m^2	nr	193+nr	4331+nr	4524+nr
- % land area	nr	0.4+nr	28.9+nr	4.6+nr

TABLE 5.46

Tree densities per hectare and crown areas as percentages of land area[1], for the eleven tree species most commonly found on two surveyed bush allotments used by Peri-urban interviewees

Rank	Species		Cultivated	Fallow	Uncult-ivated	Whole Allotment
1.	FET	per ha	2.3	32.0		15.1
		% area	0.3	5.0		2.3
2.	KOK	per ha	8.2		34.1	5.2
		% area	3.5		20.6	2.4
3.	TAV	per ha	3.7		13.6	2.3
		% area	1.0		11.1	0.8
4=	MAN	per ha	2.8		6.8	1.7
		% area	2.5		0.8	1.4
4=	FAU	per ha		3.9		1.7
		% area		nr		nr
6=	IFI	per ha	0.8		27.3	1.1
		% area	0.3		18.0	0.6
6=	TUI	per ha			47.7	1.1
		% area			8.5	0.2
8.	LOU	per ha	0.6		27.3	0.9
		% area	0.1		18.5	0.5
9.	MOL	per ha	1.4			0.8
		% area	0.2			0.1
10=	FOU	per ha			20.5	0.5
		% area			15.0	0.3
10=	TAH	per ha	0.3		13.6	0.5
		% area	0.1		8.0	0.3

Notes: 1. Density figures refer to trees recorded as having stems growing in the section under consideration; crown areas include overhanging foliage from trees rooted in adjacent sections.

Significance to fuelwood supply

For six of a total of thirteen respondents who collected fuelwood bush allotments were main collection sites. Four of these allotments belonged to the household concerned. Thirteen types of fuelwood were collected from bush allotments.

(b) Town allotments

Land allocation

Of fourteen interviewees asked to state the size of their household's town allotment twelve gave specific answers, one did not know, and one household was living on unallocated land which had not been sub-divided into allotments.

Soil

Soil quality on Peri-urban town allotments was very variable. Cowie (in preparation) showed eight soil type categories within the area included in the Peri-urban study area. The classifications given ranged from poor for cultivation other than coconuts to good for all crops. In general terms soils more susceptible to inundation by sea water were of poorer quality than those on higher land. More recent settlers who have made their homes on low-lying land were more likely to encounter serious soil limitations for growing crops on their town allotments.

Crop management

Of the nine interviewed households cultivating parts of their town allotments, four were growing traditional root crops. Other crops included plantain, bananas, papaya, passion fruit, sugar cane, edible hibiscus, and onions. All but one of fourteen responses said livestock were kept on the town allotments. The only four allotments with fruit trees were located on the higher land to the south-west of the town.

Trees on agricultural land

The only interviewee not to say that their town allotment trees were beneficial was the one whose allotment had no trees. Apart from food products, benefits given for trees included shelter, cultural and ornamental functions, medical products, and fuelwood. Thirteen of the interviewed households had planted a broad range of fruit and cultural trees, and eleven said they intended to plant trees. One respondent said the land was too poor to grow trees on.

Significance to fuelwood supply

Two Peri-urban households collected fuelwood from town allotments; for one they were the only collection site.

5.2.5.4 Commercial systems

(a) Commercial exchange of goods and services within the study area

None of the Peri-urban households interviewed paid to use land for growing crops, but one did pay a small amount for the right to collect fuelwood. Only two interviewees said they paid for vehicles to transport fuelwood they had collected, and none paid others to collect wood for them. One respondent bought fuelwood from another household in the same village and hired a minimoke to transport it.

(b) Commercial exchange outside the study area

One of the fifteen interviewees occasionally bought fuelwood at the Talamahu market in central Nuku'alofa and transported it home on a hired van. Only one of the fifteen household characteristics interviewees considered the general use of their bush allotments to be commercial cropping, but three of the farmers interviewed said they sold agricultural produce: bananas, root crops, and European vegetables. Nine households included wage or salary earners, and four obtained incomes from fishing. Only one household sometimes made copra. Just this one and one other sold whole coconuts to the Tonga Commodities Board.

(c) Support for commercial activities

Support services were similar to those available to other Tongatapu residents, but being closer to the sources of assistance might have given some advantage to Peri-urban households.

(d) Significance to fuelwood supply and consumption

The commercialisation of fuelwood within the town put some additional pressure on fuelwood resources used by Peri-urban residents, but of sixteen collection sites mentioned by wood sellers only two were within the Peri-urban study area. On the other hand, the greater use of non-wood domestic fuels in the town helped to reduce exploitation of fuelwood resources.

5.2.5.5 Social systems

(a) Demographic features

While total demographic details for the Peri-urban study area are not available it is clear that population growth on the outskirts of Nuku'alofa between 1976 and 1986 was the highest in the country. The census data have been presented in Chapter 2 (Section 2.4.3). In seven of the interviewed households the household head's home town was outside Tongatapu. They had lived on their current town allotments for between 2 and 54 years, with an average of 14.5 years. This showed at least equal stability as heads originating in Tongatapu whose average time on their current allotment was 10 years.

While the sex ratio throughout most of Nuku'alofa in 1986 was approximately even, in the new settlements of Popua and Tukutonga there were 446 males to 392 females, giving a ratio of 1.14 to 1. In the fifteen households interviewed there were 54 males to 52 females, and 60 adults to 46 children.

(b) Community facilities and services

In general terms a wider range of facilities was available in Peri-urban Nuku'alofa than in the rural villages, but there were significant exceptions. For example, Popua was not connected to the electricity grid, and sewage disposal was a potential health hazard in many low-lying areas. Transport services, in the form of buses, taxis, and minimokes, were plentiful, so that residents throughout the Peri-urban districts had ready access to the social, commercial, and government establishments in the town centre. With Nuku'alofa being the country's main shipping port ferries to the outer islands sailed from here.

Many Peri-urban villages had their own churches and primary schools, and small shops were abundant. Several secondary schools were located in Nuku'alofa as was the main Tongan campus of the University of the South Pacific. The independent 'Atenisi University was situated in Peri-urban Sopu on the western side of the town.

(c) Social characteristics

The social character of the various areas within Peri-urban Nuku'alofa varied considerably. The Peri-urban households closest to the central district were generally part of communities centred within the Urban area. In some sections the three central villages of Kolofo'ou, Kolomotu'a, and Ma'ufanga extended beyond their formal boundaries for some distance without creating new villages. In other cases, such as in low-lying Sopu, geographical factors distinguished sections of unbroken residential land from the Urban core. To the south of the town centre, Haveluloto had grown as a separate village from Nuku'alofa but by 1986 had become part of the town's continuous built-up area. Popua and Tukutonga grew as isolated communities which, although linked to the town by public transport had quite different social characteristics from the main town area. Tukutonga in particular had a distinct character due to the economic disadvantages which many of its residents endure. Most were squatters with no formal right to the land they occupied, who had been unable to obtain tenure over a town allotment. Many had moved to Nuku'alofa from outer islands. Due to the unofficial nature of much of the settlement the government had not invested in the provision of facilities. Popua had become an officially sanctioned village and in 1986 roads were being improved and areas of mangrove forest reclaimed to provide additional sub-divisions. The social coherence of the community could be expected to strengthen as amenities improve.

(d) Significance to fuelwood supply and consumption

Fuelwood supply in Peri-urban Nuku'alofa was influenced by limited access to bush allotments, a reflection of the high proportion of heads of household moving from outside Tongatapu. The low status of using open fires as cooking appliances in Nuku'alofa tended to discourage fuelwood consumption.

5.2.5.6 Fuelwood systems

(a) Sources

Two Peri-urban households bought fuelwood, one from the Talamahu market in central Nuku'alofa and one from other residents.

Bush allotments were the main fuelwood collection sites for six of the thirteen interviewed households which collected wood (Table 5.47). Coastal areas were major sources for three households, town allotments for one, a school's grounds for one, and the remaining two gathered their wood from unoccupied land. Distances to bush allotment collection sites ranged from 0.1 to 12.5 km with a mean of 7.9 km, while distances to coastal sites averaged just 0.9 km.

Four fruit tree species were collected on bush allotments along with five non-fruit species and three types of coconut residues. Seven non-fruit species supplied fuelwood from coastal sites. Only fau and feta'anu were collected from both bush allotments and coastal areas.

One of the two surveyed Peri-urban bush allotments was dominated by feta'anu but also supported a few fau trees which provided better quality fuelwood. This allotment was located close to the coast. The second Peri-urban allotment for which full data were recorded was located inland and supported a range of fruit and non-fruit trees among which koka and tava were most numerous.

(b) Harvesting, transport, and preparation

Collection frequency from bush allotments averaged 2.5 per month among the seven Peri-urban interviewees obtaining fuelwood from this source. None of the

TABLE 5.47

Percentages of fifteen fuelwood using households interviewed in Peri-urban Nuku'alofa collecting various types of wood from five categories of sources

Species Code	Bush	Town	Coast	Road-sides	Copra dryer	Totals
Fruit Trees						
KUA	13					13
MAN	7					7
MOL	13					13
TAV	13					13
All Fruit	27					27
Non-Fruit Trees						
FAU	13		13			27
FET	7		27			33
HAN			13			13
KOK	13					13
LEK			13			13
SIA	13					13
TAH	20					20
TOA			13			13
TON		7	13			20
VOL			7			7
All Non-Fruit						
Coconut Fuels						
H&S	7					7
HUS	7					7
PAL	7					7
All Coconut						
Other Types						
Wood	7					7
Overall	53	7	33	0	0	87
Valid cases:						15

bush allotments were used by respondents for commercial farming. Collections from coastal areas were more frequent, with a mean of 7.8 per month. Estimates of time spent on collection ranged from 1 to 20 hours, with a mean of 8.8 hours. Four interviewees said more time was spent collecting in 1986 than in 1985, and a similar number said they spent more time than in 1981.

One household cut live wood for fuel by lopping branches from mangrove trees. Only three respondents said they killed trees. Cane knives and axes were the most popular cutting equipment with only one household occasionally using a chainsaw. Wheeled transport was less commonly used by Peri-urban households than in 'Ahau. Seven respondents said their households carried wood by hand, and only one of these had an alternative form of transport. Four households used vans, one a horse, one a horse and cart, and one a truck. Use of the truck cost T$10 per load and one household paid either T$4 or T$6 for a van depending on the distance involved. All fuelwood was stored on town allotments except for one household occasionally storing some uncovered on their bush allotment. Only four households kept wood indoors but seven covered their wood outdoors.

Fuelwood bought from the market cost T$2.50 per bundle and was transported by minimoke to a house in Sopu at a cost of T$1.00 per load. The one household that bought standing dead trees from neighbours paid T$2 per tree and T$6 to T$8 per load for van transport. In both cases the bought wood needed some preparation before it could be burnt.

Five households brought coconut fuels direct from their bush allotments and one household collected from land owned by the Tongan Electric Power Board. Six respondents said they used residues from coconuts used in cooking and four burned the husks and shells left over from feeding pigs. One household sometimes obtained residues from a copra dryer. Five households bought coconut fuels from the Tonga Commodities Board, paying between T$1 and T$3 per van load. Four households paid T$2 per load for transport but the fifth paid T$9. Two respondents said they had to dry coconut fuel bought from the Commodities Board.

(c) Consumption patterns

Eleven Peri-urban households used the open fire as their main cooking appliance but two did not use open fires at all. All households used 'umus: eight earth 'umus and eight drum 'umus. Six households used kerosene stoves and two used gas stoves. The average number of people cooked for was 6.9 on weekdays and 7.6 on Sundays.

Nine of the fifteen Peri-urban households included coconut husk or shell among their five most important fuelwood types. The most common non-coconut type, listed by five respondents, was feta'anu (*Excoecaria agallocha*), a coastal species which was still relatively abundant because its wood was considered to be a poorer quality fuel. Four households listed fau and kuava, and three hangale, koka, sialemohemohe, and tavahi. A total of twelve fuelwood types were mentioned as best open fire fuels with sialemohemohe being most popular with three votes. Sialemohemohe was also favoured as the best fuel for the 'umu ahead of fifteen other fuelwood types.

Eleven respondents named a total of thirteen species which were no longer available to them. Most frequently mentioned, by three households, were toi and koka. Hangale, ifi, moli, and lekileki were nominated by two households. Nine of the unobtainable species would have been preferred to available fuelwood types.

Estimates of average annual fuelwood consumption indicated Peri-urban use of coconut fuel, at 1.6 tonnes per household, was less than in any other study area. Consumption of non-coconut wood at 5.1 tonnes per household per year was 20 percent less than the Tongatapu average. Of the eleven interviewees who said they used more fuelwood at particular times of year nine attributed this to preparing feasts.

5.2.6 Urban Nuku'alofa

5.2.6.1 Natural systems

(a) Physical aspects

The town is located on the northern coast of central Tongatapu, wedged between the seaward coral reef to the north and the inland lagoon to the south. While less than a quarter of its land area is elevated above the 5 metre contour, Urban Nuku'alofa is less threatened by flooding than many of the Peri-urban settlements surrounding it. The town's location on the north coast of Tongatapu means it is exposed to the occasional cyclonic winds which come from the north and north-east, but it is somewhat sheltered from the predominant south-easterlies.

(b) Biological aspects

Within the urban area there are no significant remnants of the original plant communities which would have covered this coastal zone. In 1986 the central business district had only a sprinkling of individual trees. Some amenity trees were maintained on roadsides and in public open spaces but the majority of vegetation in Urban Nuku'alofa existed outside the central business district on residential land and in school and church grounds.

(c) Cultural aspects

Having cleared the coastal vegetation which would have provided protection from inundation to inland settlements, artificial means of holding back the sea had to be utilised. In 1986 the sea wall along the length of Nuku'alofa's waterfront was being reconstructed in order to provide more effective protection and to allow the upgrading of Vuna Road. While this improved the physical environment of the town in as much as it reduced the impacts of some natural phenomena, it eliminated any possibility of natural plant communities becoming re-established on the shore.

The management of the two main public open spaces within central Nuku'alofa included the maintenance and planting of trees for amenity purposes. Apart from their purely aesthetic value such trees were appreciated for the role they play in ameliorating climatic extremes. In summer atmospheric conditions in central Nuku'alofa are often hot, humid, and dusty. Any vegetation, particularly shade trees, was welcomed by local people as it provided more comfortable conditions for pedestrians within the built-up area. While the Tongan government appeared to realise that more trees would improve the quality of life of townspeople, projects increasing economic prosperity were seen to be of overriding importance. Some planted trees in Nuku'alofa were significant landmarks; most outstanding of these were the Norfolk Island pines in the grounds of the Royal Palace, and rain trees (*Albizia saman*, previously known as *Samanea saman*) outside the Post Office and in school grounds.

Away from the central business district most trees were grown on residential town allotments to provide fruit and other products of particular value to the household. Human management has thus changed the character of vegetation within the town from the natural coastal communities to scattered individual and small groups of amenity and fruit trees.

(d) Significance to fuelwood supply

Of a total of thirty-six fuelwood collection sites mentioned by Urban interviewees eight were within the town area; six households collected from town allotments, one from an adjacent bush allotment, and one from roadsides. All estimates of distance to other sites were 2 kilometres or more. The relative lack of trees in Nuku'alofa appears therefore to lead to fuelwood users having to travel further to collect wood than rural villagers need to. This shortage of readily available supplies of wood has led to the commercialisation of fuelwood. Nine of the fifteen Urban interviewees said they bought wood and eleven bought coconut husk and shell for use as fuel.

5.2.6.2 Domestic systems

(a) Household facilities

Land

The one Urban household interviewed whose town allotment was not registered lived in a recently cleared area of bush. All those in established residential areas occupied allotments registered with the government. While three other town allotments were not registered in the name of the head of the household it can be assumed that tenure for those included in the Urban survey was more secure than for those in Peri-urban Nuku'alofa whose allotments were unregistered. Heads of seven of the households visited had lived on their current town allotments for more than forty years. In contrast, five had occupied their allotments for three years or less.

Only one interviewee claimed to have no access to any bush allotment; of the other fourteen households seven had access to one bush allotment and the other seven had access to two allotments each. Distances to the fourteen allotments for which estimates were given averaged 7.3 kilometres. Three were about 2 kilometres from the household's home while the furthest was said to be 13 kilometres away. All estimates of bush allotment area gave the regulation size of 8 acres (3.3 hectares).

Buildings

All but two of the fifteen Urban households interviewed had European or modified European houses constructed of dressed timber or concrete block walls, sheet metal roofs, and wooden or concrete floors. All but one had glass windows. One of the two modified Tongan style houses was constructed of similar materials, but the other had thatch walls, a thatched roof repaired with plastic sheeting, an earth floor, and no windows. Five households' main buildings included a kitchen and two households used part of the main living area for culinary activities. Nine households had separate kitchen buildings.

Four interviewees said they had made substantive alterations to their homes over the previous year, including in one case completely rebuilding the main house. Nine said they had plans for alterations, mostly to extend the main building.

Water and electricity

Only six of the fifteen Urban households interviewed had water piped to their main house; each of these had either their kitchen or washroom in that building. All fifteen households had readily accessible external standpipes although for one household this was on a neighbour's allotment; this household had a well on their own land. Seven respondents said they had rainwater storage tanks. Thirteen households were connected to the electricity grid.

Cooking facilities

Main cooking appliances among the interviewed households were: the open fire for eleven households, gas stoves for three, and an electric stove for one household. Each of the gas and electric stove owners also used an open fire as a supplementary appliance. The most common type of non-wood burning appliance was the kerosene stove, used by nine households. Gas and charcoal stoves were used as supplementary devices by one household each. Ten households used the traditional earth 'umu while six used the drum 'umu. The proportion of non-wood burning appliances used by interviewed households in Urban Nuku'alofa was the highest of any of the six study areas (Table 5.48).

Transport and communications

Six of the fifteen Urban interviewees said their households owned no form of transport. Six households owned bicycles but one was broken. With two households owning cars, one a minibus, one a van, and one a minimoke, the sample households in Urban Nuku'alofa owned more motor vehicles than in any other study area. Two of these motor vehicle owning households never paid for other forms of transport. Eleven households used public buses, and thirteen paid for taxis, vans, minimokes, or trucks.

TABLE 5.48

Numbers and percentages of interviewed households using six types of cooking appliances in Urban Nuku'alofa in 1986 by appliance location

Appliance type	**Appliance location**							
	Main building		Separate kitchen		External		Totals	
Open fire			9	60%	6	40%	15	100%
Earth 'umu			1	7%	8	53%	9	60%
Drum 'umu			2	13%	4	27%	6	40%
Charcoal stove	1	7%					1	7%
Kerosene stove	6	40%	3	20%			9	60%
Gas stove	3	20%	1	7%			4	27%
Electric stove	1	7%					1	7%
Electric toaster	1	7%					1	7%
Electric frypan	2	13%					2	13%
Valid cases:							15	100%

Average number of appliances per household: 3.2

Non-wood burning appliances as percentage of total: 35.4%

(b) Members of the household

Age and sex characteristics

Within the Urban households interviewed the ratio of males to females was 0.65:1, and of children to adults was 0.87:1. The average number of members per household was 7.6. 1986 census data for the three Urban villages Kolofo'ou, Ma'ufanga, and Kolomotu'a give average household size as 6.6 members and the male to female ratio as 0.98:1.

Occupations

Of sixteen different income earning occupations among members of the fifteen households interviewed five were followed by more than one person. Seven household members worked as clerks, three were drivers, three earned money from handicrafts, two were construction workers, and two farmers. Other occupations included labourer, factory worker, secretary, waitress, and mechanical engineer.

Income

Only two households earned less than T$1000 per year; nine earned between T$2000 and T$5000; no household had an income in excess of T$8000. Remittances received by eleven households ranged from T$50 to more than T$1000 per year.

(c) Domestic activities

Food and drink preparation

Compared to the pattern in Peri-urban households the number of meals cooked per day in the Urban households interviewed varied little between weekdays and weekends. On average, 2.3 meals were cooked daily Monday to Friday, 2.2 on Saturday, and 2.1 on Sunday. The haka cooking method was universally used among interviewed households. With one exception households using kerosene and gas stoves said the stoves cooked a haka quicker than an open fire. Only one interviewee said they never used an 'umu but two others cooked in the 'umu only occasionally. Frying, boiling, and roasting were regularly used by thirteen, eleven, and ten households respectively. Five households had facilities for baking and six said they would like to be able to cook that way. Three respondents said they regularly used an electric toaster.

Handicrafts

Having three households in the sample of fifteen gaining monetary income from handicrafts suggests that in some households working on handicrafts was an important activity. Eleven households heated water to boil pandanus leaves, indicating handicraft activities were carried out in many more households than just those for whom it was of commercial value.

Livestock management

Thirteen of the fifteen Urban households kept livestock on their town allotments; nine had pigs, nine had chicken, and one kept goats. All but three of these grew food crops which would need protection from the animals.

Gardening

Thirteen interviewees said their town allotments supported some food plants; in two cases this was fruit trees but in all others short-term crops such as bananas were grown.

Collecting firewood

Estimates of time taken to collect firewood ranged from half an hour to fifty-six hours per month. One household used wood so rarely that no meaningful information could be given. Of fourteen responses ten included adult male members of the household as collectors. Men from outside the household collected for six interviewees; adult females were included in four responses, and children in four. Nine of twelve respondents said they spent more time collecting wood in 1986 than in 1981, and six spent more time than in 1985. Ten households paid for transport to bring fuelwood home. Estimates of amounts paid ranged from 50 cents to more than T$20 per month. Of the nine Urban households who bought firewood eight got it from the Talamahu market in central Nuku'alofa. Frequency of purchase ranged from once a week to once a year. All households buying wood used vans, minimokes, or trucks to transport it. As purchasing firewood could be combined with buying food at the market the additional time involved in this method of obtaining fuelwood was in most cases negligible.

Transporting food supplies

For thirteen of the fourteen households which had access to bush allotments the main use of the allotment was subsistence food. The remaining household used theirs mainly for commercial crops. This suggests that a high proportion of the food requirements of the household would be brought to town from the bush allotment. The amount of time and expense involved in transporting food would depend on the distance to the bush allotment and the method of transport available to the household. If public buses were used there could well be a long walk between the bus route and the allotment so it would appear that those households who could afford to preferred to hire motor vehicles. Using typical data from the interview survey an allotment holder might pay T$5 for the use of a van to collect produce from an allotment 9 kilometres from town.

(d) Energy consumption

Electricity

All thirteen of the Urban households connected to the electricity grid used electric lights and electric irons. Seven used electric jugs to heat water, and a total of three used electric cooking appliances: stove, frying pan, and toaster.

Kerosene

Kerosene was the only lighting fuel used by the two Urban households who did not have electricity, and was a supplementary lighting fuel for seven others. Nine of the fifteen households interviewed used kerosene cooking stoves.

Gas

With three households using gas stoves as their main cooking appliances and one as a supplementary appliance, a higher proportion of interviewed Urban households used gas than in any other study area.

Woodfuels

As in all other study areas the most important use of fuelwood in Urban Nuku'alofa was for cooking. All households interviewed used at least one type of wood burning cooking appliance on a regular basis. One household had no other use for fuelwood, but twelve used it to make coconut oil, eleven to boil pandanus leaves, two to repel insects, and one household burnt wood to dry copra.

5.2.6.3 Cultivated systems

(a) Bush allotments

Land allocation

Five of the six Urban Nuku'alofa bush allotment interview respondents had access to two bush allotments, in contrast to the Peri-urban respondents who used only one allotment each. Only three of the eleven allotments used by the Urban households interviewed were within 3 kilometres of the respondents' homes. Four allotments were located more than 10 kilometres away from Nuku'alofa. Two of these four were registered by a member of the interviewee's household. While it is normal policy for the government to allocate land as close to the applicant's home village as possible, there is not enough land adjacent to Nuku'alofa to provide for all residents. The locations of surveyed bush allotments held by Urban households are shown in Figure 5.12.

All but one of the eleven allotments used by Urban respondents were of the regulation 8 acres (3.3 hectares) size. The average land area accessible to the Urban households interviewed was 14.3 acres (5.8 hectares), 5.5 acres (2.2 hectares) more than the Peri-urban average, and marginally larger than the rural average of 14.1 acres (5.7 hectares). The average area used by Urban respondents, 12.6 acres (5.1 hectares) was the largest of all study areas. The areas of the three surveyed bush allotments ranged from 7.5 to 8.7 acres (3.0 to 3.5 hectares), with between 48 and 85 percent of their total areas cultivated (Table 5.49).

Soil

The broad spread across the island of the agricultural allotments used by Urban Nuku'alofa households meant that the soil conditions encountered were varied. However, as the soil types which cover the majority of the island are rated as good for food crops, most allotments provided fertile conditions for cultivation. Seven of the eleven allotments included in the Urban survey were said to be 'very fertile'; two were classed as 'fertile'; and two described as 'not very fertile'.

TABLE 5.49

Summary of areas of cultivated, fallow, and uncultivated sections of three surveyed bush allotments used by Urban Nuku'alofa households, in m^2 and as percentages of whole allotment areas

Allotment:	U5	U14	U15	Totals
Cultivated Sections				
- m^2	26 000	20 100	16 900	63 000
- % whole	85	65	48	65
Fallow Sections				
- m^2	3500	9500	17 100	30 100
- % whole	11	31	49	31
Uncultivated Sections				
- m^2	900	1500	1200	3600
- % whole	3	5	4	4
Whole Allotment				
- m^2	30 500	31 100	35 200	96 800
- % whole	100	100	100	100

All six bush allotment interview respondents said they had been able to improve soil fertility, by grazing cattle on the land, by leaving the land fallow, by adding fertilizers, or by growing leguminous plants.

Agricultural land management

All six Urban respondents said they managed their bush allotments primarily for non-commercial production, and all used a crop rotation system. On currently cropped allotments the average proportion of land cultivated was 65 percent: 1.7 ha (4.3 acres) of 2.7 ha (6.7 acres). Crops had not been planted on three allotments, so that overall 46 percent of the land available to interviewees was being cultivated at the time of the interviews.

As in the Peri-urban study area the commonest main crop was cassava (Table 5.50). Yams, taro, and plantain were each grown as main crops on three of the eight cultivated allotments. Plantain, taro, and edible hibiscus (pele) were the most popular supplementary crops. Two allotments were said to support only two crops each, but the average number of crops per allotment was 4.9.

As in 'Ahau, yams were grown only in the first year of the crop rotation, usually accompanied by giant taro (kape) and plantain. All but one of the eight allotments grew American taro (talo futuna) in the second year. In four cases the land was left fallow in the third year. At 1.1 years the average fallow period on Urban households' allotments was the shortest of any study area.

Only one of the six Urban farmers interviewed did not use a tractor and plough. All used the traditional digging spade and hoe, and one used a mechanical cultivator. All said that hoeing was their only means of controlling weeds, but three used chemical sprays to reduce the impacts of pests and diseases. The numbers of people working on the allotments, from three to seven, showed less variation than in other study areas. One allotment was worked by a cooperative group and one had an employed caretaker; all other workers were members of the households or their families.

Yams and American taro were each specified by three households as being most important products; two responses gave all produce as being 'most important';

and one interviewee said cassava was most important. Only two of the six respondents sold agricultural products, and only two sold whole coconuts to the Tonga Commodities Board. None made copra.

TABLE 5.50

Percentages of bush allotments used by Urban Nuku'alofa respondents to bush allotment interviews on which various types of crops were grown, by management technique

Crop Type	Crop Rotation			No Rotation			All Allotments		
	Main Crop	Supp. Crop	O'all	Main Crop	Supp. Crop	O'all	Main Crop	Supp. Crop	O'all
Ym	38	25	63				38	25	63
T	38	38	75				38	38	75
Ka		25	25					25	25
Cs	75	13	88				75	13	88
Ho	38	50	88				38	50	88
Ba		25	25					25	25
Pa		25	25					25	25
Sc		13	13					13	13
Hi		13	13					13	13
Pe		38	38					38	38
Sp	13	13	25				13	13	25
Valid cases:	8	8	8	0	0	0	8	8	8

Trees on agricultural land

One of the eleven allotments included in the Urban survey was said to have no trees except coconuts. Respondents listed between four and ten tree species as being present on the other ten allotments. Only two of the six interviewees said that all trees were beneficial; the others specified various fruit trees and koka, fau, tavahi, and tuitui. As in most other study areas food was the main reason for perceiving trees as beneficial (Table 5.51). Only one interviewee complained that some trees were a nuisance; the plants claimed to make weeding difficult were talatala, a shrub or small tree, and pakaka, a herb (Table 5.52). Respondents' lists of self-regenerating trees included many fruit trees but also trees meeting culturally important requirements such as producing dyes, handicraft materials, and traditional medicines. Comments about the influence of trees on crops were weighted marginally towards beneficial rather than detrimental effects. Four respondents spoke in favour of trees, three saying they provided windbreaks and

TABLE 5.51

Percentages of six respondents to bush allotment interviews in Urban Nuku'alofa giving various reasons for trees on agricultural land being a benefit and for protecting them during clearing of fallow and weeding

Reason/ Useful Product	Benefit from trees	Reason for protecting trees
Food	100	100
Fruit		
Dye	50	33
Fuelwood	67	17
Medicine	17	17
Oil	17	
Building material	50	17
Fencing	17	
Handicraft		17
Cultural decoration		17
Rope	17	
Numerous		33

two stating they helped to improve soil fertility. One interviewee said trees blocked the sun, one thought big trees took stored energy out of the soil, and a third complained that tree roots got in the way of crops. Only one respondent had plans to destroy any trees, to provide material for building fences.

Four of the six Urban interviewees had planted trees, between 1960 and 1982. Most commonly planted were coconut trees for food and income. The only other types planted were mango, and mei, both for fruit, and lou'akau for handicraft material. Only two respondents intended to plant trees in the coming year. Both said they would plant coconuts; one would also plant ifi, and the other intended to plant timber trees. One of the three surveyed allotments (U5) had significantly lower numbers and crown areas of trees on cultivated and fallow sections than did the other two (Tables 5.53 and 5.54).

Detailed surveys of two bush allotments belonging to Urban households showed koka to be the tree most frequently found on both cultivated and fallow land (Table 5.55). Overall fau was the next most prolific species, with a density of 2.6 compared to koka's 5.6 per hectare. Somewhat surprisingly, mango and mei, the two fruit tree species most commonly encountered on rural study area allotments, were present in lower numbers than tava and avoka. Mango and tava were recorded on all three allotments, as were koka and fau. Avoka and tuitui were found on two allotments each, and ten other species were present on one allotment each.

Significance to fuelwood supply

Of the fourteen interviewed households who collected fuelwood, ten gave one of their own bush allotments as their most important collection site and three cited an allotment belonging to another household. Overall, twenty-one of the thirty-eight collection sites mentioned were bush allotments. These allotments yielded twenty-four different types of fuelwood.

TABLE 5.52

Percentages of six respondents to bush allotment interviews in Urban Nuku'alofa identifying fruit and non-fruit tree species on agricultural land as being of benefit or a nuisance, and tree species protected during the clearing of fallow and weeding

Species	Benefit	Nuisance	Protect During Clearing	Protect During Weeding
Fruit trees				
AVO	33		17	
FEK	17			
IFI	50		17	17
KUA	33			
MAN	50		17	
MEI	33		17	
MOL	67		50	50
Py				33
TAV	17			
TEL			17	17
VII	17			
Total numbers of fruit species	9	0	6	4
Non-fruit trees				
FAU	33			17
HEH			17	17
HEI			17	
Hi				17
KOK	67		33	33
LOU	17			
MOO	17			
PAK		17		
SII			33	33
TAH	67			17
TAK			17	17
TAL		17		
TEV			17	
TOI	17			
TON	17			
TUI	17			
UHI	17			
Total numbers of non-fruit species	9	2	6	7
Total numbers of fruit and non-fruit species	18	2	12	11
Non-specific categories				
Fruit	17		33	
Medicinal			17	17
Others for fuel	17			
None		83		

TABLE 5.53

Numbers and densities of coconut, fruit, and non-fruit trees on cultivated, fallow, and uncultivated sections of three bush allotments used by Urban Nuku'alofa households

	U5	U14	U15	Totals
Cultivated Sections				
<u>Numbers of trees</u>				
Coconuts	nr	258	nr	258+nr
Fruit trees	5	15	1	21
Non-fruit trees	5	19	28	52
Total numbers	10+nr	292	29+nr	331+nr
<u>Trees per hectare</u>				
Coconuts	nr	128	nr	41+nr
Fruit trees	2	7	1	3
Non-fruit trees	2	9	17	8
Total numbers	4+nr	145	17+nr	53+nr
Fallow Sections				
<u>Numbers of trees</u>				
Coconuts	nr	112+nr	nr	112+nr
Fruit trees	1	7	10	18
Non-fruit trees	1	14	39	54
Total numbers	2+nr	133+nr	49+nr	184+nr
<u>Trees per hectare</u>				
Coconuts	nr	118+nr	nr	37
Fruit trees	3	7	6	6
Non-fruit trees	3	15	23	18
Total numbers	6+nr	140+nr	29+nr	61+nr

Continued

TABLE 5.53 Continued

	U5	U14	U15	Totals
Uncultivated Sections				
Numbers of trees				
Coconuts	nr	5	nr	5+nr
Fruit trees	2	2	0	4
Non-fruit trees	1	0	0	1
Total numbers	3+nr	7	nr	10+nr
Trees per hectare				
Coconuts	nr	34	nr	14
Fruit trees	21	14	0	11
Non-fruit trees	11	0	0	3
Total numbers	32+nr	48	nr	28+nr
Whole Allotment				
Numbers of trees				
Coconuts	204	375+nr	197	776+nr
Fruit trees	8	24	11	43
Non-fruit trees	7	33	67	107
Total numbers	219	432+nr	275	926+nr
Trees per hectare				
Coconuts	67	121+nr	56	80+nr
Fruit trees	3	8	3	4
Non-fruit trees	2	11	19	11
Total numbers	72	139+nr	78	96+nr

TABLE 5.54

Crown areas of fruit and non-fruit trees over cultivated, fallow, and uncultivated sections of three bush allotments used by Urban Nuku'alofa households

	U5	U14	U15	Totals
Cultivated Sections				
Fruit - m^2	243	470	40	753
- % land area	0.9	2.3	0.2	1.2
Non-fruit - m^2	312	461	541	1314
- % land area	1.2	2.3	3.2	2.1
All trees - m^2	555	931	581	2067
- % land area	2.1	4.6	3.4	3.3
Fallow Sections				
Fruit - m^2	45	418	215	678
- % land area	1.3	4.4	1.3	2.3
Non-fruit - m^2	15	384	542+nr	941+nr
- % land area	0.4	4.0	3.2+nr	3.1+nr
All trees - m^2	60	801	757+nr	1618+nr
- % land area	1.7	8.4	4.4+nr	5.4+nr
Uncultivated Sections				
Fruit - m^2	107	80	0	187
- % land area	11.3	5.5	0	5.1
Non-fruit - m^2	22	5	23	50
- % land area	2.3	0.3	1.9	1.4
All trees - m^2	129	85	23	237
- % land area	13.7	5.8	1.9	6.5
Whole Allotment				
Fruit - m^2	395	967	255	1617
- % land area	1.3	3.1	0.7	1.7
Non-fruit - m^2	349	850	1106+nr	2304+nr
- % land area	1.1	2.7	3.1+nr	2.4+nr
All trees - m^2	744	1817	1360+nr	3922+nr
- % land area	2.4	5.9	3.9+nr	4.1+nr

TABLE 5.55

Tree densities per hectare and crown areas as percentages of land area[1.], for the ten tree species most commonly found on three surveyed bush allotments used by Urban interviewees

Rank	Species		Cultivated	Fallow	Uncult-ivated	Whole Allotment
1.	KOK	per ha	4.4	8.3	2.8	5.6
		% area	0.8	2.0	1.2	1.3
2.	FAU	per ha	2.4	3.3		2.6
		% area	0.8	0.8		0.8
3=	TAV	per ha	1.0	2.7	2.8	1.5
		% area	0.4	0.6	0.4	0.5
3=	TUI	per ha	0.2	4.6		1.5
		% area	<0.1	0.3		0.1
5.	AVO	per ha	0.5	1.7	5.5	1.0
		% area	0.1	0.8	1.4	0.4
6=	MAN	per ha	0.6	1.0	2.8	0.8
		% area	0.2	0.4	3.1	0.4
6=	MEI	per ha	1.1	0.3	0.0	0.8
		% area	0.4	0.3	0.2	0.4
8=	LOU	per ha		1.0		0.3
		% area		0.1		<0.1
8=	NGA	per ha	0.5		0.0	0.3
		% area	0.1		0.1	<0.1
8=	NON	per ha	0.3	0.3		0.3
		% area	0.1	<0.1		0.1

Notes: 1. Density figures refer to trees recorded as having stems growing in the section under consideration; crown areas include overhanging foliage from trees rooted in adjacent sections.

(b) Town allotments

Land allocation

Seven of fifteen interviewees offered an estimate of the size of their town allotment, with a median value of 750 m^2 (30 perches).

Soil

Soil types in Urban Nuku'alofa included Nuku'alofa and Sopu sands and Vaini clay. Assessments of quality for growing food crops have been given as poor or fair for the Nuku'alofa and Sopu soils and good for Vaini clay (Cowie, in preparation).

Crop management

Ten of fifteen households interviewed grew bananas or plantain on their town allotments, but only two grew root crops. Eight households obtained food products from trees on their town allotments.

Trees on agricultural land

All interviewees thought the trees on their town allotments were beneficial, mostly for the food they produced, but also for their decorative value, for medicinal and cultural purposes, for shelter and shade. Five respondents gave fuelwood as a benefit of town trees. Twelve households had planted trees over the previous thirty years. A total of twenty-four species were mentioned. The eleven interviewees who said they intended to plant trees in the future wanted to plant species ranging from the ubiquitous fruit trees: mango, mei, and tava, to cultural trees which were becoming scarce.

Significance to fuelwood supply

Six households collected a wide variety of fuelwood types from town allotments. In each case this source of wood was supplementary to bush allotments

5.2.6.4 Commercial systems

(a) Commercial exchange of goods and services within the study area

The Urban Nuku'alofa study area included the Kingdom's main shopping district and largest fruit, vegetable, and handicraft market. It also contained a high proportion of the government offices and many other of Tonga's large employers. The volume of commercial exchange of goods and services was higher here than anywhere else on the island.

Participation in paid employment was higher here than in any other study area. Only two of the fifteen interviewed households did not include a wage or salary earner. The head of one of these two households was a retired public servant, and the other household earned an annual income in excess of T$1000 from commercial farming. This household was the only one to describe the general use of its bush allotment as commercial production. Only the two households that owned passenger vehicles did not pay for transport by bus or taxi. Seven interviewees said they hired vans or trucks. One household paid T$30 to T$45 per year for the right to collect fuelwood from a bush allotment, but none said they paid for land for crop production. Two households had others help them with fuelwood collection; one paid with food, the other with cash. Ten interviewees said their households paid between 50 cents and T$20 per month for vehicles to transport collected fuelwood. Of nine households buying fuelwood eight purchased it from woodsellers at Talamahu market. Two regular purchasers said they did not pay for transport; others reported transport costs of T$1 to T$2 per load.

(b) Commercial exchange outside the study area

One of the nine households buying fuelwood purchased it from villagers living in the south-east corner of the island. One respondent said the cost of transport was included in the price of the truckload of wood.

Two of the fifteen Urban households interviewed made copra. Two of the six farmers interviewed said they sold whole coconuts to the Tonga Commodities Board, and two sold other agricultural produce.

At least one of the wage earners in the interviewed households worked outside the Urban study area, at the desiccated coconut factory which was situated at Peri-urban Haveluloto.

(c) Support for commercial activities

The general financial support discussed in the section on 'Ahau applied also to Urban Nuku'alofa, but because of their greater involvement in commercial transactions and higher rate of formal employment the average household in Urban Nuku'alofa was likely to have access to more sources of financial assistance than the average rural household. Personal contact is important in Tongan society and advice from friends and colleagues would have been very valuable.

(d) Significance to fuelwood supply and consumption

The recent population growth in Nuku'alofa had been largely due to the attraction of commercial activities in the town. The subsequent increase in residential land use had led to severe reductions in the local availability of fuelwood. In light of growing difficulties with obtaining wood supplies a relatively high proportion of Urban residents had adopted non-wood fuels for domestic purposes. Fuelwood itself had become a commercial commodity, the supply of which in 1986 was providing a livelihood for at least six woodsellers. The market for fuelwood in Urban Nuku'alofa was sustained largely by the desire of householders to use the traditional '<u>umu</u> to cook their main Sunday meal.

5.2.6.5 Social systems

(a) Demographic features

The total population of the three villages making up central Nuku'alofa rose by 16.1 percent between 1976 and 1986 from 18 312 to 21 265, while average household size dropped from 6.73 to 6.58. Variation between male and female numbers was less than 2 percent in both censal years. Given that the greatest population growth occurred in the Peri-urban sections of the town, the increase in the Urban study area must have been less than 16 percent but actual data are not available.

The interview survey sample of fifteen households contained 45 males and 69 females. This imbalance occurred in numbers of children, 19 to 34, as well as adults, 26 male to 35 female. Nine heads of household gave Nuku'alofa as their home town, with three coming from Vava'u, two from Ha'apai, and one from 'Eua. Heads of household originating in Nuku'alofa had lived on their present town allotments for an average 33.6 years, more than twice the average time of 16 years for those coming from the outer islands.

(b) Community facilities and services

Urban Nuku'alofa residents had easy access to a full range of domestic, commercial, church, and government facilities. Reticulated electricity and water were available throughout the Urban study area, as were telephones. A comprehensive range of goods was on offer in Nuku'alofa shops and in the government run Talamahu market. Service industries ranging from household electricians and plumbers to banks and insurance agencies were represented in the town. Medical and pharmaceutical facilities were more readily accessible in Nuku'alofa than in most other parts of Tongatapu. Entertainment amenities were relatively numerous and varied, including hotels, night clubs, cinemas, and restaurants. Sporting facilities were mainly located outside the central district but were generally within easy reach of the town. Travel agencies and airline offices were mostly situated in central Nuku'alofa.

Transport services were more readily available in Urban Nuku'alofa than in any other part of the Kingdom. The main bus station and taxi ranks were located beside the market in the central business district. The main offices of all Government Ministries were situated within the Urban study area, as were the main police station, the Parliament building, and the Royal Palace. All the major churches were represented in the Urban study area and many had their main church buildings there.

(c) Social characteristics

As elsewhere in Tonga the social structure of Urban Nuku'alofa was characterised by aspects of the traditional chiefly hierarchy, status accorded to occupations and activities. With Nuku'alofa being the primary location for Western-style economic development, attitudes here appeared to be more strongly focused on attainment of monetary wealth. However, rather than work against the traditional structure this has largely reinforced the supremacy of the royal and noble families. Those who already had money and access to land and resources found it easier to increase their wealth than did commoners. Those lacking material wealth and social privileges could most readily increase their financial resources by working overseas. In 1986 commercial enterprises being initiated in Nuku'alofa were funded by earnings from temporary employment overseas. Within Nuku'alofa the best jobs paid considerably less than equivalent positions in New Zealand, Australia, or the USA, but the social status attached to salaried employment, particularly with the government, was high.

5.2.6.6 Fuelwood systems

(a) Sources

All but one of the Urban households interviewed purchased either wood or coconut residues for use as fuel. Eight households bought wood from the Talamahu market. One of these and one other household bought wood from other sources, and six households did not buy any wood. A total of eleven households bought coconut fuels from the Tonga Commodities Board and three of these also bought offcut slabs of coconut stems from sawmills.

Of the fourteen households who collected fuelwood thirteen gave bush allotments as their main collection sites and one said the mangrove forest was most important. Of thirty-eight sites mentioned twenty-one were bush allotments, seven town allotments, and two coastal areas. One respondent said waste wood was brought over from a sawmill on 'Eua (Table 5.56).

The average distance to bush allotment collection sites was 7.4 km with distances ranging from 2 to 16 km. The one coastal site for which a distance was suggested was approximately 27 kilometres from the home. All town allotment sites were less than 1 km from the home with a mean distance of 0.29 km.

TABLE 5.56

Percentages of fifteen fuelwood using households interviewed in Urban Nuku'alofa collecting various types of wood from five categories of sources

Species Code	Bush	Town	Coast	Road-sides	Copra dryer	Sawmill	Totals
Fruit Trees							
IFI	7						7
KUA	40						40
MAN	7	7					13
MEI	7	7					13
TAV	13						13
All Fruit	53	13	0	0	0	0	60
Non-Fruit Trees							
AKV		13					13
FAU	33						33
FKV			7				7
HIK		7					7
KOK	60			7			67
LOU	13						13
NGA	7			7			13
NGT	7						7
OKE		7					7
SIA	33	7		7			47
SIT		7	7				13
TAH	33						33
TEH		7					7
TIM						7	7
TOA				7			7
TOI	20		7				27
TON	7	7	7				20
TUI	7						7
All Non-Fruit	93	27	13	13	0	7	93
Coconut Fuels							
COC	27						27
H&S		7					7
HUS		7					7
LOH	13						13
NIU	13						13
PAL	33	13					33
PUP	20	7					20
PUU	20	13					27
SHE		13					13
TOU	13	7		7			27
All Coconut	53	33	0	7	0	0	53
Other Types							
Cs	13	7					20
Others	13						13
All 'Other Types'	27	7	0	0	0	0	33
Overall	93	40	13	13	0	7	93
Valid cases:							15

Bush allotments were the locations of five fruit trees and ten non-fruit trees providing fuelwood, and seven types of coconut residues. On town allotments two fruit and seven non-fruit species were sources of fuelwood, and on coastal land Urban households collected fuelwood from four non-fruit trees.

The most frequently recorded tree species on the three surveyed bush allotments used by Urban households were koka, fau, tava, and tuitui. The next three most numerous trees, avoka, mango, and mei, also made a significant contribution to the total crown area.

(b) Harvesting, transport, and preparation

The frequency of fuelwood collection from bush allotments used by commercial farmers averaged 0.7 per month. In contrast to the trend in the rural study areas the frequency of collection from non-commercial allotments was higher, at 2.0 collections per month. Collections from coastal sites were very much less frequent at an average of 0.2 per month. Only collections from town allotments were made at a frequency similar to the rural study areas at 14.2 per month. Estimated times spent on fuelwood collection ranged from 0.5 to 56 hours per month with a mean of 19 person hours. Six of twelve responses indicated that more time was spent collecting fuelwood in 1986 than in 1985, and nine households spent more time than in 1981.

Two households cut live wood for fuel, one by felling koka trees and the other by coppicing sialemohemohe. Two respondents said they ring-barked koka trees and five burned trees to kill them. All fourteen households used axes in harvesting fuelwood and thirteen used cane knives. Four households regularly used chainsaws and one did so occasionally, while two used handsaws regularly and one occasionally. The most popular form of transport was the van, utilised by thirteen households. Five transported wood by truck and a similar number carried by hand. Two used boats and one a minimoke. Payment for vans varied from T$2 to T$16 depending on distance, and one household paid T$30 for the use of a truck.

All fourteen households reduced the length of their collected wood after it had been brought to the town allotment to make it suitable for burning. Eleven used cane knives, ten axes, and two handsaws. Wood was most commonly stored outside and uncovered on town allotments with ten households keeping it there all the time. Three households stored continually indoors and two covered stored wood outside on the town allotment. Twelve households frequently stored wood in secondary locations on town allotments and one sometimes stored wood uncovered on their bush allotment.

Apart from the commercial sources supplying eleven households coconut fuels were obtained from cooking and pig-feeding residues by fifteen and twelve households respectively. Fourteen respondents said they brought coconut fuels directly from their bush allotments, three collected residues from copra dryers, and two obtained offcuts from a sawmill. Those buying coconut fuels did so on average once every two months, in all but one case purchasing one van or truck load at a time.

(c) Consumption patterns

Eleven Urban households interviewed used open fires as their main cooking appliances and the other four used them as supplementary appliances. All but three households using the open fire as their main appliance had kerosene or gas stoves as supplementary appliances. Fourteen respondents cooked in 'umus: nine in earth 'umus and six in drum 'umus. Open fires were said to be alight for between 20 minutes and more than 2 hours for cooking a single meal. Numbers of people cooked for were 7.4 on weekdays and 7.3 on Sundays.

Fourteen households included coconut fuels among their five most important fuelwood types. The most popular non-coconut types were koka and sialemohemohe, each nominated by six households. Kuava was important for four households and tava and tongo for three.

Eighteen fuelwood types were suggested as being the best for use on the open fire with sialemohemohe and kuava each being named by three households. Five respondents listed sialemohemohe as best fuel for the 'umu, three nominated tava, two named kuava, tavahi, coconut stemwood, and koka, with eight other types being mentioned by one household each. Seven households named a total of twelve species as being no longer available; seven of these species were said to be preferred to currently available fuelwood types.

Interviewees' estimates indicate that the average Urban household used 5.9 tonnes of wood and 3.3 tonnes of coconut residues as fuel each year. The total of 9.2 tonnes per year was slightly higher than the overall average. Of seven households using more fuelwood at particular times of the year four gave the preparation of feasts as a reason. Three said they used less wood during the rainy season.

6. AN EVALUATION OF THE FUELWOOD SITUATION ON TONGATAPU AND OPTIONS FOR FUTURE FUELWOOD SUPPLY STRATEGIES

6.1 Introduction

The fieldwork results presented in Chapter 5 show that fuelwood is an important source of domestic energy in urban, peri-urban and rural communities on Tongatapu. This chapter draws on those results to provide an integrated evaluation of the fuelwood situation on Tongatapu. As has been stressed throughout this thesis fuelwood systems are intimately linked to a broad range of social and natural facets of the environments which support them. Material from Chapter 2, the general description of the Tongan environment, is, therefore, used in conjunction with the assessments of interactions between fuelwood systems and natural, domestic, cultivated, commercial, and social systems. An examination of Tongatapu fuelwood supply in 1986 is followed by an assessment of the role and impacts of fuelwood consumption at that time. Particular limitations affecting aspects of fuelwood systems are discussed and their potential effects evaluated. These sections fulfil the final stage of the descriptive phase of the thematic approach: to describe and discuss factors within and acting on the theme.

The creative phase of the thematic approach is addressed in Section 6.5. A procedure to guide the design and selection of mechanisms for ensuring sustainable supplies of adequate quantities of fuelwood is presented. Possible strategies for implementing this procedure to improve the fuelwood situation on Tongatapu are discussed.

As in Chapter 5, tree species are generally referred to in the text by their Tongan names, and in tables by their three letter codes. A full list of codes, with Tongan, botanical, and English names is given in Appendix 3.

6.2 Roles and impacts of fuelwood supply on Tongatapu in 1986

6.2.1 Fuelwood supply mechanisms

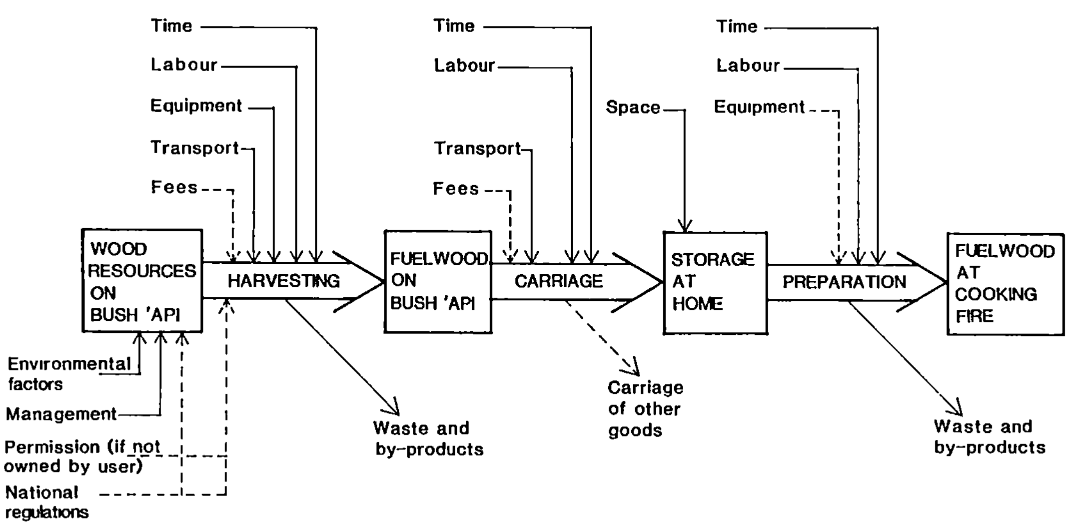
In 1986 fuelwood was obtained by Tongatapu households via three main routes: non-commercial collection; commercial supply through woodsellers; and commercial supply through the Tonga Commodities Board. The stages making up these routes and the inputs to them are represented in Figures 6.1, 6.2, and 6.3. Information given in the study area profiles in Chapter 5 has shown that sites of non-commercial collection included roadsides, copra dryers, and town allotments, but that the main sites were bush allotments and coastal forest areas. Figure 6.1 models the typical mechanism of supply from bush allotments but supply methods from other non-commercial sites were very similar. For example, gathering scraps of wood on nearby town allotments probably would not have required cutting equipment or vehicular transport but in essence the sequence of harvesting, carriage, and preparation was the same. In each case the essential direct inputs to the process were time and labour.

In the commercial supply mechanisms the use of vehicular transport and mechanical equipment became more important, and the payment of fees played a much more significant role. In the case of commercial supply through woodsellers, vehicles were required to move the wood from the collection site to the point of sale. For most woodsellers supplying domestic users this meant taking the wood to Talamahu market in Nuku'alofa. The volume of wood handled by several sellers made the use of chainsaws very attractive; otherwise, equipment used consisted mainly of handsaws and axes. Commercial woodcutters were likely to be charged by allotment holders for access to collection sites, and fees were charged for the use of selling pitches at the market. If transport had to be hired to bring the wood into town, this would involve a substantial fee. Harvesting and preparation of the wood was normally done by the woodsellers themselves, so that profits made from sales mainly represented recompense for this work.

The mechanism of supply of coconut husks and shells through the Tonga Commodities Board was rather different, in that the supply of fuelwood was incidental to an industrial enterprise. Whole coconuts were collected and brought into Nuku'alofa in order for their meat to be processed into desiccated coconut. The costs of the inputs to supply the nuts to the factory and to remove the meat had to be paid whether or not the husks and shells were to be used as fuel. Husks were used to fuel the factory's boiler to raise process steam, but significant quantities were left over. There was considerable advantage in having the residues removed from the factory site to reduce storage problems. The husks and shells were therefore sold relatively cheaply; in terms of dollars per megajoule they were five to ten times better value than a bundle of firewood bought at the Talamahu market.

FIGURE 6.1

Diagrammatic representation of stages in and inputs to the typical mechanism for supplying fuelwood from bush allotments through non-commercial collection on Tongatapu in 1986



6.2.2 Estimates of quantities supplied

Calculations of average annual fuelwood requirements have been based on the volume estimates of daily fuelwood consumption given by interview respondents. These indicate that in 1986 the average Tongatapu household needed approximately 21 m^3 of wood and 18 m^3 of coconut fuels per year. This

FIGURE 6.2

Diagrammatic representation of stages in and inputs to the typical mechanism for commercial supply of fuelwood through woodsellers on Tongatapu in 1986

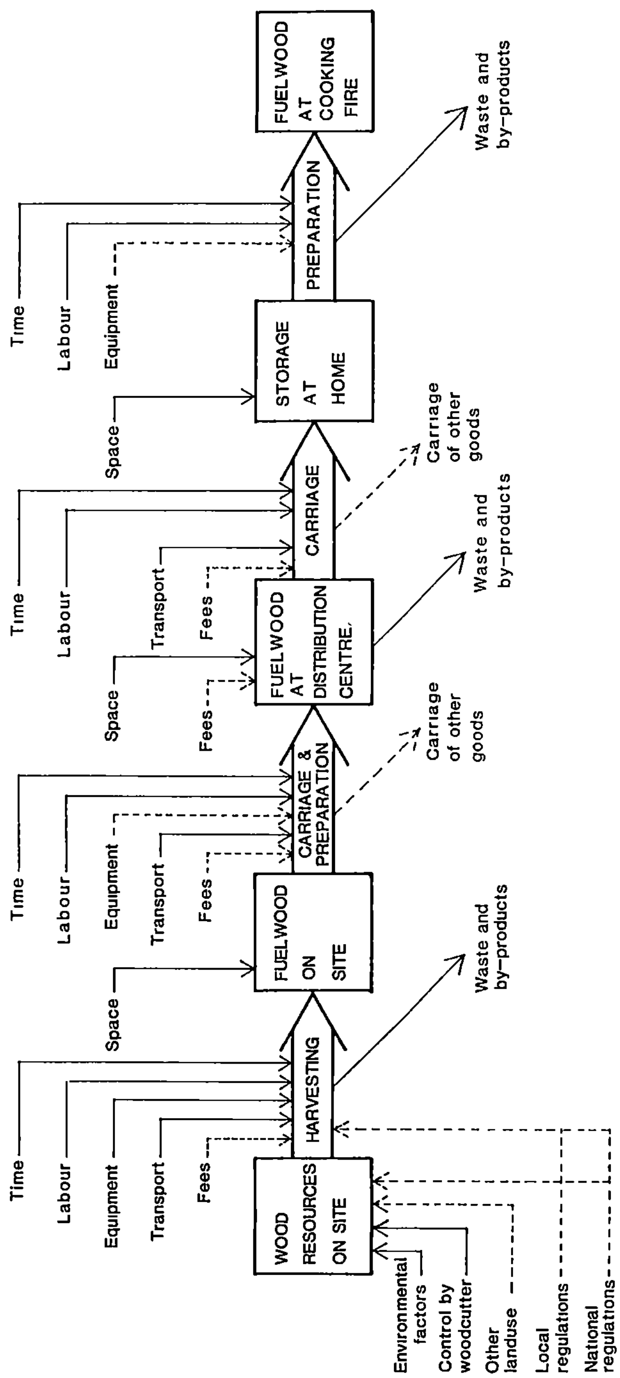
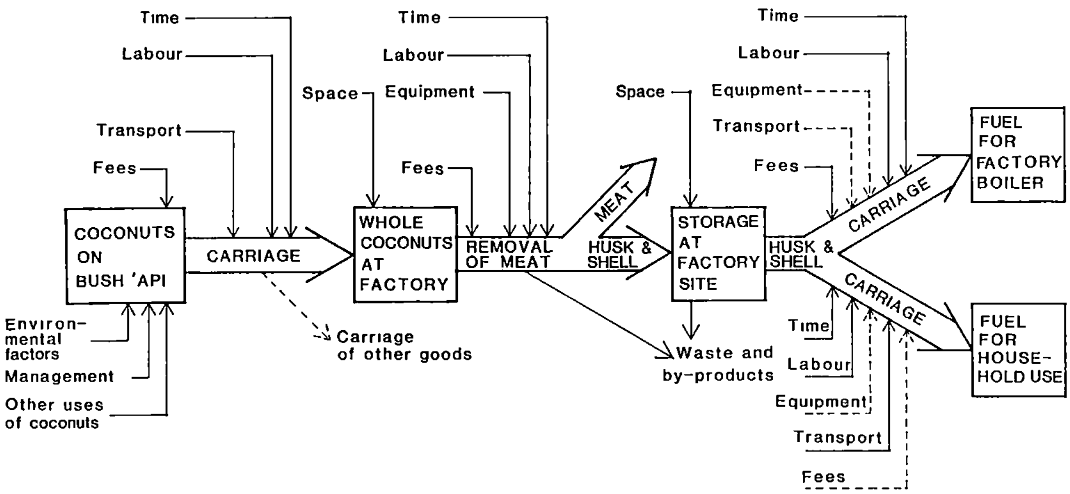


FIGURE 6.3

Diagrammatic representation of stages in and inputs to the typical mechanism for commercial supply of coconut husks and shells through the Tonga Commodities Board on Tongatapu in 1986



approximates to 6.4 air-dry tonnes of wood and 2.7 air-dry tonnes of coconut fuels (Table 6.1), and represents a total gross energy requirement per household of 127 gigajoules (GJ)[1] per year.

In three of the rural study areas, interviewees' estimates of their household fuelwood requirements were remarkably consistent. In the fourth area, Lavengatonga, a larger quantity of wood was used per household and proportionately less coconut fuel. This difference can be explained by the ready supply of dead sialemohemohe in the eastern district of Tongatapu. The average total fuelwood requirement in Urban households was very similar to the rural

1. Volume to air-dry weight conversion factors and assumed energy contents are listed in Appendix 7.

total but included a higher proportion of coconut fuels. The data for Peri-urban Nuku'alofa showed the average total consumption to be 30 percent less than the average of the other five study areas. Particularly low here was the contribution of coconut fuels, an indication of lack of both access to agricultural land.

The proportion of fuelwood requirements met from commercial sources varied dramatically between the study areas in Nuku'alofa and rural Tongatapu. Among the sixty rural households interviewed none bought wood and only two paid for coconut fuels. Both of these were Folaha households which had their own motorised transport. In contrast, two thirds of the Nuku'alofa households included in the interview survey purchased fuelwood: fourteen in the Urban, and six in the Peri-urban study areas. Of the 580 tonnes of wood used as fuel each year by the ninety interviewed households, about 5 percent had been bought. Some 22 percent of the 240 tonnes of coconut fuels consumed annually in the sample households came from commercial sources.

Estimates based on interview data from the author's survey suggest that in total almost 90 000 tonnes of fuelwood was needed to meet Tongatapu's annual domestic needs in 1986 (Table 6.1). By weight this consisted of 71 percent wood and 29 percent coconut fuels. Extrapolation from the percentages calculated for interviewed Nuku'alofa and rural households suggests that quantities in the order of 3600 tonnes of wood and 6600 tonnes of coconut fuels (air-dry equivalent) would have been purchased in the year by Tongatapu households.

6.2.3 Sources of fuelwood

Whether the mechanism for supplying fuelwood to the consumer was commercial or non-commercial the ultimate source of the majority of wood used as fuel was the same: a bush allotment or coastal forest.

Of eleven woodsellers interviewed at the Talamahu market in Nuku'alofa, ten obtained wood from bush allotments and the eleventh collected from other agricultural land. Two cut wood only on their own allotments but nine gathered from land owned by others. Four woodsellers harvested wood from coastal forests and two from other government controlled land. The locations of these

TABLE 6.1

Estimates of average annual fuelwood requirements for households in the six study areas, and estimated total requirements for Nuku'alofa, rural Tongatapu, and the whole of Tongatapu in 1986

Average Household Requirements (air-dry tonnes per year)

	Wood	Coconut Fuels	Totals
Rural Study Areas			
'Ahau	6.8	2.9	9.8
Vaotu'u	6.3	2.9	9.2
Folaha	6.5	3.0	9.5
Lavengatonga	7.8	2.1	9.9
Rural Averages	6.9	2.8	9.6
Town Study Areas			
Peri-urban Nuku'alofa	5.1	1.6	6.7
Urban Nuku'alofa	5.9	3.3	9.2
Town Averages	5.5	2.4	7.9
All Study Areas	6.4	2.7	9.1

Estimated Total Requirements (air-dry tonnes per year)

	Wood	Coconut Fuels	Totals
Nuku'alofa	21 100	9300	30 400
Rural	40 300	16 300	56 600
Tongatapu	61 400	25 600	87 000

commercial sources of fuelwood were spread across the island, but among those for which information was obtained the majority of sites were in the eastern district.

The concentration of fuelwood collection sites in the eastern part of Tongatapu was related to the ready availability of sialemohemohe (leucaena) which had been killed by the leucaena psyllid. The impact of this insect clearly illustrates the significance of natural phenomena on human activities. The devastating effects of the psyllid on the leucaena stands that had dominated this part of the island made clearing the trees much easier. This assisted management of cultivated areas and provided a glut of fuelwood for local households and commercial woodcutters; among interviewed woodsellers sialemohemohe was the most important species sold. Effects of the invasion by the exotic psyllid insect thus rapidly pervaded domestic and commercial as well as natural and cultivated aspects of Tongatapu society.

In the long term the demise of leucaena could result in significant impacts on the island's cultivated and fuelwood systems. Halting natural regeneration of an aggressive coloniser would reduce the effort needed to clear and maintain plots for cultivation and thus permit a farmer to have a greater proportion of land under crops at a time. Without the threat of invasion by leucaena there would be a greater opportunity for large-scale European style agriculture. The elimination of extensive stands of leucaena by a natural phenomenon could thus trigger human actions which would reduce populations of other naturally regenerated trees on agricultural land. On the other hand the survival of tree species particularly favoured by farmers could be more secure without competition from leucaena. If the research strategies recommended by Fakalata (1986) are successfully implemented, psyllid resistant varieties of *Leucaena leucocephala* suited to Tongan conditions should become available. Carefully managed stands of sialemohemohe could play a very useful role in integrated land use on Tongatapu. Such a transition to managing for positive benefits a tree that has been considered an undesirable weed, could in itself bring about substantial changes to land management attitudes.

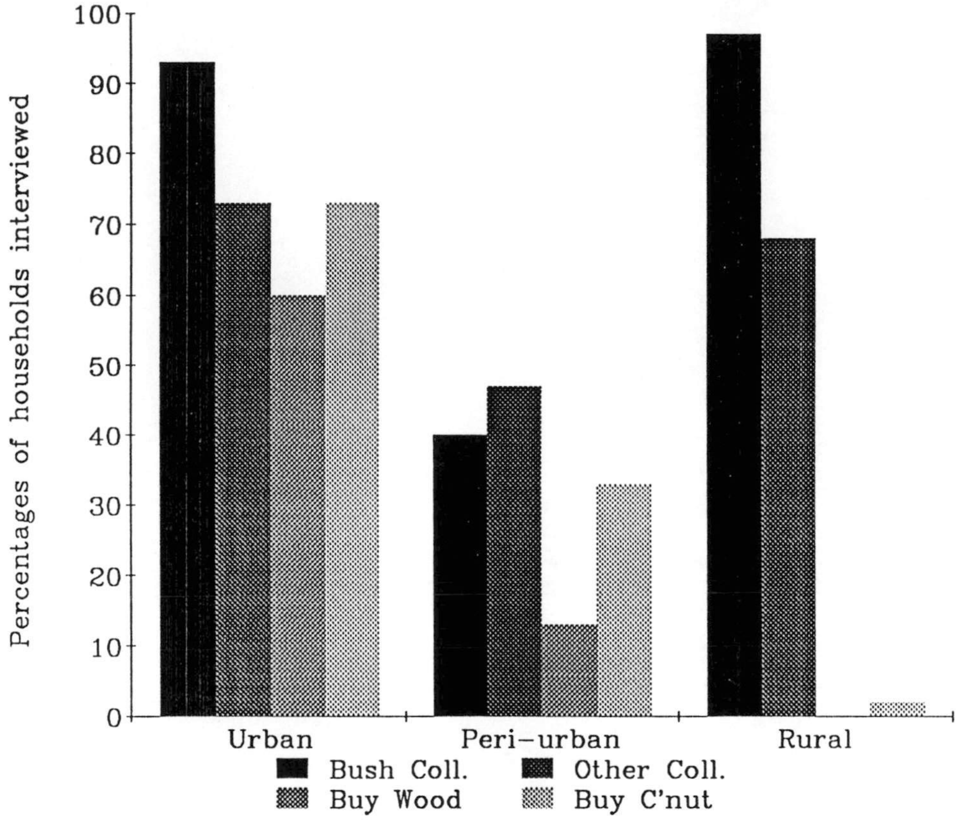
All but one of the woodsellers' collection sites for leucaena were bush allotments, the exception being government land near Niutoua on the north-east coast. Bush allotments were also the main source of most of the other species sold by woodsellers. Coastal sites provided additional supplies of several species collected from bush allotments, but only one type of fuelwood was obtained exclusively from coastal land.

Bush allotments accounted for more than half of the fuelwood collection sites mentioned by household interviewees in all study areas except Peri-urban Nuku'alofa. Overall, 60 percent of all sites used by the eighty-five respondents were bush allotments, 15 percent were town allotments, and 14 percent coastal land. The proportion of bush allotments included as main collection sites was 84 percent in the rural study areas, and 93 percent in Urban Nuku'alofa. In contrast, in Peri-urban Nuku'alofa only 46 percent of fuelwood collecting households interviewed said their most important sites were bush allotments. The greatest variety of sites given as main sources of fuelwood came from the Peri-urban interviewees who referred to six different land categories. Overall the Peri-urban respondents had access to the fewest sites, an average of 1.2 per household. Urban interviewees collected from an average of 2.7 sites, and rural households from 2.8 sites. This discrepancy indicates significant social differences between the populations of the different areas as it reflects the lack of secure access to agricultural land among Peri-urban households. While some Peri-urban interviewees were able to counteract this restriction on the collection of fuelwood by purchasing wood and in particular coconut fuels, the proportion with adequate purchasing power was very much smaller than in Urban Nuku'alofa (Figure 6.4).

Half the bush allotment users interviewed said that the provision of fuelwood was a benefit of having trees on agricultural land. The only benefit more frequently mentioned was the production of food (Table 6.2). Overall, far fewer respondents gave fuelwood as a reason for protecting particular trees during clearing or while weeding. The highest proportions, four of nine and two of six, occurred in 'Ahau and Peri-urban Nuku'alofa, the study areas where the average bush allotment interviewees had access to the smallest areas of agricultural land.

FIGURE 6.4

Percentages of households interviewed in 1986 in Urban, Peri-urban, and Rural Tongatapu study areas collecting fuelwood from bush allotments and other sites and purchasing wood and coconut fuels



Bush allotments played the major role on Tongatapu in the supply of fuelwood for domestic consumption. In rural areas and for many town residents most wood was brought directly from the allotments, but even in cases where wood was bought from merchants most of it came from bush allotments. Coastal land and town allotments were collection sites for households across the island but a higher proportion of interviewees gave the coast as an important source of fuelwood. Copra dryers were nominated as most important sources of fuelwood by two respondents, one in Vaotu'u and one in Folaha. The three Peri-urban interviewees who did not give bush allotments, coastal land, or town allotments

TABLE 6.2

Percentages of forty-six respondents to bush allotment interviews giving the twelve most commonly cited reasons for trees on agricultural land being a benefit and for protecting them during clearing of fallow and weeding

Reason/ useful product	Benefit from trees	Reason for protecting trees
Food	85	78
Fuelwood	52	22
Dye	37	24
Building material	30	4
Medicine	28	20
Oil	9	4
Fencing	9	2
Rope	7	0
Soap	7	0
Crop supports	7	0
Income	4	9
Household uses	2	7

as their main sources of wood offered three different land types: school grounds, government land, and uncultivated agricultural land.

This pattern of locations for fuelwood collection suggests that for households which had ready access to bush allotments supporting naturally regenerated vegetation as well as cultivated crops, such sites provided the majority of the wood requirement. Where access to fuelwood on bush allotments was available but inconvenient, householders collected from sites closer to the home, choosing better quality fuel in the most accessible locations first. Households unable to utilise such sources collected whatever type and quality of wood they could find on any accessible land.

The characteristics of land used as fuelwood sources depended on many natural factors and human activities apart from fuelwood collection. Impacts resulting from involvement in the fuelwood supply system varied according to the extent of fuelwood collection, the resilience of the natural ecosystem, and the type and extent of land management. The amount of wood taken was most significantly affected by the physical ease of access to the site, the fuel quality of the available wood, and the ownership and control of the land. These general criteria were applicable to situations across Tongatapu but the significance of each criterion varied with social and economic characteristics of communities and individual households.

6.2.4 Fuelwood species

6.2.4.1 Commercial supply

As described above, sialemohemohe was the species most commonly sold by interviewed woodsellers due to its ready availability from bush allotments in the eastern district of Tongatapu. In a total of nineteen fuelwood types the three next most important species were koka, loupata, and fo'ui, all coming from agricultural land. The only other species to be sold by at least four woodsellers were fao and filimoto, which were collected from both bush allotments and coastal land. The only species collected exclusively from coastal land was touhuni, sold by just one woodseller. Four fruit trees were mentioned: mango, sold by two woodsellers, and tava, moli, and kuava, sold by one woodseller each. The eight non-fruit species sold which have not been mentioned above were: ngatata, tavahi, pula, fau, masikoka, hangale, lopa, and toi. Seven of these were collected exclusively from agricultural land; only hangale was also obtained from coastal and government land.

6.2.4.2 Non-commercial supply

Of eighty-eight fuelwood using Tongatapu households interviewed, 94 percent said they collected fuelwood from non-fruit trees, 65 percent collected from fruit trees, and 61 percent gathered coconut residues for use as fuel. The dominant wood species, koka, provided fuel for 63 percent of households, more than reported collecting coconut fuels. Given that the coconut residues consisted of nine specific categories, the dominance of koka was quite outstanding. The next most commonly collected fuelwood types were kuava, fau, and tava, gathered by 42, 40, and 39 percent of fuelwood users respectively (Table 6.3). In total thirty-eight non-fruit species, eight fruit species, and ten categories of coconut fuel (nine specific types and one general category) were said to be collected by fuelwood using households.

Thaman's (1984) analysis of data from a survey conducted for the UN Pacific Energy Development Programme gives coconut fuels as more commonly used than koka, with kuava, sialemohemohe, fau, and tava, all providing fuelwood for more than 20 percent of households.

TABLE 6.3

Percentages of fuelwood using households interviewed in Urban, Peri-urban, and Rural Tongatapu collecting various types of fuelwood

	Urban	Peri-urban	Rural	Totals
General categories				
Coconut fuels	53	20	74	61
Fruit trees	60	27	76	65
Non-fruit trees	93	80	98	94
Ten most commonly collected non-coconut species				
KOK	67	13	74	63
KUA	40	13	50	42
FAU	33	27	45	40
TAV	13	13	52	39
SIA	47	13	36	32
TAH	33	20	21	23
MOL	0	13	24	18
MAN	13	7	22	18
TON	20	20	12	15
TOA	7	13	9	9
Valid cases:	15	15	58	88

6.2.5 Harvesting and distribution

The frequencies at which fuelwood was harvested varied considerably across the six study areas. In 'Ahau those collecting from bush allotments did so on average 10.5 times per month whereas those in Vaotu'u collected 2.3 times per month and Urban households collecting from bush allotments did so just 1.8 times per month. The range of average collection frequencies from coastal sites was even wider, with no coastal collections in Lavengatonga and just 0.2 per month for the Urban study area, but 15.8 collections in 'Ahau. Frequencies of collections from town allotments showed less variation; from 8.0 times per month in Peri-urban Nuku'alofa to 14.2 times per month in the Urban study area.

Some aspects of collection activities were similar in all study areas but others varied with environmental features of the different sites and characteristics of the collecting communities. In the majority of fuelwood using households in each of the six study areas adult males collected fuelwood. The proportion was higher in rural villages where farming was an important occupation. The lowest average number of people per household said to be involved in fuelwood collection occurred in Peri-urban Nuku'alofa. Here wood collectors averaged just 1.3 per household. Wood was collected for thirteen Peri-urban households by a total of seventeen people: nine adult male household members, four adult females, three children, and one adult male from outside the users' household. At the other extreme, responses in Folaha indicated that an average of 2.2 people per household collected fuelwood. In 18.5 percent of Nuku'alofa fuelwood using households respondents said fuelwood was collected solely by women and children; the comparable proportion in the rural study areas was 6.9 percent.

The estimated amount of time taken per month to collect fuelwood also varied considerably. The mean estimate in Peri-urban Nuku'alofa, 8.8 hours, was less than half the overall mean for the other five study areas. Peri-urban Nuku'alofa also had the lowest number of households using wheeled vehicles to transport their fuelwood; four respondents said they used vans, one used a truck, and one used a horse and cart, but seven carried their wood by hand or, in one case, on horseback. The data recorded for Peri-urban Nuku'alofa suggest that the collection activities undertaken by these households were more effectively carried out than in other study areas; that is, a greater volume of fuel was brought home per trip than would have been predicted from data gained in the other study areas.

6.2.6 Stocks of fuelwood on collection sites

Almost all fuelwood collected on Tongatapu in 1986 was dead wood removed from bush allotments and forested coastal areas. The volume of dead wood generated depended on a range of factors influencing production of wood and the rate at which it died. Ecological factors reflecting the physical and biological characteristics of the site affected not only the number, species, and sizes of trees present, but also included direct causes of death. Significant specific physical agents contributing to the generation of dead wood have been strong winds and associated fierce seas, particularly during cyclones and hurricanes. Tropical cyclone Isaac, which struck Tongatapu in 1982, left a sizeable resource of dead wood in the mangrove swamps; this augmented supplies to villagers and commercial woodsellers for several years. A dramatic recent example of a biological killer of trees was the invasion of the leucaena psyllid that had provided a glut of sialemohemohe fuelwood in 1985 and 1986.

Physical conditions for tree growth were generally very good throughout Tongatapu so that all areas had a high potential for fuelwood production even though types of wood varied. Localised limiting factors were reflected in patterns of species distribution across the island. Coastal plant communities were quite different from the native inland forest due to the need to resist salt-spray and intermittent inundation. On inland sites differences between plant communities were less likely to be caused by variations in physical environmental factors, which were fairly constant, than by biological and human influences. Why extensive stands of sialemohemohe did not exist beyond the eastern district was not clear, but in its absence kuava was a dominant invasive species in the central and western districts. While distribution of naturally regenerated species was determined by physical and biological factors, numbers of trees of all species were substantially controlled by humans. The impact of management depended on its intensity, but as increasing areas of land were taken for broad scale agriculture renewable fuelwood stocks dwindled. In areas devoted to intensive crop management numbers of native species could have reduced dramatically.

On bush allotments managed by traditional methods numbers of naturally regenerated trees were generally high. Land left fallow would quickly be re-colonised by plant species close enough to spread seed onto the fallow area. Where traditional crop rotation techniques had been abandoned, the opportunity for fallow trees to regenerate and thus provide a stock of fuelwood did not occur. Conversion of land to intensive farming did not mean that all trees were removed, but those allowed to remain on cultivated areas were generally those that had particular value to the landholder. Table 6.4 shows that of all trees with diameters at breast height (DBH) greater than 10 cm on three surveyed bush allotments more than a quarter were koka, and about a half were fruit trees. Eighty percent of the trees belonged to five species: mango, mei, tava, koka, and

TABLE 6.4

Numbers and volume indicators[1.] of non-coconut trees with diameters at breast height greater than 10 cm recorded on three bush allotments used by households interviewed in Folaha, Lavengatonga, and Urban Nuku'alofa, by species

Study area:	Folaha		Lavengatonga		Urban Nuku'alofa	
Allotment reference:	F1		L2		U15	
	No.	Vol. m^3	No.	Vol. m^3	No.	Vol. m^3
Fruit trees						
API			1	0.1		
APT			1	<0.1		
AVO	4	2.9				
IFI	2	2.3	1	2.5		
MAN	13	12.8	5	4.9	2	0.4
MEI	17	6.8	13	5.8		
MOL	1	0.6	4	1.6		
TAV	3	2.2	9	4.0	9	2.7
TEL			2	1.6		
VII	1	3.2				
Fruit totals	41	30.7	36	20.7	11	3.1

Continued

TABLE 6.4 Continued

Study area:	Folaha		Lavengatonga		Urban Nuku'alofa	
Allotment reference:	F1		L2		U15	
	No.	Vol. m^3	No.	Vol. m^3	No.	Vol. m^3
Non-fruit trees						
FAU	5	2.8			4	1.4
KOK	13	82.5	1	0.1	40	114.4
LOU					3	0.9
MAL	1	<0.1	1	nr		
MSK			1	0.1		
NGA	1	<0.1			3	1.1
NGT			1	1.2		
OKE	2	1.1	2	2.4		
PUL			4	0.3		
SIA			1	0.1		
SIT					1	0.2
SPI			1	0.2		
TUI			5	2.0	14	5.0
VAV			1	nr		
Non-fruit totals	22	86.5	18	6.2 +nr	51	123.0
Overall totals	63	117.1	54	26.9 +nr	62	126.1

Notes: 1. The volume indicators given here have been generated by multiplying the cross sectional area at breast height by the estimated height of the tree. This formula was suggested by the UN Pacific Energy Development Programme (1985) as suitable for estimating approximate volumes of mango and tava trees. The volume indicators are presented to allow preliminary comparisons but should not to be taken as accurate representations of actual wood volumes.

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tuitui. While each of these had valuable uses, as fruit and dye producers and boundary markers, only koka and tava were sources of fuelwood collected by more than 20 percent of interviewees. Mango, tava, and koka trees were the only

TABLE 6.5

Summary of densities per hectare of trees with diameters at breast height greater than 10 cm representing the species most commonly recorded on surveyed bush allotments

Tree species	Study areas 'Ahau	Vaotu'u	Folaha	Lavenga-tonga	Peri-urban	Urban
KOK	6.3	7.4	3.0	2.3	5.2	5.6
MEI	3.3	0.5	2.0	1.4		0.8
FAU	2.7	2.1	1.1		1.7	2.6
MAN	2.4	1.4	1.8	1.3	1.7	0.8
TAV	2.1		0.5	2.7	2.3	1.5
MOL	1.4	0.6	0.3	0.9	0.8	
NGA	1.0					0.3
VAV	1.0			1.4		
IFI	0.6		0.7		1.1	
TOT	0.6					
FUT		1.6				
LOU		0.7		0.6	0.9	0.3
SII		0.6				
TAH		0.6	0.2		0.5	
FAO		0.5				
TUI		0.5		1.1	1.1	1.5
AVO			0.7			1.0
VII			0.2			
LOP			0.2			
OKE			0.2			
FOU				0.6	0.5	
PUL				0.6		
FET					15.1	
NON						0.3
Numbers of bush allotments	5	3	3	3	2	3
Percentage of allotment area cultivated	60	33	73	48	55[1.]	65

Notes: 1. Estimated figure.

species recorded on all three sample allotments, used by Folaha, Lavengatonga, and Urban Nuku'alofa households. The indicators of solid wood volumes included in Table 6.4 suggest that koka trees were dominant not only in numbers but also in terms of the quantity of biomass. These volume indicators have been included not to supply accurate information on wood volumes, but to give a clearer impression of potential to provide fuelwood than would data relating numbers of trees alone. Densities of trees with diameters at breast height greater than 10 cm on all surveyed bush allotments for which full data were recorded, confirm the dominant status of koka, mango, mei, and tava (Table 6.5). Two other species, fau and moli, were found in five of the six study areas. Fau was present in relatively high densities, but in only one area did the density of moli trees exceed one per hectare.

The most significant factors affecting tree populations on Tongatapu relate to land management. When considering standing trees as stocks of potential fuelwood it is therefore useful to employ tree categories reflecting aspects of both human use value and ecological characteristics. The three categories adopted here are:

(i) special purposes trees;

(ii) invasive species and early colonisers;

(iii) indigenous and established introduced non-protected species.

Category (i) includes those trees which were given special protection by land managers because of significant particular value they had to the human community. Category (ii) trees are those observed to have especially strong colonising characteristics. While they might well have had some valuable uses, these trees were the ones most likely to be considered a nuisance by cultivators. Other native and well established introduced trees which were not generally given special protection are classified in category (iii). Codes and Tongan names for trees in categories (i) and (ii) are listed in Appendix 5. All five of the main species recorded on the three sample bush allotments referred to above had special purposes that warranted their protection. The three fruit trees and koka would always be included in category (i). While some landholders would categorise tuitui as an established introduced non-protected species, it has been included in category (i) because tuitui trees were usually afforded protection and managed as boundary markers.

The distribution pattern of small trees, with diameters at breast height less than 10 cm, was rather different to that of the larger trees. Numbers of small trees recorded on the three sample allotments are presented in Table 6.6. Only kuava was found on all three allotments, while large numbers of four other species were monitored on individual sites. Over one hundred and thirty fiki trees formed a living fence on the Folaha allotment, but it was the Lavengatonga site which supported remarkably high numbers of particular species. Here two hundred and fifty-eight te'ete'emanu trees were counted, and stands of more than one thousand pula trees and nearly five thousand sialemohemohe were estimated. This illustrates the natural potential in this area for rapid and overwhelming invasion of pioneer tree species onto unmanaged or fallow land. The highest number of trees of a single species on the Urban household's allotment was the twenty-three tuitui maintained as boundary markers. Fruit species comprised just 2 percent of the total number of small trees on the Lavengatonga allotment. Actual numbers of small fruit trees were lower on the other two allotments but proportionally they were more significant, at 7 percent in Folaha and 32 percent on the Urban household's allotment. Percentages of small trees (with DBH less than 10 cm) of species maintained for special purposes were somewhat different to percentages of fruit trees. Kuava trees were not counted as special purpose trees but categorised as invasive, but the main differences arose from the inclusion of fiki, kofi, and tuitui trees. The percentages of special purpose trees were 91 percent in Folaha, 3 percent on the Lavengatonga allotment, and 39 percent on the allotment managed by the Urban interviewee. The proportions of category (ii), invasive, species varied just as dramatically. Only 2 percent of small trees on the Folaha allotment fell into this category, compared to 91 percent and 18 percent for the Lavengatonga and Urban interviewees' allotments respectively. The highest proportion of non-protected indigenous trees, 44 percent, was recorded for the Urban household's allotment, but this represented forty-seven trees compared to four hundred and forty-seven on the Lavengatonga allotment.

Stocks of fuelwood on coastal land around Tongatapu varied considerably from site to site. Shorelines within or adjacent to many coastal villages had been virtually denuded of vegetation. In such high pressure areas, even where mature trees remained, constant disturbance by domestic animals and human activity generally prevented regeneration. Similar impacts occurred on fuelwood collection sites further away from residential areas. For example, the coastal area close to 'Ahau which has been described in Section 5.2.1.1 above was under

TABLE 6.6

Numbers of trees with diameters at breast height less than 10 cm recorded on three bush allotments used by households interviewed in Folaha, Lavengatonga, and Urban Nuku'alofa, by species

Allotment:	F1			L2			U15			
Estimated height:	<2m	2-4m	>4m	<2m	2-4m	>4m	<2m	2-4m	>4m	Totals
Fruit trees										
API				1						1
APT				2		7				9
IFI	4									4
KUA	4			18	35	6	14	5		82
MAN	1			2	3		2	5		13
MEI	3			5	14	2				24
MOL		1		9	33	1				44
TAV				6	1		3	6		16
TEL	1			3						4
Fruit totals	13	1	0	46	86	16	19	16	0	197
Non-fruit trees										
AHI				1	3	3				7
FAU		2	1				5	13		21
FIK	126	10								136
FIL				3	2					5
FOU		1		9	15	2				27
HEH				2		1				3
KFI	32									32
KLA							2			2
KOK	5						2	1		8
LOP				2	6	4				12
LOU		1		2	3		4	11		21
NGA	1							1		2
NGT				8	10	5				23

Continued

TABLE 6.6 Continued

Allotment:	F1			L2			U15			
Estimated height:	<2m	2-4m	>4m	<2m	2-4m	>4m	<2m	2-4m	>4m	Totals
NON				5	6					11
OKE						1				1
PUL				418	391	255				1064
SIA[1.]				180	4040	540				4760
SII				35	32	5				72
SIT		4						7		11
TAH					1		2	2		5
TAN		3		2	24	58				87
TEE				203	55					258
TOI					1					1
TOT						1				1
TUI				2	3		11	12		28
UHI				5						5
VAV				1						1
Non-fruit totals	164	21	1	878	4592	875	26	47	0	6604
Overall totals	177	22	1	924	4678	891	45	63	0	6801

Notes: 1. Estimated numbers of sialemohemohe trees were extrapolated from a count made of the number of stems in a 500 m^2 quadrat.

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continued pressure which disallowed recuperation. However, this same site did illustrate that vegetation could survive when perceived to perform functions valued by humans. The dense strip of fau trees immediately inland from the area of most severe degradation had been preserved almost certainly because it protected the adjacent banana plantation from wind and salt spray. Such screening vegetation was more likely to be totally protected if it grew on land under the control of individual farmers. On the windward coast to the west of 'Ahau evidence was seen of the cutting of trees which would have provided shelter for agricultural land. In this case the trees grew on the shore a short distance away from the bush allotments. This situation illustrates that there are different perceptions of fuelwood stocks. Farmers cultivating allotments close to the coast would not consider the natural shelter belts to be appropriate sources of fuelwood, but at least some individuals with no personal interest in the maintenance of shelter considered the destruction of coastal trees to be an acceptable method of obtaining fuelwood. Similar attitudes were evident among residents of villages near the Fanga 'Uta and Fanga Kakau lagoons. Mangrove swamps which were considered by the government to have outstanding ecological value were sites of regular fuelwood collection. If the vegetation of these swamps was healthy and close to its natural condition a limited amount of cutting would have been ecologically sustainable. However, the degraded appearance of the swamp forests suggested that continued cutting of live wood was depleting the stock at an unsustainable rate.

Another source of fuelwood was trees growing within town and village boundaries. Surveys of town trees showed a wide variety of species was grown on town allotments and common land within these residential areas[2.]. Twenty-eight species were identified within 'Ahau's town area and twenty-seven at Tukutonga. Given the similarities in environmental conditions at these two study sites, the presence of many of the same tree species was expected. Toa, fau, and mei were the most frequently recorded species in Tukutonga and figured among the top six species in 'Ahau. In each village planted trees were predominant. Toa trees had been planted in Tukutonga for soil stabilisation and shelter; mei were planted in both villages for fruit production. Fau was the most persistent of the native coastal species but smaller numbers of feta'anu, milo, puataukanave, telie, and touhuni were also recorded. Of the twenty-seven species represented in Tukutonga nine were Category (i), special purpose, trees (as listed in Appendix 5). The thirty-six specimens of these species formed 16 percent of the total two hundred and twenty-five trees recorded. If toa were to be considered a special purpose tree in this situation the number would rise to one hundred and forty-five, 64 percent of the total. In 'Ahau, 57 percent of a total of two hundred and thirty-nine trees were of Category (i) species. The only Category (ii), invasive, trees recorded in either village were a group of sialemohemohe in Tukutonga.

Of a total of six hundred and forty-six individual trees recorded on four survey sites in Urban Nuku'alofa, four hundred and seventy-seven, 74 percent, were

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2. All trees over 2 metres in height were recorded in these town tree surveys, irrespective of stem diameters.

Category (i), special purpose, trees. In addition, a total length of 304 metres of hedges of Category (i) species was measured: 30 m of kalakala'apusi and 274 m of tanetane. Three of the top four species in the Urban survey were fruit trees: mei, mango, and tava, accounting for 39 percent of the total individual trees. Four of the ten most frequently recorded species (mango, tava, fau, and kuava) were among those listed by Urban interviewees as important fuelwood types. In 'Ahau three important fuelwood types were included in the top ten town trees, and three of Tukutonga's ten commonest town trees were said to be important fuelwood types for Peri-urban interview respondents.

While all wood could be burnt as fuel, when seeking information on stocks of wood that are likely to make useful contributions to fuelwood production it is necessary to consider householders' perceptions and preferences. Special preferences are discussed in more detail in Section 6.3.4 below; here, interviewees' perceptions of levels of supply of their most important species are considered. Tables 6.7 to 6.10 indicate perceived current and expected future levels of supply of coconut fuels and the ten most commonly collected non-coconut species.

High proportions of interviewees burning coconut residues considered those fuels to be in plentiful supply (Table 6.8). Respondents who said they used coconut residues without specifying particular types unanimously agreed that coconut fuels were plentiful. However, in two cases data from responses referring to specific residue fuels indicated that more than half the respondents thought supplies were currently less than plentiful. The one 'Ahau respondent who used palalafa, coconut frond spines, considered the supply to be only adequate, and only one of three Urban interviewees using toume, coconut flower sheath, considered that fuel to be in plentiful supply. Respondents' perceptions on likely future levels of supply largely reflected their views of current supplies, but expectations of the decline of specific coconut fuels appear to demonstrate areas of concern in Urban Nuku'alofa. Of six responses related to husk (HUS) and six related to shell (SHE) four in each case thought supplies would decline in the future. This is significant because a major source of husk and shell for Urban households was the desiccated coconut factory. The concern about future supplies of husk and shell could have resulted from a lack of confidence in the continuing operation of the factory, or maybe anticipation that all waste would be burnt at the factory.

TABLE 6.7

Percentages of interviewees considering coconut fuels to be in plentiful supply at the time of interview. The data presented are based on interviewees' responses about their five most important fuelwood types.

Fuelwood type	Study areas[1.] A	V	F	L	Rural	PU	U	Overall
COC	100	100	100	100	100		100	100
H&S	100	88	80	100	90	100	100	91
HUS	100	100	100	75	89	80	86	82
L&T							100	100
LOH	50	100	100		75		100	83
NIU	50			100	67		100	80
PAL	0[2.]	100	100	100	86	100	100	90
PUP	100				100		100	100
PUU	75			83	80		60	73
SHE	100			100	100	75	86	87
TOU				100	100		33	50

Notes:
1. The letter codes used as headings refer to the study areas as follows: A - 'Ahau; V - Vaotu'u; F - Folaha; L - Lavengatonga; PU - Peri-urban Nuku'alofa; U - Urban Nuku'alofa.
2. Data, including zeros, are included only for those fuelwood types cited as 'most important'.

Reported opinions on levels of supply of the most commonly collected non-coconut species varied considerably (Table 6.9). The two species considered to be in plentiful supply by more than 90 percent of respondents using them were fau and tongo. However, two of four Peri-urban interviewees considered fau to be scarce. For both species fewer than half the respondents expected future supplies to be less than current supplies or to continue to be scarce. The situation with sialemohemohe was, as expected, somewhat different. Eighty-five percent of users thought current supplies were plentiful but 68 percent believed that supplies would decline. Apart from fau and tongo the only species whose decline was expected by less than half the interviewees was mango. Four out of five

TABLE 6.8

Percentages of interviewees expecting levels of supply of coconut fuels to decline or to continue to be scarce. The data presented are based on interviewees' responses about their five most important types of fuelwood.

Fuelwood type	Study areas[1.] A	V	F	L	Rural	PU	U	Overall
COC	0[2.]	0	25	0	11		0	10
H&S	0	25	20	25	15	0	100	18
HUS	0	0	0	25	11	50	67	30
LOH	50	0	0		25		50	33
NIU	50			0	33		50	40
PAL	100	0	0	0	14	0	0	11
PUP	0				0		0	0
PUU	25			50	40		20	33
SHE	0			0	0	0	67	29
TOU				0	0		33	25

Notes: 1. The letter codes used as headings refer to the study areas as follows: A - 'Ahau; V - Vaotu'u; F - Folaha; L - Lavengatonga; PU - Peri-urban Nuku'alofa; U - Urban Nuku'alofa.
2. Data, including zeros, are included only for those fuelwood types cited as 'most important'.

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mango users had said supplies were plentiful, and only two expected supplies to decline or to be scarce in the foreseeable future. *Koka*, *kuava*, *tava*, and *toa* were each said to be plentiful by between 50 and 75 percent of respondents, but similar proportions of interviewees expected supplies to decline. While the anticipation of decline was not so severe with these species as with *sialemohemohe*, it did reflect serious expectations of fuelwood shortages. Perceptions of levels of supplies of wood from *moli* trees indicated that for some species such shortages already existed. Overall, only 20 percent of respondents using *moli* wood considered supplies to be plentiful; none of the six interviewees in the 'Ahau, Lavengatonga, and Peri-urban study areas who used *moli* described its level of supply as plentiful. This suggestion of serious shortages of *moli* fuelwood was

TABLE 6.9

Percentages of interviewees considering non-coconut wood species to be in plentiful supply at the time of interview. The data presented are based on interviewees' responses about their five most important types of fuelwood

	Study areas[1.]							
Fuelwood type[2.]	A	V	F	L	Rural	PU	U	Overall
KOK	80	86	50	0[3.]	73	67	40	68
KUA	83	75	80	100	77	33	67	72
FAU	86	83	100		89	50	100	91
TAV	63	67	0		58	50	33	54
SIA		100	75	93	89	100	67	85
TAH		33	25		29	33	0	27
MOL	0	33	20	0	20	0		20
MAN		50	100		66	100	100	80
TON			83		83	100	100	92
TOA	100				100	0		50

Notes:
1. The letter codes used as headings refer to the study areas as follows: A - 'Ahau; V - Vaotu'u; F - Folaha; L - Lavengatonga; PU - Peri-urban Nuku'alofa; U - Urban Nuku'alofa.
2. The fuelwood types included here are the ten most commonly collected non-coconut fuelwood species.
3. Data, including zeros, are included only for those fuelwood types cited as 'most important'.

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strongly reinforced by the number of times it was given as a fuelwood type that was no longer available. Overall, 16 percent of respondents said they had used moli in the past but could not obtain it at the time of interview (Table 6.11). This was the only type of fuelwood to be mentioned in this regard in all six study areas. The species next most frequently cited as no longer available were koka and toi, each being mentioned by 9 percent of interviewees. The study areas where the highest proportions of respondents listed fuelwood types as being unavailable were Folaha and Peri-urban Nuku'alofa: 80 and 79 percent respectively. The fact that only three of the total of eighty-six respondents claimed

TABLE 6.10

Percentages of interviewees expecting levels of supply of non-coconut species to decline or to continue to be scarce. The data presented are based on interviewees' responses about their five most important types of fuelwood.

Fuelwood type[2]	Study areas[1]: A	V	F	L	Rural	PU	U	Overall
KOK	80	54	88	100	70	33	80	68
KUA	83	63	50	0[3]	62	67	33	59
FAU	29	50	60		44	75	0	45
TAV	63	67	100		68	50	67	67
SIA		0	100	57	63	0	83	68
TAH		67	100		86	67	100	82
MOL	100	50	100	100	80	100		80
MAN		50	100		67	0	0	40
TON			33		33	33	50	36
TOA	50				50	100		75

Notes:
1. The letter codes used as headings refer to the study areas as follows: A - 'Ahau; V - Vaotu'u; F - Folaha; L - Lavengatonga; PU - Peri-urban Nuku'alofa; U - Urban Nuku'alofa.
2. The fuelwood types included here are the ten most commonly collected non-coconut fuelwood species.
3. Data, including zeros, are included only for those fuelwood types cited as 'most important'.

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that particular coconut fuels were no longer available supported the view of the majority that supplies were plentiful and likely to remain so.

The information collected through interviews and surveys of trees in bush allotments, coastal sites, and residential areas permitted an assessment of the general situation with regard to fuelwood stocks on Tongatapu in 1986. Many of the favoured fuelwood species had been so severely depleted that their wood was no longer available. The commonest sources of wood for fuel were trees protected or managed for other purposes. Due to the decline in non-coconut trees, coconut

TABLE 6.11

Percentages of household characteristics interview respondents nominating previously used fuelwood types as being no longer available

	Study areas[1.]						
Fuelwood type	A	V	F	L	Rural	PU	U	Overall
Coconut fuels								
H&S		(7)[2.]			(2)			(1)
NIU			7		2			1
PAL				7	2	7		2
PUP					0	7		1
Totals	0	(7)	7	7	3+(2)	7	0	3+(1)
Fruit trees								
FEK			7		2			1
IFI			7		2	14		3
KUA	7			7	3	7		3
MEI	7				2			1
MOL	7	36	20	13	19	14	7	16
TAV					0		7	1
Totals	21	36	27	20	26	29	14	24
Non-fruit trees								
AHI	7	7			3	7	7	5
AKV	7				2			1
FIL			7	13	5			3
FKV			27		7		7	6
FOU		7	13	7	7	7		6
FUT		7			2			1
HAN						14	7	3
KAK				7	2			1
KOK		7	13	7	7	21	7	9
LEK			13		3	14		5

Continued

TABLE 6.11 Continued

Fuelwood type	A	V	F	L	Rural	PU	U	Overall
	Study areas[1.]							
Non-fruit trees (Continued)								
LOU			7		2			1
NGT		7	7	7	5	7	7	6
SIA		7	7		3	7	7	5
SIT							7	1
TAH		7	13		5	7	14	7
TAL		7		7	3			2
TOA		7			2			1
TOI	7		7	7	5	21	14	9
TON			20		5	7	14	7
Totals	21	21	80	33	40	64	43	44
Overall Totals	29	43	80	40	48	79	50	53
Valid cases:	14	14	15	15	58	14	14	86

Notes: 1. The letter codes used as headings refer to the study areas as follows: A - 'Ahau; V - Vaotu'u; F - Folaha; L - Lavengatonga; PU - Peri-urban Nuku'alofa; U - Urban Nuku'alofa.
2. Interviewee's response indicated the fuel type was much less available but not unobtainable

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residues had become more significant as domestic fuelwood because they offered continuing supplies.

6.2.7 Impacts of fuelwood collection on fuelwood stocks

The impacts of the collection of fuelwood on the level of stocks are determined by sets of factors related to:

(i) fuelwood production; and

(ii) fuelwood removal.

The rate of production of fuelwood depends on: physical characteristics of the site; ecological characteristics of the plant communities on the site; and land ownership, control, and management. The ways in which aspects of these factors interact to affect wood production rates vary from site to site but physical, biological, and cultural elements play a role in every case. Physical and biological factors were fundamental in determining the natural distribution of tree species across the island. Human activities have influenced the vegetation in two ways: by direct impacts on the plants themselves, and by changing the physical and biological components of the plants' external environments.

Direct impacts have resulted in increases in fuelwood production as well as decreases. Introductions of aggressive species such as leucaena and guava have contributed to increased rates of biomass production. While such introductions have caused significant changes to the distribution patterns of tree species on Tongatapu, they have provided sources of rapidly renewable fuelwood. Production rates have also been adversely affected by direct human intervention. Clearing of all types of forest to make way for agricultural, residential, and infrastructural development has occurred ever since humans first settled on the island. The rate of clearing has accelerated so greatly during the lifetimes of present inhabitants that no extensive areas of undisturbed vegetation survive. Disturbance less severe than total clearance has also had major effects on stands of natural vegetation. The degree of impact on rates of biomass production has varied with the resilience of the plant communities and the extent and nature of the disturbance. For example, the removal of favoured fuelwood species from areas of coastal forest in the 'Ahau study area has dramatically changed species diversity and thus severely reduced the ability of the community to recover to its former condition.

The recovery of plant communities to a maturity at which they regain a role as fuelwood sources has varied greatly according to land management. This in turn has depended on who has effective control over the land. In the case of agricultural land, attitudes of land-holders have greatly affected levels of fuelwood stocks. On bush allotments managed to traditional crop rotation principles, adequate vegetation was present for a reasonable level of fuelwood collection to have no significant impact on fuelwood stocks. Where large proportions of the available land had been cleared for commercial cropping, particularly where mechanised ploughing occurred, continued collection of fuelwood has had a much greater effect on the remaining non-crop vegetation.

The quantity of fuelwood gathered from a site was affected by a range of varied influences reflecting the size of the demand for fuelwood, accessibility to the site, and the type of wood on the site. Evidence gathered during fieldwork on Tongatapu in 1986 suggested that accessibility was the most significant factor. Areas of common land readily accessible from communities in which wood was an important fuel were most heavily affected by fuelwood collection. In contrast, tracts of land under private control and relatively remote from centres of fuelwood demand were observed to be only minimally affected. The types of wood available from a site also greatly influenced the collection effort focused on it. This was particularly evident in coastal areas where premium tree species had been all but eradicated while those yielding poor quality fuel remained. The cutting of live wood on common land, where restraint by any one individual was unlikely to result in sustainable supplies being available for that individual, had led to serious degradation of the vegetation and therefore of fuelwood stocks. In such cases continued gathering of fuelwood would have particularly serious consequences because trees producing good quality fuel would not be allowed to grow to a size at which they could provide sustainable supplies.

As much of the fuelwood collected from agricultural land came from trees maintained for non-fuelwood purposes, the removal of wood from many sites was effectively controlled. A farmer would not be willing to jeopardise the continuing provision of more valuable products, such as fruits, for the sake of obtaining fuelwood. In situations where taking wood from protected trees was not permitted and stands of non-protected trees on bush allotments were inadequate to meet fuelwood requirements, the main alternatives were coconut residues and wood collected from common land. Preferences for solid wood over coconut residues led to fuelwood collection placing considerable pressure on vegetation such as coastal forest which was accessible to all.

6.2.8 Impacts of fuelwood collection on natural and cultivated systems

The nature of fuelwood collection is such that it removes wood gradually, so that any degradation of vegetation usually occurs incrementally. The process is, therefore, quite different from clearance for broad scale agricultural or residential development. However, in the long term the impact of sustained fuelwood collection can be as severe as rapid clearance. The type and severity of impacts on natural and cultivated systems caused by fuelwood collection depend on the extent and methods of collection and on characteristics of the natural and cultivated systems. External factors, such as the presence of invasive plant species on adjacent land and the level of demand for fuelwood, can play important roles.

On Tongatapu the severity of degradation of coastal forest areas has been due to unrelenting pressure by fuelwood collectors, and in some areas clearance and reclamation to provide land for building. The impacts of intensive fuelwood collection tend to have been concentrated in areas adjacent to residential areas which maintained a high demand for fuelwood over a relatively long period of time. Within the study areas the greatest damage to coastal vegetation was being effected in 'Ahau and Tukutonga and by the depletion of mangroves around Folaha. Least degradation appeared to occur in Lavengatonga where alternative sources of fuelwood on agricultural land were plentiful.

The collection of dead wood is considered to have had relatively little direct impact on the health of plant communities but once uncontrolled cutting of live wood began, forested areas were quickly affected. As cutting continued, each incremental removal of live wood would have had an increasingly serious impact. Availability of chainsaws and motor vehicles had greatly reduced the time and effort needed to harvest trees and transport the cut wood. The potential damage to a natural community that could be caused by a single visit to collect fuelwood had therefore been very significantly increased. Where removal of live wood was controlled, such as on land managed for agriculture, the impacts of taking fuelwood were less severe in themselves but the overall management had changed the natural ecosystem into a very different combination of cultivated and protected species.

On coastal land the decline of favoured fuelwood species dramatically altered characteristics of the plant communities. Brief surveys of land adjacent to the village of 'Ahau and in Peri-urban Nuku'alofa confirmed that heavy pressure on unmanaged areas caused severe degradation. In both areas trees yielding high quality fuel had been removed while poorer quality species remained. Such selective cutting seriously impairs the regeneration of the plant communities to a condition representative of their former species combinations. This change affects not only the ecological integrity of the communities but also their ability to provide materials valued by the local people. While valued trees on bush allotments were protected, coastal trees producing culturally important items such as medicinal ingredients, bark for dyes, and seeds and flowers for decoration were readily accessible to all to be cut for fuelwood.

6.2.9 Impacts of fuelwood collection on domestic, social, and commercial systems

The collection of fuelwood had a range of impacts on aspects of domestic, social, and commercial systems on Tongatapu. The impacts were evident at levels from the individual household to the whole island.

The collection of fuelwood met essential daily requirements of virtually all rural households and a high proportion of urban households[3]. By providing energy for many domestic activities, collected fuelwood substituted for expensive commercial fuels. In households which had the resources to buy commercial fuels, collecting fuelwood helped to free available resources for the purchase of non-fuel commodities. The cost of collecting fuelwood was the time and effort required of collectors to harvest, transport, and prepare the wood. Each of these components varied from household to household and from village to village. Some interviewees in each of the six study areas said their main fuelwood collection method was for an adult male member of the household to bring wood from a bush allotment. In the rural villages this was the most common way of obtaining fuelwood. This procedure caused the minimum of disruption to the household's routine. The adult male was in almost all cases the person devoting most time to agricultural work on the bush allotment, so gathering and transporting fuelwood could be readily assimilated into his work schedule. In many cases women and sometimes children were also regular workers on the bush allotment, and so were also involved in fuelwood harvesting and transport.

Where such an ostensibly convenient method of fuelwood collection could not be adopted or did not provide an adequate quantity of wood, excursions were made

3. The roles of fuelwood consumption are discussed in Section 6.3 below.

from the home with the specific purpose of collecting fuelwood. While such ventures were normally to the closest source of wood, they tended to make greater demands on time than did the collection of similar quantities of wood on regularly visited bush allotments.

The collection of fuelwood had several ramifications within village social systems. One of the most important expressions of social cohesion was feasting. As most households prepared at least one feast per year, usually in association with a church, large amounts of fuelwood were required for this purpose and its collection was often a considerable undertaking. On a smaller scale, the provision of adequate quantities of good quality wood to fuel the Sunday 'umu made an essential contribution to the maintenance of a culturally important activity. The process of collecting fuelwood often both relied upon and contributed to social ties within a community. Households commonly gathered fuelwood from bush allotments belonging to other households. Only four of the forty-five bush allotment holders interviewed said that rights to take fuelwood rested only in the holder's household. The majority of responses included members of extended families and many said that others outside the allotment holder's household could collect wood with the owner's permission. Four respondents said that anyone in the village had the right to take fuelwood from their allotment.

The use of vehicles to transport fuelwood appeared to link households in a way which reinforced social status. Within the rural study areas only a small proportion of households owned either a cart or a motor vehicle. In one village a householder was frequently asked to lend his cart for the carriage of agricultural produce and fuelwood. He generally felt obliged to meet such requests but would have preferred not to have this obligation. Many owners charged a fee, generally T$2.00 to T$5.00, for the use of their vehicle. The payment of such charges probably eliminated the social obligations associated with the favour of lending a vehicle, but the implications of this commercialisation were not investigated.

Fuelwood collection could potentially lead to some problems in social systems. For example, if children were to be required to spend long periods of time collecting wood their schooling could be adversely affected. If fuelwood stocks became more degraded there would be a greater chance of wood being taken from bush allotments without the landholders' permission. If such activity were to become common the mistrust it would generate could severely upset established social stability.

For the majority of households interviewed, the collection of fuelwood involved no financial transactions. A minority paid for transport facilities, more commonly among Nuku'alofa households, and two interviewees said they paid for wood which they harvested themselves.

6.3 Roles and impacts of fuelwood consumption on Tongatapu in 1986

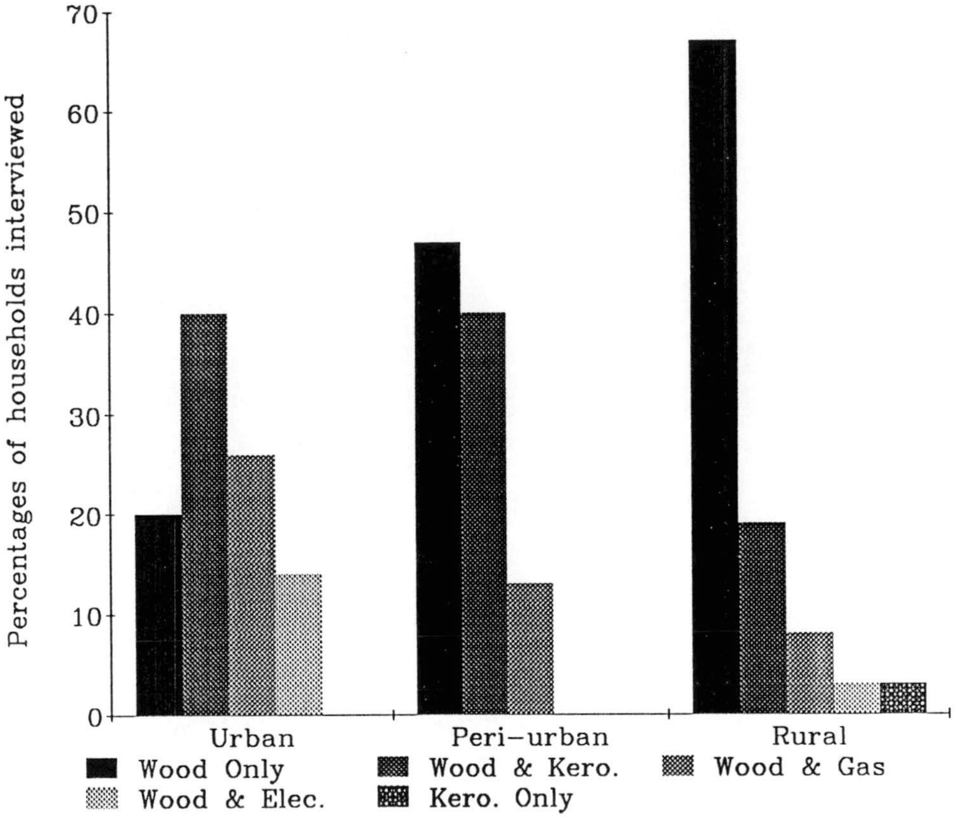
6.3.1 Purposes for which fuelwood was used

In all study areas cooking was the most significant purpose for fuelwood consumption. Only two of the ninety households interviewed did not cook with fuelwood, although two in Peri-urban Nuku'alofa used it only in the 'umu. The dominance of wood as cooking fuel was most clearly evident in the Rural study areas where it was the sole cooking fuel for 67 percent of interviewed households. Comparative figures for Peri-urban and Urban Nuku'alofa were 47 and 20 percent respectively The pattern of fuelwood use, as the sole cooking fuel and in combination with kerosene, gas, and electricity, is shown in Figure 6.5.

Proportions of interviewees using fuelwood to heat water were similar in Nuku'alofa and Rural study areas: 90 percent and 87 percent respectively. Some marked variations were evident, however, in percentages of households using fuelwood for purposes other than cooking. While wood was used to fuel fires for boiling pandanus leaves in 80 percent of Urban households interviewed and 82 percent in the Rural study areas, only 60 percent of Peri-urban respondents said they burnt fuelwood for this purpose. Similarly, coconut oil was produced by 80 percent of Urban and 67 percent of Rural households, but only 40 percent of Peri-urban households. An even greater contrast was evident with regard to drying copra; 40 percent of Rural interviewees used wood and coconut residues to fire dryers and 13 percent of Urban respondents did so, whereas none of the Peri-urban used fuelwood for this purpose. The Peri-urban study area also had the highest proportion, 27 percent, of households not using fuelwood for non-cooking purposes.

FIGURE 6.5

Percentages of households interviewed in 1986 in Urban, Peri-urban, and Rural Tongatapu study areas using various combinations of fuels to meet their domestic cooking requirements



Notes: 1. 'Wood' includes all woody biomass fuels; 'Kero.' means kerosene; 'Gas' refers to bottled liquid petroleum gas; 'Elec.' refers to grid electricity bought from the Tonga Electric Power Board;

6.3.2 Estimated quantities of fuelwood consumed

The per person fuelwood consumption data presented in Table 6.12 are based on interviewed households' estimates of quantities of fuelwood used. These figures show study area averages of estimated total annual fuelwood consumption to vary from 950 to 1770 kilogrammes per person per year. Only in Urban Nuku'alofa was the weight of wood consumed less than 65 percent of the total average fuelwood consumption, and coconut fuels more than 35 percent. In

Lavengatonga, where sialemohemohe was plentiful, 78 percent of the total average per person consumption was wood. The next highest percentage of wood, 77 percent, was recorded in the Peri-urban study area, where the area of agricultural land available to the average household was at its lowest.

The consumption of commercial fuelwood varied considerably between the Nuku'alofa and rural study areas. The estimated 2.4 tonnes of husk and shell purchased per year by the two Folaha households buying coconut fuels represented 5.3 percent of the total annual coconut consumption of the fifteen households in the Folaha sample, and 1.4 percent of the total for the sixty rural households interviewed. One interviewee in 'Ahau obtained offcut slabs of coconut stems from a sawmill but did not pay for them. These represented 6.8 percent by weight of the estimated total amount of coconut fuel consumed annually by the sample households in rural study areas. If this is added to the husk and shell bought by Folaha households the amount of coconut fuel coming from commercial sources was 3.3 percent of the annual consumption by rural households.

The situation with regard to purchased fuelwood was quite different in Nuku'alofa. Overall, 17 percent of the estimated annual wood consumption and 69 percent of coconut fuels consumed came from commercial sources. The contributions made by bought coconut fuels were similar in the Peri-urban and Urban study areas with 73 percent and 67 percent of the respective totals. However, a considerably higher proportion of wood was bought by Urban households than by their Peri-urban neighbours. The 4.0 tonnes of wood bought per year by Peri-urban households interviewed accounted for 5.2 percent of their annual requirements, but Urban respondents purchased 24 tonnes, 28 percent of yearly consumption. Overall, 33 percent of fuelwood consumed by the Nuku'alofa households interviewed was purchased.

The consumption estimates derived from results of the author's interview survey are consistently higher than estimates presented by other studies. A comprehensive investigation of fuelwood consumption was made by the UN Pacific Energy Development Programme in 1984. That study estimated average per person per day consumption to range from 1.4 kg in Kolomotu'a to 2.2 kg in

TABLE 6.12

Estimates of per person fuelwood consumption among households interviewed in six study areas in Nuku'alofa and rural Tongatapu in 1986

	Wood		Coconut fuels		Totals	
Study area	kg/day	kg/year	kg/day	kg/year	kg/day	kg/year
'Ahau	3.4	1240	1.5	530	4.9	1770
Vaotu'u	3.1	1120	1.4	520	4.5	1640
Folaha	3.0	1110	1.4	520	4.5	1630
Lavengatonga	3.1	1130	0.9	310	4.0	1450
Rural	3.1	1150	1.3	460	4.4	1610
Peri-urban	2.0	730	0.6	220	2.6	950
Urban	2.1	780	1.2	430	3.3	1210
Nuku'alofa	2.1	750	0.9	330	3.0	1080
Overall	2.7	1000	1.1	410	3.9	1410

eastern Tongatapu (UN Pacific Energy Development Programme 1985). The rural average of these data was 2.1 kg; the Nuku'alofa average was 1.4 kg; and the weighted average for the whole of Tongatapu was 1.8 kg per person per day. These averages are all approximately two-thirds the value of the estimates based on the author's survey results.

There are a number of possible explanations for this discrepancy. It is possible, though unlikely, that the patterns of fuelwood consumption in the two sets of households sampled were significantly different. A second possibility is that the discrepancy reflects seasonal variations in consumption. The author's survey was conducted between January and June 1986; the UN Pacific Energy Development Programme study was undertaken in November and December 1984. The more likely reason for the differences in survey results is to be found in the methods of collecting the data. The UN Pacific Energy Development Programme estimates were based on weighings of quantities of fuelwood considered by householders to represent one day's requirements. The author's estimates are based on data gained from interview questions about fuelwood consumption, responses to which were generally given in volume units such as baskets, bundles, and cart-loads. From a small number of measurements for each unit, standard unit volumes were calculated. These were used to obtain household volumes, and conversion factors were employed to gain estimates by weight.

In both studies there could have been inaccuracies in householders' assessments of quantities of fuel used. The monitoring technique used in the UN survey could have been subject to underestimation if householders were unused to compiling collections of fuelwood to be consumed over a one day period. The author's approach attempted to overcome this artificiality by allowing respondents to describe quantities in whatever terms they felt most comfortable using. Supplementary questioning was used to ascertain whether unit sizes were non-standard. While care was taken to accurately measure volumes and weights of samples of fuel relating to the measurement units, variations between households in the density of stacking could have generated significant discrepancies.

There are shortcomings to whichever monitoring technique is adopted. Even if all fuelwood used by a household is weighed over an extended period there is a real chance that consumption patterns are changed by the imposition of the monitoring programme. The two sets of data available for Tongatapu are probably best interpreted as both being valid approximations of fuelwood consumption. If more precise estimates should be required it is recommended that further monitoring in a full range of Tongatapu communities and at all times of year should be undertaken to provide continuing information about patterns and trends in fuelwood consumption.

6.3.3 Types of fuelwood consumed

The data collated from responses to household characteristics interviews indicate that overall the most significant general type of fuelwood used originated from non-fruit trees; 93 percent of fuelwood using respondents included this category of wood among their five most important fuelwood types. Coconut fuels were said to be important for 84 percent and fruit tree wood for 63 percent of households (Table 6.13). The highest proportion of respondents saying coconut

TABLE 6.13

Percentages of fuelwood using households interviewed in Urban, Peri-urban, and Rural study areas including various categories and species of wood among their five most important fuelwood types

	Urban	Peri-urban	Rural	Totals
General categories				
Coconut fuels	93	67	86	84
Fruit trees	53	40	70	63
Non-fruit trees	93	87	95	93
Non-coconut species				
KOK	40	20	57	48
KUA	27	27	45	39
SIA	40	20	36	34
FAU	13	27	33	28
TAV	20	13	33	27
MOL	0	13	26	19
TAH	7	20	12	13
TON	20	13	10	13
PUL	0	0	12	8
FET	7	33	0	7
Valid cases:	15	15	58	88

fuels were among their five most important fuelwood types was recorded in Urban Nuku'alofa where fourteen of the fifteen interviewees (93 percent) stated this to be the case. In the rural study areas the figure was 86 percent and in Peri-urban Nuku'alofa coconut fuels were important for 67 percent of households.

Of a total of thirty-five non-coconut species mentioned in households' lists of most important fuelwood types seven were fruit trees. Of these only kuava and tava were cited by more than 10 percent of households in Urban, Peri-urban, and Rural study areas. Moli was included by 26 percent of rural households but no Urban respondents mentioned it. In two of the rural villages no more than ten species were said to be important, and in both cases a single species was dominant. In Vaotu'u all fourteen fuelwood using households included koka among their five most important fuelwood types while in Lavengatonga all fifteen included sialemohemohe. In Urban Nuku'alofa, where sixteen species were named, koka and sialemohemohe were equally popular, each included by just six households. Each of the five species most commonly nominated in the Urban study area had been cited as important in at least one of the Rural villages, but the most frequently listed species in Peri-urban Nuku'alofa had not been mentioned elsewhere. Feta'anu was generally considered to offer poor quality fuelwood and so was in most areas one of the last types of wood to be considered. The fact that it was important to five Peri-urban households suggests that good quality fuelwood was hard to find. Being a coastal tree, feta'anu grew predominantly on land to which all collectors had access.

6.3.4 Types of fuelwood preferred

While a broad range of wood species and coconut residues was named as preferred fuelwood types, three species were particularly favoured: sialemohemohe, koka, and kuava (Table 6.14). Patterns of popularity of these fuelwood types varied across the six study areas. Of the total of eighty-seven respondents twenty-four gave sialemohemohe as their preferred fuel for the open fire, but fifteen of these lived in Lavengatonga. Preferences for sialemohemohe as 'umu fuel were similarly dominated by all fifteen Lavengatonga households. For use as open fire fuel both koka and kuava were among the most favoured species in the three rural study areas other than Lavengatonga and in Urban Nuku'alofa. Opinions about these same two species as 'umu fuel was rather different. All but one of fourteen Vaotu'u respondents included koka as a 'best' type for the 'umu; next most favoured was moli, named by five households. In 'Ahau preferences were more evenly spread. Koka and tava were the two species nominated as preferred 'umu fuel by five households; next came moli and toa, mentioned by three and two interviewees respectively. In Folaha six species got at least two votes as best 'umu fuel. Kuava came at the top of the list, nominated by six respondents, then tongo, given by five, followed by koka and moli, both included by four households. In the four rural study areas a total of thirteen fuelwood types were offered as preferred 'umu fuels. A larger number of fuelwood types was mentioned by Nuku'alofa households, a total of twenty-four, including five types of coconut residue. Only five species were nominated as preferred 'umu fuels by more than two Nuku'alofa households. Sialemohemohe was given by eight respondents, koka and tava both by four, and moli and kuava both by three. The main difference between Urban and Peri-urban Nuku'alofa was the inclusion of more coastal species as preferred fuelwood types by the Peri-urban households.

TABLE 6.14

Most frequently mentioned fuelwood types preferred by households interviewed in 1986 in Rural Tongatapu and Peri-urban and Urban Nuku'alofa, and percentages of fuelwood using households naming preferred types

Rural Tongatapu		Peri-urban Nuku'alofa		Urban Nuku'alofa		Overall	
Fuelwood types preferred for use on the open fire							
SIA	31%	SIA	21%	SIA	20%	SIA	28%
KUA	22%	FAU	14%	KUA	20%	KUA	20%
KOK	17%	HAN	14%	KOK	13%	KOK	15%
TON	10%	TOA	14%	MOL	13%	MOL	10%
TAV	7%	HUS	14%	TAV	13%	TON	9%
H&S	7%	SHE	14%				
Fuelwood types preferred for use in the 'umu							
KOK	38%	SIA	21%	SIA	33%	KOK	30%
SIA	29%	FAU	14%	TAV	20%	SIA	29%
MOL	21%	HAN	14%	KOK	13%	MOL	17%
KUA	17%	KOK	14%	KUA	13%	TAV	16%
TAV	17%	LEK	14%	TAH	13%	KUA	15%
		MOL	14%	NIU	13%		
		TOA	14%				

6.4 Limitations on components of the fuelwood systems on Tongatapu

6.4.1 Limitations on fuelwood supply

6.4.1.1 Supply from unmanaged forest land

The main limitation on fuelwood supply from accessible unmanaged forest was severe degradation. Heavy pressure on unmanaged coastal and inland forests had caused damage to plant communities which imposed limitations on both current and potential future supplies of fuelwood. Even if fuelwood collection could be prevented from further eroding fuelwood stocks threats of clearance for development would still exist. While some legislative protection existed to control the cutting of mangrove trees it was not effective in stopping the destruction of mangrove forests. Even this attempt at protection related only to mangrove species; other favoured fuelwood trees had been almost totally removed from large areas of coastal forest.

The largest areas of remnant forest in the interior of Tongatapu were under the control of a boarding school and the Environment, Parks and Reserves Division of the Ministry of Lands, Survey and Natural Resources. The best preserved section of forest, at Pelehake in the eastern district (King 1986), was designated a reserve in 1986 which precluded its being a site for fuelwood collection.

6.4.1.2 Supply from cultivated land

Increasing use of land for more intensive agriculture affected supplies of fuelwood in a number of ways. Abandonment of traditional crop rotation systems with their long periods of fallow meant that there was less land under fallow at any time, and that less vegetative biomass was produced before the fallow area was cleared for renewed cropping. This not only reduced the volume of fuelwood available from fallow land, but also degraded the source of mature trees to generate new fallow growth. The move away from traditional management techniques was instigated by the desire to maximise commercial gain from farming, and facilitated by the availability of 'modern' agricultural machinery and inputs. In providing the means for farmers to cultivate large proportions of their available land the use of tractors and ploughs encouraged the clearance of trees but did not require their complete removal. While most lesser valued tree species were less abundant on commercial allotments than on traditional allotments, traditionally protected trees, such as fruit trees and koka, were often still protected. This suggested that some landholders were keen to attain advantage from commercial cropping, but still wanted to retain the most beneficial aspects of traditional management systems. The types and numbers of trees remaining on such allotments placed a limitation on fuelwood supply. The traditional management of koka trees included lopping branches to provide trellis material to support yams, but the removal of branches from productive fruit trees was unlikely to be acceptable.

Overall, the increasing commercialisation of agricultural activity had tended to lead towards lower priorities being given to non-commercial benefits of land management such as fuelwood production. Seventy-two percent of interviewees said they had planted trees on their bush allotments but none gave fuelwood production as a reason for planting. Of the twelve non-coconut types planted seven (mei, mango, avoka, moli, tava, ifi, and vi) were fruit trees, three (oke, 'timber', and pulukamu) were timber trees, one (lou'akau) produced handicraft material, and one (fiki) was the tree conventionally used to support vanilla vines (Table 6.15). The domination of protected species on bush allotments tended to reduce the quality of available fuelwood as well as the quantity. Wood from the most commonly planted tree, mei, was considered to be a low quality fuel. Only moli and tava were commonly held in high regard as preferred fuelwoods.

6.4.1.3 Supply from town trees

Supplies of fuelwood from town trees were limited largely because the growth of trees in town areas required positive consideration and actions by residents. With the exception of some little-used corners, land within village and town boundaries was under heavy pressure of human utilisation and disturbance by domestic animals. There was little opportunity on most town allotments for naturally regenerated vegetation to proliferate. The great majority of trees growing in towns were those which, by performing particular purposes, were worthy of special protection. Limitations similar to those for protected trees on bush allotments also applied to town allotments. By far the most commonly

TABLE 6.15

Numbers and percentages of interviewed households planting trees on bush allotments, by type of tree in rank order

Rank Order	Tree Code	Number of Households Planting	Percentage of Total Households	Percentage of Tree-planting Households
1	MEI	17	37	52
2	MAN	14	30	42
3	LOA	7	15	21
4=	AVO	5	11	15
4=	MOL	5	11	15
4=	TAV	5	11	15
7	IFI	4	9	12
8=	OKE	2	4	6
8=	TIM	2	4	6
8=	VII	2	4	6
11=	FIK	1	2	3
11=	PLK	1	2	3
Valid cases:			46	33

grown tree was mei, planted by nearly half of all interviewed households (Table 6.16). Five of the ten most frequently planted town allotment species were fruit trees (mei, mango, moli, tava, and 'apele initia); one (lou'akau) provided handicraft material; and four (kalosipani, si, tuitui, and 'olive) were grown as ornamentals and for the production of culturally significant decorative materials such as seeds, fruits, and flowers. All types of tree were also valued for the shade and shelter they provided. As with the trees planted on bush allotments, only two of these ten species (moli and tava) were favoured fuelwoods. The desire for trees around the home to present an attractive appearance as well as provide specific material benefits largely precluded the use of planted trees as sources of fuelwood.

Surveys of trees in town areas within the Urban and Peri-urban Nuku'alofa study areas and in 'Ahau indicated that while planted trees were dominant, some

TABLE 6.16

Numbers and percentages of interviewed households planting most frequently mentioned types of trees on town allotments, by type of tree in rank order

Rank Order	Tree Code	Number of Households Planting	Percentage of Total Households	Percentage of Tree-planting Households
1	MEI	42	47	56
2	MAN	19	21	25
3	LOA	10	11	13
4=	KAL	9	10	12
4=	MOL	9	10	12
6=	SII	6	7	8
6=	TAV	6	7	8
6=	TUI	6	7	8
9=	API	5	6	7
9=	OLI	5	6	7
11=	FAU	4	4	5
11=	LEM	4	4	5
11=	MOH	4	4	5
11=	TOA	4	4	5
15=	AVO	3	3	4
15=	FEO	3	3	4
15=	HEI	3	3	4
15=	KAU	3	3	4
15=	KUA	3	3	4
15=	PUA	3	3	4
15=	SIL	3	3	4
Valid cases:			90	75

naturally regenerated species were present in significant numbers. These were located mostly on common or unallocated land and unoccupied allotments. In Tukutonga the commonest tree was toa, which had been extensively planted to provide protection from the wind but which, given suitable protection, would self-regenerate. Next most common in this area was fau, one of the main components of the natural vegetation. Mei trees were less than half as abundant as fau, largely because the coastal conditions in Tukutonga were far from ideal for this fruit species. The next two most frequently recorded species, telie and touhuni, were representative of the natural plant community but were present in small numbers: seven and six specimens respectively compared to one hundred and nine toa trees and forty-six fau. The fact that toa trees had been planted to perform the wind protection function previously provided by natural vegetation indicates that further degradation of coastal trees by removal of live wood for fuel would be unwelcome. Fuelwood collection would, therefore, be limited to the dead wood generated mainly by planted trees.

In Urban Nuku'alofa, planted fruit and ornamental trees predominated. Mei, mango, and tava were present in large numbers, as was tanetane, an ornamental small tree used in hedges on allotment boundaries. Even here, fau, a species less likely to be closely protected, was relatively common; twenty-eight fau trees over 2 metres high were recorded, compared to one hundred and eleven mei and eighty mango trees. However, given the density of population in the Urban area these few trees could make little contribution to the total fuelwood requirement.

The situation in 'Ahau was similar; eight of the ten commonest town trees were listed in the special purpose category (Appendix 5). Of the other two species fau was relatively abundant, with fifty-two specimens to mei's sixty-three, but only six lalatahi trees were recorded. As in the other areas surveyed the majority of town trees were protected for special, non-fuelwood, purposes, and many produced less favoured, lower quality fuel. Significant quantities of fuelwood were unlikely to be available from town trees unless its provision was valued highly enough for trees to be specially planted and protected.

6.4.1.4 Supply of woody residues for use as fuel

Sawmilling was a relatively small-scale activity on Tongatapu in 1986. As there were very few trees grown specifically for timber, the majority of the wood processed came from the stems of senile coconut palms. While offcuts from milling operations were sold, both by the truck-load and in small bundles, the volume of fuelwood available represented a small proportion of total consumption on the island. A limitation to the widespread use of this residue fuel was the need to transport it from the mill to the home. This restricted its use to local households, owners of suitable vehicles, and those who could afford to hire such transport.

In 1986 significant quantities of coconut husk and shell were sold by the Tonga Commodities Board to Nuku'alofa residents. The desiccated coconut factory was processing approximately 160 000 coconuts per week. All the shells and about two-thirds of the husks were sold to the public. The air-dry weight of these weekly residues would have been about 71 tonnes, representing approximately 37 percent of Nuku'alofa's coconut fuel consumption. Following the closure of the desiccated coconut factory in January 1989 (*Matangi Tonga* 5(5), October/November 1990, p.36) the volume of coconut residue produced by industrial processes must now be considerably reduced.

Obtaining coconut husks and shells from the factory site in Haveluloto required the use of a suitable motor vehicle. For those households who did not have their own transport the cost of hiring a vehicle was greater than the price charged for the coconut residue. The location of the factory on the outskirts of Nuku'alofa meant that it was a convenient source of fuel only for town residents and those living in adjacent villages.

Coconut residues generated in rural villages were generally fully utilised as fuel. Domestic residues from food preparation and from feeding pigs were almost always used as cooking fuel. The quantities of husks and shells made available by these processes were not adequate to provide for all cooking requirements. Copra drying usually used fewer husks and shells as fuel than were available from the nuts being processed, and the surplus was usually used as domestic fuel. The copra drying process did, however, require some wood to be burnt, so overall the fuel energy required by conventional village scale dryers was likely to be at least as great as the energy content of the husks and shells of the coconuts dried.

6.4.2 <u>Limitations on the use of fuelwood</u>

6.4.2.1 Natural phenomena limiting fuelwood use

There were two aspects of the physical natural environment which placed limitations on the use of fuelwood. During the rainy season most households used less wood due to the difficulty of finding dry fuel and the inconvenience of operating an open fire in wet conditions. Similarly, flooding, either from rain or by inundation from the sea, created conditions on low-lying town allotments which made the use of fuelwood difficult or unpleasant. Households who had alternative methods of cooking, or who were prepared to eat food which did not need cooking, would avoid using wood fires in such situations. The problem with using open fires in wet conditions was most severe in areas subject to waterlogging. In Nuku'alofa, districts most frequently seriously affected by flooding were also those areas inhabited by people who did not have the resources to use cooking appliances other than the open fire. Householders whose normal kitchen sites were under water resorted to making use of raised ground, such as roadsides, to set their cooking fires (Plate 5). This was clearly an inconvenient and unsatisfactory situation.

6.4.2.2 Lack of household facilities

Few households had efficient wood stoves, or convenient indoor facilities for cooking with wood fires. While some householders preferred to use wood burning cooking appliances, most of those interviewed expressed interest in replacing open fires with kerosene, gas, or electric stoves. There appeared to be varied reasons for these preferences, but without facilities available to make wood a convenient fuel to use, commercial fuels were more attractive. For wood to be able to compete with electricity, gas, and kerosene, indoor appliances which were clean and convenient to use would be essential. In 1986 a local engineering firm did produce a metal wood burning stove with a flue, but the cost of production, nearly T$300, put it beyond the reach of the average household.

6.4.2.3 Hazards presented by the use of fuelwood

While all cooking devices have hazards associated with their use, air pollution and safety hazards related to wood burning appliances are of particular concern.

Woodsmoke generated by open fires and stoves can be a source of unpleasant irritation to the appliance operator. Unless provision is made to effectively remove the smoke it can cause considerable immediate discomfort and prolonged exposure can have serious detrimental effects on human health (De Koning 1987;

Smith 1987; Quraishi 1985). Health impacts claimed to result from high exposure to woodsmoke can be grouped into six categories: low birth weight babies; acute respiratory infections in children; chronic obstructive lung disease; heart disease caused by pulmonary distress; cancer; and eye problems (de Koning 1987, Smith 1987). While some researchers consider that links between exposure to woodsmoke and cancer in humans have not been substantiated (Smith 1987), the irritation caused to eyes and the respiratory tract is sufficient reason for most people to want to avoid continued exposure to woodsmoke. Uncomfortable working conditions constitute a significant disincentive to continued utilisation of wood burning appliances.

All the while a household does not have facilities such as an enclosed stove with flue, or a well designed chimney which would allow the clean use of a wood fire within the main living building, the healthiest locations for the cooking fire are in the open air or in a traditional Tongan kitchen. Operating an open fire within a closed building with no chimney has other disadvantages apart from the serious risks to health. Creosote, caused by the condensation of tar compounds in the smoke, is deposited on exposed surfaces and rapidly builds up as a sticky black coating unless those surfaces are frequently cleaned. Leaching of creosote into water supplies could represent another risk to health (Todd 1986).

A potentially serious hazard of using a wood fire indoors is the risk of setting fire to the building. Deaths caused by traditional Tongan houses, fale Tonga, catching fire are tragically frequent (*Tonga Chronicle*, 5 October 1990, p.3, and 16 November 1990, p.1). The traditional pattern of building use did not have cooking fires located in sleeping houses; this reduced the risk to human life, but if fires are to be used in more modern buildings which do include sleeping quarters adequate safety measures must be taken.

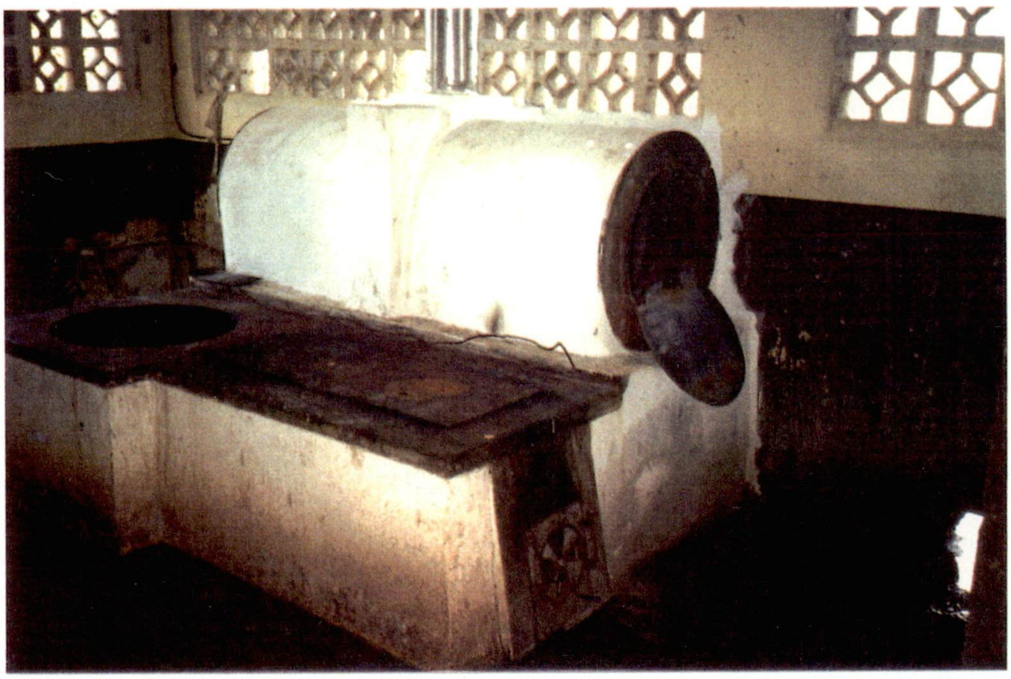
Wherever an open fire is located risks to human well-being exist, in particular the danger of young children falling into the fire or touching hot surfaces. While similar hazards are present with the use of other cooking appliances, they are more difficult to guard against with an open fire.

PLATE 5

Flooding sometimes forces peri-urban households to cook on the roadside

PLATE 6

An institutional woodstove introduced by the UN for use in schools



6.4.2.4 Inconveniences of using fuelwood

There are several factors that contribute to fuelwood being an inconvenient fuel to use. Compared to commercial fuel appliances open fires and many wood stoves are time consuming, dirty, uncomfortable to operate, limited in the cooking methods they offer, and low in social status.

Operation of a wood burning appliance requires fuel handling and preparation, lighting of the fire some time before it is to be used, and maintenance of the appliance itself. Woodsmoke and ashes produced by the fire make its management a dirty activity as well as uncomfortable and unhealthy. However, open fires do have advantages; they are simple to construct, versatile, and easy to regulate, and when well managed can be surprisingly efficient (Flood 1986; Micuta 1985). A restriction on cooking methods with open fires is that they cannot easily be used to bake food; this was increasingly in demand among interviewees in 1986. To be operated to their optimum efficiency open fires need constant attention and a fair degree of skill. The time demanded to manage a fire can put unwelcome restrictions on the fire operator's social activities. In 1986 the open fire was the accepted appliance for cooking and heating water in the rural villages, where only a few households used kerosene, gas, or electric stoves on a regular basis. In Nuku'alofa the prevailing attitude towards open fires appeared to afford them a low social status.

6.5 A proposed strategy for identifying options to achieve a sustainable balance between fuelwood supply and fuelwood consumption on Tongatapu

Achieving a sustainable balance between the supply and consumption of fuelwood would require a range of changes to the system operating on Tongatapu in 1986. Changes could be made at a number of levels, in a range of sectors within the system, and in various combinations. The second, creative, phase of the research theme required the presentation of a strategy for gaining sustainable improvements in the fuelwood situation. The strategy developed to fulfil that requirement is described here.

6.5.1 Introduction to the proposed strategy

The determination of options to improve the balance between fuelwood supply and demand is a development activity and thus strategies will vary according to the approach to development adopted by those implementing the programme of change. An institutional approach conforming to capitalist objectives would utilise quite different implementation programmes from a personal approach aimed at satisfying basic needs. This wide spectrum of attitudes towards change reflects the broad range of needs that exists in developing societies. Given this context, it is not possible to abstractly prescribe a plan of action that will be acceptable to all. What is outlined here is a strategy to guide the development of appropriate programmes of change to improve local fuelwood situations.

The focus of the strategy is a procedure to design and select options to make practical contributions to a programme of change. Operation of this procedure depends fundamentally on two components: decision-making and information. Practical achievement of the aim and objectives established by the procedure requires a third component: implementation. The composition of each of these three components will vary according to particular characteristics of the society in which the procedure is to operate, and the way in which the procedure is approached. Carrying out the procedure requires inputs in two other areas: initiation and facilitation. In sequential order the stages of the strategy would be:

- initiation;
- facilitation of the design and selection procedure;
- decision-making, to complete the design and selection procedure;
- practical implementation of options selected to constitute the programme of change.

The fulfilment of each stage requires input of adequate, relevant information.

Activities relating to these stages are carried out as everyday events at an individual scale by householders and landholders. The process is unlikely to be analysed in this way, but each component is present in whatever change is instigated. An idea for an improvement in agricultural management might be initiated by a government message on the radio, by a tip from a neighbour, by advice from a foreign development assistance volunteer, or by the farmer recognising a problem him/herself. The collation of information to facilitate the development of possible solutions could be undertaken by the individual farmer or a group of farmers, or perhaps by a government adviser called in to assist. The decision-maker in the case of the individual scale activity will normally be the landholder or householder, but others' approval might be required. At this scale of activity the implementation is likely to be the responsibility of the individual.

Larger scale programmes of change to improve the balance between fuelwood supply and demand inevitably involve more complex processes. More people are involved and affected, and the range of factors to be considered broadens. When developing a fuelwood strategy, the scale at which it is to operate needs to be carefully assessed. Operating the design and selection procedure repeatedly at a very small scale is unlikely to be efficient in terms of the effort required from organisers. At too large a scale, the individuals on whom the success of the strategy will depend could feel any input they could make would be so small that involvement would not be worthwhile. It is, therefore, necessary to strike a balance that suits the available resources and is appropriate to the structure of the community. This question of scale is addressed in more detail below during the development of a possible strategy for the island of Tongatapu.

At whatever scale the strategy is to operate, its effectiveness will rely on the quality of information available, the capabilities of the facilitators and decision-makers, and the enthusiasm and skills of the practitioners who are to implement the programme of activities. Access to adequate information is essential for all parties to the strategy: initiators, facilitators, decision-makers, and practitioners. The holistic model which guided the description of the regional environment required by the thematic approach to the Tongatapu research suggests a broad variety of information needs to be collated. The relevance of formal presentation of components of this description will depend on the background of the individuals needing to be informed. All will have some knowledge of the environmental context but this is likely to have been gained from a range of perspectives. More detailed information about factors influencing fuelwood production and consumption will be required to assist consideration of options for local communities. It is suggested that the systems framework utilised in the Tongatapu research to provide profiles of the six study areas (Figure 1.4) would be a useful foundation for the compilation of this information. Considerable discussion will be required if all participants are to understand the attitudes held by various affected groups towards the factors that significantly impinge on the fuelwood situation. For the optimum solution to be found and implemented this broad understanding and tolerance of others' perspectives must be achieved. Technical information must be presented in such a way that all participants gain a meaningful understanding of it.

To operate successfully, facilitators and decision-makers require certain analytical and communication skills. It is also important that their standing within the community should be such as to ensure that their roles and recommendations will be respected. In tackling an issue as broad as overcoming fuelwood shortages there are likely to be people involved in making decisions who have quite different priorities. All those whose decisions can be identified to have significant influence on the viability of a programme to change fuelwood supply and demand should, ideally, be involved in the collective procedure to identify options. In particular, decision-makers should include representatives of the people to benefit from the programme of changes to be implemented, representatives of those providing resources, and representatives of those components of the environment which would be affected by the proposed changes. The latter group should have as detailed as possible an understanding of the direct and indirect implications for physical, biological, and cultural components. The role of the facilitator is crucial in maintaining a balance when addressing the various factors which will influence decision-makers. The choice of facilitator is therefore vital to the successful undertaking of the strategy.

The practitioners who implement the options selected by the decision-makers are perhaps the most important people to participate in the strategy. Without their activities no practical gain can be achieved. If they are enthusiastic participants benefits will be much greater than if they have to be coerced into involvement. It is important for consideration of their requirements to be included at all stages of the strategy. If an option selected is the installation of improved wood-burning stoves, detailed appraisal of the needs and preferences of stove users will be absolutely essential for the programme to be successful. If fuelwood production is to be enhanced by planting trees on agricultural land, the implementation of such an option would rely on landholders being able to anticipate clear benefits. For this to occur, consideration of tree-planting as an option would have to have been based on a thorough understanding of land management practices.

The nature of the procedure to guide the identification of options is central to the proposed strategy for bring about a programme of change. This procedure is examined next, and its relationship to the roles of the initiation and implementation stages outlined. Ways in which all stages of the strategy might operate on Tongatapu are discussed in Section 6.5.3.

6.5.2 A procedure for the design and selection of options

The development of the procedural guidelines presented here has been underlain by the assumption that fuelwood systems are to be sustainable. This criterion demands an approach that is quite different from an approach based on, say, the maximisation of short-term monetary gain. To achieve sustainability the broad implications of any proposal need to be assessed as well as the degree to which the central objective is attained. Changes in non-human ecological systems as well as in anthropocentric socio-economic conditions thus need careful consideration. If the sustainability sought includes the continued well-being of non-human entities, as required by the non-anthropocentric approach argued in Chapter 1, then impacts on natural components of the environment will be as significant as effects on human-centred components.

The procedural guidelines developed to assist the design and selection of options to achieve sustainable fuelwood systems consist of the following steps.

1. Define, and justify, the aim and objectives which the chosen option is to meet.
2. Determine the system boundaries within which the aim and objectives operate.
3. Identify as broad a range as possible of technically feasible contributions towards achieving the defined aim and objectives.
4. Discuss the recognisable advantages and disadvantages, idiosyncrasies, and potential influences of the range of feasible contributions, within the defined system boundaries.
5. Assess the compatibility of the various contributions identified, then use them in the development of integrated programmes which would provide a route for achieving the aim and objectives.

6. Investigate likely implications of suggested changes in relation to factors outside the stated system boundaries.
7. Assess the suitability of each possible option.

The first step is clearly the most important, and in some cases could be the most difficult to fulfil. It might not be satisfactorily completed until work has been carried out on subsequent steps and should be constantly reassessed as more information becomes available. However, every effort should be made to clarify the aim and objectives as early as possible, as they are fundamental to the process.

It is useful to define a single, broad aim as a statement of direction, followed by objectives which, taking into account local environmental conditions, specify achievements to be met in order to fulfil the aim. Priority ranking of objectives will assist with comparative assessment of options. The justification of the aim and objectives might be quite straightforward, for example to meet a development objective already set down by the government. In other cases, particularly where pursuing the proposed option would use resources in demand for other purposes, the justification might have to be more detailed. The benefits of preparing a justification lie not only in providing arguments to counter possible criticism; the process leads the proponents to question and refine their expectations of the programme of change, and thus clarifies the precise nature of the aim and objectives. Compiling a justification should also establish a basis for open discussion between affected parties.

Precise definition of system boundaries is unlikely to be possible, but approximations will be useful. It is suggested that the utilisation of the systems model adopted for describing profiles of study areas will assist research on the likely effectiveness and impacts of proposed changes. Acknowledging that the broad system to which the aim and objectives apply is made up of overlapping and interacting lower level systems, such as the natural, domestic, cultivated, commercial, and social systems described in the study area profiles, is a valuable preliminary step in the assessment process. Use of the progressive contextualisation technique (Vayda 1983) in association with the multi-level systems model will assist the identification of relevant factors to be encompassed by system boundaries.

The search for feasible contributions to meeting the aim and objectives, required for the third stage of the procedure, should be as broad as possible. This would involve all interested parties being able to make suggestions. To stimulate the accumulation of the widest range of potential contributions it is suggested that non-linear techniques be included in the research process. An unstructured method that could be utilised would be brainstorming: taking note of any spontaneous response to the statement of the theme under consideration. More formalised approaches have been suggested by Edward de Bono (1982) in relation to his concept of lateral thinking. He advises searching for a provocative suggestion which would not normally be put forward; this can then be used as a stepping stone to move towards a feasible proposal. A second de Bono method is to identify the core direction of conventional thinking in relation to the subject matter and then to make a positive effort to escape from that direction. The third technique he proposes relies on random stimulation. A word selected at random is used as the basis for exploring connections with the theme; approaching the theme from a novel direction generates new ideas.

Not all proposals resulting from these forms of stimulation will be technically feasible, but exploring reasons for their inappropriateness will help to clarify the requirements which an option must meet to be considered suitable.

Another of de Bono's thinking tools could be applied to the discussion of characteristics required by the fourth step of this procedure. The 'PMI' technique is used to direct attention to 'Plus', 'Minus', and 'Interesting' points of the subject matter in turn (de Bono 1982). Generating responses quickly in each area without thinking about their ramifications produces a broad range of factors which support or detract from a proposal, and also yields suggestions of incidental effects which might not otherwise have been considered. If this technique is approached from a broad perspective it can incorporate the non-anthropocentric stance required to attain sustainability in non-human as well as human components of the environment.

Whether or not the de Bono techniques are adopted, the full spectrum of potential advantages, disadvantages, and other expected impacts will not be comprehensively identified without adequate discussion with the people involved in the proposed activity. Technical information will also be useful to the assessment of impacts, but it is important that contributions should not be discounted just because adequate technical data are not available. If technical knowledge is deficient with regard to a preferred option then, if at all possible, the required information should be obtained, but in any case the option should be subjected to the remainder of the design and selection procedure before a decision is made on whether to adopt it. The opportunity for an adverse technical evaluation to rule out the proposal will still be there.

The successful development of a programme to balance fuelwood supply and consumption will depend on the integration of the elements identified by this procedure with all other aspects of the environment in which it is intended to operate. The fifth step in the procedure involves the selection of component activities to be integrated into the local environment in such a way that the combination would be a viable route for achieving the aim and objectives. Given that large numbers of potential contributions will have resulted from steps three and four, a suitable mechanism will be required to decide on optimum arrangements of components. The nature of this mechanism will vary from case to case. In some instances it might consist solely of comprehensive discussions with all involved parties. In different circumstances formal approaches allocating point scores to each contribution on the basis of effectiveness in meeting technical requirements, compliance with users' preferences, impacts on the natural environment, and so on, might be more appropriate. Most cases will probably require a combination of assessment techniques. Formalised methods are often necessary to properly evaluate technical criteria and many such methods developed elsewhere and relevant to particular technologies will be available. Amendments might be required to make these assessment techniques appropriate to local conditions, and informal discussions are usually essential to obtain feedback from the people affected by the proposal.

The next stage in the procedure calls for likely indirect ramifications of proposals to be investigated. This will require knowledge about conditions beyond the boundaries of the system to which previous assessments have been confined. The main reason for this evaluation is to determine that the proposed changes will not be made at the expense of other persons or ecosystems living outside the system under consideration. With regard to well designed, sustainable development proposals the likelihood is that neighbouring human communities will be stimulated by the proposed activities rather than deprived by them. Adequate technical information will be required if possible ecological impacts are to be accurately assessed, and specialist skills are likely to be needed to carry out analysis and interpretation.

The final step of this procedure is the assessment of the overall suitability of each option to allow a final selection to be made. This step consists of two tasks: to assess how well proposed options would satisfy the aim and objectives, and to evaluate whether the nature of likely adverse impacts is such as to preclude an option's implementation. The flexibility of this approach is such that if one aspect of the otherwise most suitable option detracts from its attractiveness, that component could be amended or reassessed by reference to the bank of information collated about alternative contributions. The collation of information about broad ranges of activities with potential to contribute towards achieving the aim and objectives also facilitates the construction of a network of interconnected contributions rather than a linear route. Such an end-product would not only provide some insurance against possible detrimental effects of future environmental change, but, if carefully designed, would also enhance subsidiary benefits.

These procedural guidelines are presented as an aid to developing proposals for change that, once implemented, will meet the requirements of the aims and objectives set for them. The guidelines can also be utilised to reassess the appropriateness of component activities once a scheme has been established. If initially selected contributions are found in practice not to satisfactorily fulfil the roles expected of them, the relevant steps in the procedure can be followed again to re-examine, and if necessary redefine, the requirements of that component of the scheme and to identify appropriate changes to overcome the deficiency.

A complete strategy to bring about changes to fuelwood systems to reduce imbalances between supply and demand would involve components apart from the procedure for the design and selection of options. Before the procedural guidelines could be followed, the need for improvements to the fuelwood situation would have to be recognised. A decision would have to be made that a strategy to generate a programme of change was required. The initiator of the strategy need not be intimately involved in the community where the need for change is perceived. A range of people, including government and church officials, development consultants or researchers, and members of local or international non-government organisations involved in development assistance, could become aware that change was required. In many development situations programmes of change have been most successful where the local people themselves have identified problems and sought help to overcome them.

The operation of the design and selection procedure itself would require three main components: facilitation, decision-making, and information. For full advantage to be gained from the procedure it would have to be coordinated by an individual or small group who understood how the various steps related to one another, what inputs were required to achieve satisfactory results from each step, and how the information gained could best be utilised to design an appropriate programme of change. The role of the facilitator would be to ensure that the information presented was properly considered and that relations between various aspects of any proposals were adequately investigated. The facilitator would thereby provide conditions for the decision-makers to be as well informed as possible about all relevant facets of the likely impacts of proposed changes. While there is likely to be somebody in most communities with suitable skills and experience, it would probably not be appropriate for the facilitator to be a person with intimate involvement in the systems to be changed. A totally impartial, respected member of another community within the same society, or a foreigner with an adequate understanding of local conditions might be more suitable. In some cases a government official could be appropriate, but difficulties might arise if attainment of the established aim required activities at variance with government policy.

The decision-makers' role is central to the design and selection procedure. They are required to determine what achievements should be sought, assess information presented about potential activities, and formulate a programme of selected changes to meet the set aim and objectives. As those making decisions about what actions should be taken need to have a full understanding of the local situation they should be local people. Certain individuals or groups will undoubtedly have particular responsibilities and rights regarding aspects of proposed changes. Their roles should be fully considered but kept in perspective. Relationships between privileged individuals and others in their communities will vary according to the cultural characteristics of different societies, but few cultures would condone advantage to the privileged minority preventing the implementation of projects to benefit the majority. For a programme of change to provide this benefit, decisions about its design would be best made by those who will contribute directly to its operation and gain from its successful implementation. While the inclusion in decision-making of all those directly involved in a proposal will often not be practicable, they should be adequately represented on the panel of decision-makers.

As stated above, information from a variety of sources would be needed for assessment by the decision-makers. The nature of information can be categorised as local, technical, and institutional. Local information would be that obtained from people directly involved in the systems to be affected by the proposed changes. This information could be presented in various forms but would be most likely to be readily understood by others directly affected by the proposals. Technical information is less likely to be available from local sources or to be readily comprehensible to the decision-makers without some form of interpretation. It is the task of the facilitator to ensure that the essential features of technical information are properly communicated to all participants in the procedure. The purpose of technical information will often be to provide data in a form suitable for scientific analysis. The information is likely to be about phenomena for which local people have their own explanations. The conclusions of scientific investigation will be of greatest value if they can be shown to expand and illuminate local knowledge rather than displace it.

The third type of information needed for decision-making is institutional. This includes requirements of government regulations and policies, constraints imposed by cultural traditions, and limitations imposed by funding agencies. While the decision-makers themselves will probably be the people who best understand the local cultural situation, details of government policies and the potential for gaining outside assistance will almost certainly have to be sought from non-local sources.

Having completed the design and selection procedure, the components of the proposed programme have to be implemented before any material gains can be attained. If the activities proposed have been well designed, based on a thorough understanding of local conditions and of the technical feasibility of the technology to be utilised, problems in implementation should be minimised. However, it is virtually impossible to cover all eventualities, so the need for modifications should be expected. Experience of success and failure will enhance the information base used to design new programmes, and knowledge gained about all aspects of implementation of activities generated by the strategy should be shared as widely as possible so that maximum advantage is ensured from each programme.

6.5.3 An approach to the development and implementation of a programme of change to improve the fuelwood situation on Tongatapu

This approach to constructing a programme of change to improve Tongatapu's fuelwood situation utilises the strategy described in Section 6.5.2. Before describing how the strategy could be employed, the salient characteristics of the Tongatapu context are outlined.

Problems relating to domestic fuelwood supply and demand vary from community to community across Tongatapu. Significant differences in the role of fuelwood in meeting a household's energy requirements and in access to sources of fuelwood have been identified. The major variations in access to resources were found to occur between rural and peri-urban households; differences in patterns of use were most pronounced between rural and urban households. Any general programme addressing the island's fuelwood problems would have to take these regional variations into account. Access to land and fuelwood resources depends increasingly on financial wealth as well as on status within the traditional social hierarchy. Needs (1988) reported conversations with banana growers who claimed that a commoner would have to pay a noble thousands of dollars to obtain any allocation of land. At the same time nobles were said to give land to relatives and close friends without requiring such payment. This situation not only increased inequalities between those of noble birth and commoners, but, by requiring big financial returns, ensured that newly allocated land would be managed intensively and so incidental production of fuelwood was likely to be low.

While the increasing scarcity of land directly benefited the nobles financially, the move to greater commercial transaction of resources and commodities gave an opportunity for commoners to challenge the status of nobles. By being very successful in business a commoner could gain the monetary resources to permit the display of superficial trappings of a wealthy lifestyle hitherto only available to the royal family and nobles. Needs (1988) describes the ongoing transformation from the social collectivities of the traditional social strata to class relations based on capitalist relations of production. Acknowledgement and understanding of such developments in the social hierarchy will be essential to the successful implementation of changes to the fuelwood system.

Closely linked to the changes to Tongatapu's social structure is the notion of development. As discussed in Chapter 3, this term is interpreted in various ways depending on an individual's perspective and the context in which it is used. In the context of fuelwood production on Tongatapu, if development is measured by the volume of monetary transactions, the commercialisation of fuelwood distribution would boost development even if less fuelwood were used because consumers could not afford to buy it. If development is taken to mean improvements in living conditions of the human population then provision of adequate quantities of good quality fuel and efficient, clean-burning appliances would make a valuable contribution, irrespective of how much money changed hands.

6.5.3.1 Initiating the strategy

Strategies to improve fuelwood conditions on Tongatapu could be employed at a range of scales, from a few households to the whole island. It is suggested that the procedure to select practical activities would be best operated at the community level, involving a single village or residential area, or perhaps a group of landholders using adjacent allotments. To be most effective the strategy should operate in as many communities as possible. It would be possible to initiate the strategy in each location but activities could be instigated more rapidly if a centralised operation of initiation were established. This would require planning and organisation to ascertain how information about the strategy would be disseminated and how facilitators and decision-makers would be selected. This should be the extent of the initiators' involvement. The role of initiation is simply to start the process. The essence of the strategy, that decisions should be made locally, would be compromised if central initiators were to act as facilitators or to place restrictions on how communities sought solutions to their local fuelwood problems. However, if the strategy were to be established in a number of communities, there would be a need for coordination to allow transfer of information. It is therefore suggested that the centralised initiation should be the responsibility of the Parliament, and that the coordinating role be delegated to an appropriate unit within a Government Department, perhaps the Energy Planning Unit.

Once the programme of strategies to find solutions to fuelwood problems had been announced, organisation within individual communities could begin. The coordinating body would have to make available information on how the strategy should be pursued, how technical and other information required by the panel of decision-makers could be obtained, and what the benefits could be expected from participation in the strategy. Providing advice on how to run the procedure for the design and selection of options would perhaps be done most effectively through training seminars once facilitators had been selected.

6.5.3.2 Conducting the procedure for the design and selection of options

Each of the seven steps listed in the procedural guidelines in 6.5.2 are briefly discussed here, in the context of the proposed utilisation of the strategy on Tongatapu.

(a) Definition and justification of the aim and objectives which the chosen option is to meet

The aim is to make a significant contribution to achieving a sustainable balance between fuelwood supply and demand on Tongatapu without generating adverse impacts on the environment.

An initial set of objectives is as follows:

1. to collate information on current and likely future fuelwood production and requirements and their environmental impacts, to facilitate

assessments of whether supply and demand are in balance and whether that balance is sustainable;

2. to make available to Tongatapu residents energy efficient and clean burning fuelwood stoves that are well suited to their households' needs and within their means to purchase or make;
3. to increase the production of fuelwood on agricultural, non-agricultural, privately controlled, and commonly accessible land;
4. to minimise adverse environmental impacts of fuelwood supply and consumption activities;
5. to improve the efficiency of fuelwood harvesting, distribution, and preparation;
6. to ensure that appropriate and adequate methods of fuelwood supply remain in, or are returned to, the control of individual households, and thereby to redress imbalances between urban, peri-urban, and rural households;
7. to facilitate and encourage systems of fuelwood production that optimise the co-production of other valued commodities and services.

These aim and objectives can be justified in several ways, for example: ensuring there are adequate supplies to meet demand would reduce inconvenience to fuelwood collectors; introducing fuel-saving devices such as smokeless stoves would bring health benefits to fuelwood users; fuelwood provides an affordable alternative to petroleum fuels for individual households; continued use of fuelwood benefits the country's economy by reducing the amount of foreign exchange required for the purchase of petroleum fuels.

(b) Determination of the system boundaries within which the aim and objectives operate

The Tongatapu fuelwood system is taken to include all factors acting on fuelwood consumption by households, institutions, and commercial enterprises on Tongatapu in 1986. It includes all aspects of fuelwood production, harvesting, distribution, processing, and consumption. Effects of factors such as availability of kerosene stoves, demand for oven-baked food, and government policies on land tenure are considered to be factors impinging on elements of fuelwood supply and consumption from outside the fuelwood system.

(c) Identification of as broad a range as possible of technically feasible contributions towards achieving the defined aim and objectives

Following de Bono's technique of seeking provocative suggestions, two extreme actions are put forward as potential ways of ensuring that future fuelwood supplies on Tongatapu would be adequate to meet requirements:

1. the immediate cessation of fuelwood consumption, thereby reducing the total requirement to zero;
2. the implementation of a fuelwood production programme whose minimum rate of output would be greater than the maximum possible rate of consumption.

These illustrate the extremes of the range of conceivable scenarios. While both suggestions would in reality be impossible to achieve, in ideal circumstances they would be technically feasible and are therefore worthy of consideration. Their disadvantages and features of particular interest are discussed as part of the next stage in the procedure.

Between the extremes of ending fuelwood consumption and providing for 100 percent of possible consumption lie a myriad of potentially valuable inputs towards meeting the aim and objectives. The representative examples of contributions briefly discussed here are grouped into options for increasing supply and options for reducing demand.

Options for increasing fuelwood supply on Tongatapu

Mechanisms of fuelwood supply in Tongatapu in 1986 have been described in Section 6.2.1 to have followed three main routes: non-commercial collection, commercial supply through woodsellers, and commercial supply through the Tonga Commodities Board. The components of the supply process common to all three routes have been identified as production, harvesting, distribution, and preparation. Increases in fuelwood supply could be made by altering processes within these components, by combining current processes in more efficient ways, or by introducing novel processes. Each of these routes would amend current mechanisms. An alternative approach would be to introduce combinations of new fuelwood supply activities which would constitute original mechanisms.

The component of the Tongatapu fuelwood system whose enhancement could potentially have the greatest impact on volumes of fuel supplied, is wood production. The fuelwood consumed at the time of the author's fieldwork was produced in a range of managed and unmanaged systems (King 1987a). The examples of possible improvements to fuelwood supply considered here relate to bush allotments and coastal wood production systems.

To the extent that all agricultural land is under human control, all fuelwood obtained from bush allotments is derived from managed systems. However, information about individual allotments clearly shows that some sections are never cultivated, but support naturally regenerated vegetation. Left effectively unmanaged these areas would continue to produce varying quantities of biomass that could be used as fuel. Alternatively, these sections of land could be managed for increased fuelwood production. The nature and intensity of management could range from merely protecting the area from disturbance to ensure natural regeneration, to planting exotic short rotation trees that require skilful husbandry and a range of external inputs. The technical feasibility of such schemes would vary according to site conditions and the abilities of the land-holder. Use of these presently uncultivated areas need not be devoted entirely to fuelwood production. Tree products which, in favourable circumstances, could be grown in association with fuelwood include building timber, traditional handicraft, medicinal, and decorative materials, and fruits for both subsistence and commercial gain. Additional benefits of managing these areas could include shade and shelter for livestock, and windbreak protection for crops. All of these potential advantages of tree management were mentioned by farmers interviewed during the author's fieldwork. It is unlikely, however, that any interviewee was aware of the range of production techniques that could be applied to such situations.

The cultivated sections of all bush allotments surveyed supported at least a few permanent trees. These were most commonly planted or specifically protected trees which were of special value to the landholder. Fuelwood production was insignificant in the determination of which trees were encouraged to grow in cropped areas of allotments. With careful planning it would be possible to plant many more trees within cultivated areas, and thereby increase fuelwood production. Species could be selected to suit the conditions required by desired agricultural crops, and to yield commercially valuable produce, as well as making a contribution towards fuelwood supplies.

Cropping areas of many bush allotments still produced relatively large numbers of temporary trees during fallow periods. While the recent trend has been to reduce fallow to periods that severely limit wood production, it is certainly technically feasible for fast growing trees planted at the start of a fallow period to yield substantial quantities of fuelwood within two or three years.

With the coconut palm being one of the major fuelwood trees, encouragement given for the replanting of coconuts makes an important contribution to achieving sustainable supplies of fuelwood. Linking the promotion of coconut replanting into a comprehensive scheme to achieve sustainable supply and consumption of fuelwood would benefit both objectives.

Research into agroforestry systems which combine tree and agricultural crop production has resulted in detailed information about numerous techniques suited to particular conditions throughout the world. Compiling a comprehensive assessment of agroforestry systems described in other countries which could potentially be suited to conditions on Tongatapu would be a major research undertaking in itself. Probably the most effective way of describing what combinations of trees and agricultural crops would be technically feasible on Tongatapu would be to examine the principles on which agroforestry elsewhere is based and to relate them to Tongatapu conditions. Künzel (1989) has outlined the status of agroforestry in Tonga and made suggestions for its development. His approach of focusing closely on current activities and particular circumstances in Tonga needs to be balanced by a more open assessment of possibilities; this could be achieved by adopting de Bono's lateral thinking techniques.

Coastal forest areas on Tongatapu are becoming more and more degraded and thus progressively less able to supply fuelwood. As with uncultivated bush allotment land, options are available for unmanaged and managed wood production. Any management regime proposed for coastal land, which is open to common access, would have to be quite different from management of allotment land. Tree species used would have to be tolerant of harsher environmental conditions and would need to perform additional functions such as preventing coastal erosion and protecting agricultural land from salt-laden winds. Any programme of tree-planting on common coastal land would require far more resources to be devoted to preventing human disturbance than would be needed on privately controlled bush allotments. As stated for bush allotments, a broad range of potential techniques could be adopted to increase wood production on coastal land, from minimum intervention to afford a degree of protection, to the provision of intensive external inputs.

Methods of harvesting wood could be changed to increase the proportion of total production that was available as fuel. The collection of dead wood is convenient, but without a system for ensuring that the wood is gathered as soon as it is dry enough to burn, some of the potential fuel energy will be lost due to rotting. The proportion of the total amount of dead wood generated on Tongatapu which is utilised as fuel could be increased by removing restrictions on access to land and by improving transport facilities. Some bush allotments, particularly those with a high proportion of their land in fallow, produce more dead wood than can be used by the allotment holder. Making this wood available for other households to harvest would increase the overall efficiency of dead wood utilisation.

An alternative harvesting strategy would be to cut live wood so that the drying process could take place under controlled conditions and so minimise wastage. If tree management techniques were altered so that relatively large numbers of trees were being grown for fuelwood production, mechanised harvesting might be appropriate. The production and harvesting methods would have to be designed as an integrated system as the use of cutting, trimming, and binding machines would require the trees to be grown in appropriate configurations. The equipment used to cut wood also has an effect on the amount of waste material generated. Mechanised systems should be less wasteful than manual cutting, but the efficiency of different types of hand-held equipment will also vary. For example, felling large trees with a chainsaw produces less waste than felling with axes.

The long term sustainability of fuelwood supplies could be improved by the introduction of novel harvesting programmes, as long as these were used in a manner compatible with the production system. The methodical adoption of harvesting techniques such as coppicing, pollarding, and trimming could facilitate a vast range of options for the permanent inclusion of trees on agricultural land. Coppicing has been practised for cutting sialemohemohe and kuava but has not been widely accepted as a land management technique. Species used as boundary markers, such as ngatae and tuitui have been pollarded, and koka trees have traditionally been trimmed to provide material for felei, support for yam vines. These practices could be extended to other species for the provision of fuelwood. Any other, less formalised, harvesting options should also be considered, even if they will ultimately be discarded. Even existing practices which are perceived as detrimental to sustainable fuelwood production should be included among the options assessed.

By exploring non-conventional options a broad range of technically feasible modes of distribution can be built up. At one extreme would be individual collectors carrying home arm-loads of dead sticks; at the other extreme, large trucks, barges, or even helicopters could be used to transport numbers of whole trees at a time. Between the extremes lie innumerable possibilities utilising human, animal, fuel, and alternative energy sources. For example, box trailers drawn by bicycles are common in some countries and could be introduced to Tongatapu. Horses are already used as draught animals; what other animals could be used in this way? Bullocks and mules come readily to mind, but many other animals would be worthy of consideration. The conventional transport fuels are, of course, oil based and imported, but locally generated biomass wastes could provide producer gas or liquid fuels to serve the same purpose. Alternative energy sources include waves, wind, and solar radiation, all capable of generating electricity which could power vehicles to transport fuelwood. Wind could be used directly to drive sailing barges and even land based vehicles under appropriate conditions.

Methods of preparing wood depend on the requirements of its application, but the range of technical possibilities is just as broad as for production, harvesting, and distribution techniques. Mechanical action can render solid wood any size smaller than that harvested. Wood can be split, sawn, and carved into pieces of any shape; machines are available which will reduce it to blocks, chips, and sawdust; and by recombination wood can be converted into almost any form required. Limitations on the manipulation of solid wood result from natural configurations of its fibrous structure, from its relatively narrow density range, and from the variability of its equilibrium moisture content under different environmental conditions. Thermo-chemical and biochemical processes can be used to convert woody biomass into solid, liquid, and gaseous fuels, such as charcoal, methanol, and producer gas (Hall, Barnard, and Moss 1982). Of these derivative fuels, only charcoal was used by Tongatapu households in 1986. While the special equipment needed for the production and use of liquid and gaseous fuels was not available, discussion about their potential roles in the fuelwood system would be essential for any comprehensive assessment of future options.

All the above changes in the production, harvesting, distribution, and preparation stages of fuelwood supply could be made within the existing mechanisms without necessarily changing other components of the supply system. Options requiring the development of mechanisms which would be original, at least in the Tongatapu context, should also be identified and evaluated. As in the other categories, it will be useful to gather as diverse an assemblage of potentially feasible mechanisms as possible. These will vary enormously in size, complexity, input requirements, efficiency and rate of fuelwood production, generation of by-products, and type and quality of fuelwood produced.

One of the simplest mechanisms would be for a household to plant trees on their own land and simply protect them from disturbance until they are ready for harvesting as fuelwood. While aspects of this strategy are effectively the same as for existing mechanisms, the act of planting trees specifically for fuelwood would be sufficient for the strategy to be classed as original. Another mechanism for individual households would be the adoption of agroforestry techniques involving the intercropping of agricultural crops with short rotation trees for fuelwood. If such a production system were to be used by a number of individual farmers, or if a community were to instigate a larger scale programme, the purchase of mechanical harvesting equipment might be viable. Tree-planting schemes initiated by community groups would not be unprecedented on Tongatapu; church congregations in Lavengatonga combined to plant roadside amenity trees in 1986. Community programmes to increase the production of fuelwood could operate by encouraging others to plant and look after trees individually, or by establishing group projects for households to work together in managing woodlots for the benefit of all. Woodlots could be dedicated solely to fuelwood production or designed as multipurpose resources. The range of possible combinations of different types of trees with or without crop plants would be enormous. As well as agroforestry systems referred to above, tree plantations managed primarily for production of industrial or handicraft resources could provide enough wood residue by-products to be the basis of a fuelwood supply mechanism; woodlots established to perform environmental functions, such as windbreaks or erosion control, could also yield substantial volumes of fuelwood so long as removal of wood for such purposes was strictly managed on a sustainable basis.

The major production factor required to establish woodlots would be land. As vacant land is in short supply right across Tongatapu, suitable sites for woodlots might be difficult to secure. There would be several ways in which feasible options for the initiation of stands of trees for fuelwood could be developed. A community group could make a formal agreement with a local landholder for the use of land to grow fuelwood for the benefit of all in the group. This arrangement might involve payment of a cash rental, or reimbursement in kind, perhaps a reciprocal agreement to use land belonging to other group members for growing crops. An alternative might be for the group to establish the woodlot on land owned or leased by a church or maybe government land allocated to a school. If woodlots were to be proposed for all communities on the island, provision of land, and perhaps other facilities, by the government to allow the community groups to create the plantations might be a viable approach.

If areas of land suitable for woodlots were not available, community groups could still coordinate and promote tree-planting for fuelwood by organising land-holders to jointly establish shelter-belts, boundary marker trees, hedgerows, and any other appropriate linear formations of trees. Local experimentation and trials with different species grown in varied configurations could stimulate interest while helping to provide data to allow optimisation of future plantings.

Implementation of novel agricultural systems could introduce new mechanisms for the supply of fuelwood; indeed, in the case of land being cleared for mono-cropping this has already happened. There are, however, ways of managing land so that agricultural, tree crop, and fuelwood production are all increased. If advanced agroforestry systems capable of such enhanced productivity were comprehensively adopted on Tongatapu, all aspects of fuelwood supply mechanisms could change.

Irrespective of where trees were to be planted and what management system was to be employed, appropriate propagation facilities would be required to generate new planting stock. Tree species which are already commonly planted, such as mei and kaute, can be readily regenerated by individual landholders. Planting material of many other preferred species are more difficult to obtain, either because their propagation requires special care or because mature specimens of the tree are scarce.

It is proposed that a major contribution to promoting sustainable supplies of fuelwood would be the establishment of local or regional tree nurseries. These could be of various sizes according to local requirements and operational resources. One way of assessing the options for nursery size is to adopt the de Bono technique of starting with the opposite to the conventional approach (de Bono 1982). Conventionally, nurseries for large scale tree-planting projects are centralised, medium to large scale, and run by experienced, paid staff. Planting material is produced either to meet the requirements of institutionally organised plantations or for sale for private use. The antithesis would be a large number of widely dispersed nurseries, each operated by an inexperienced, unpaid individual, producing a very small number of trees which were given away to whoever wanted them. Each of these unconventional characteristics applies to a successful tree nursery scheme in the Walapane district of central Sri Lanka. Individual schoolchildren raise twenty to thirty tree seedlings at a time in home 'nurseries'[4]. When the seedlings are ready for planting out the community environmental programme decides where they could best be utilised. Another system of small-scale local nurseries can be found in Tasmania, where, with encouragement and support from Greening Australia, increasing numbers of schools are collecting and germinating tree seed and growing seedlings (Dr T. Stadler, Landcare Course Coordinator, National Soil Conservation Program, Hobart, Australia, personal communication, 20 April 1991). Those schools which have chosen to sell seedlings have generated significant incomes. Both these

4. Information about this scheme was gathered by the author during a brief visit to the Walapane Environmental Programme in March 1990.

models for producing tree seedlings could be adopted on Tongatapu with minimal modifications.

At a slightly larger scale a group of landholders could set up and manage a nursery specifically to provide the tree seedlings they require to establish new agroforestry systems on their own land. Alternatively, to avoid the need for every landholder to be involved in nursery work, a community group might run a nursery to sell seedlings to landholders within their own village. If government funds were available perhaps a network of medium-sized nurseries would be set up across the whole island to provide planting material at subsidised prices.

The Forestry Division of the Ministry of Agriculture, Fisheries and Forests (now the Ministry of Agriculture and Forests) has made significant contributions to reafforestation since the 1960s. However, koka, the species which can be said to be the most significant non-coconut tree in the traditional agricultural system, has been of minor importance to the Division's programme (King 1985; Thaman 1984b). This suggests that greater attention should be paid to the needs of land-holders and the significance of traditional plant associations before decisions about the promotion of tree species are made.

Any contribution made by nurseries needs to be accompanied by sound practical advice about growing trees on agricultural land. This sort of information would conventionally be disseminated by extension officers of the Ministry of Agriculture and Forestry. A provocative suggestion would be that the job could be done by anyone: a bus-driver, a nurse, an unemployed youth. Contemplation of this proposal could suggest that perhaps all these people ought to be trained in how to grow trees. Or perhaps rather than waiting for Ministry employees to visit villages to instruct them, village representatives should make the effort to find out how best to plan and implement tree-planting schemes and share this information with others in their community. In the case of someone in full-time paid employment teaching others about tree-planting could only be a spare-time activity. If a community considered it important enough, an unemployed person could be given an income to learn and pass on the necessary skills. Such a local 'tree expert' could give advice covering the growing of trees for all the traditional reasons identified as important by local residents as well as for the benefits normally associated with commercial activity.

This concept of training non-specialists in tree production techniques would make its greatest long-term contribution if it were applied to the teaching of children. In this case one of the local 'tree experts' would most appropriately be a school-teacher who would have the skills to transfer information to the children and to suitably channel their enthusiasm. Most adults are keen that the next generation should enjoy better living conditions than they have had themselves. Once children are empowered to create a healthy environment on which to base their future, only the most selfish of adults would not support them. This support must include making the institutional changes required in the society to ensure that the movement to improve the environment is hampered by regulation and inertia as little as possible. It is vital, therefore, for the decision-makers participating in the fuelwood strategy design procedure to ensure that the options they select are socially acceptable and sustainable as well as appropriate to physical and biological environmental conditions.

Fuelwood production on Tongatapu is an inseparable component of overall land utilisation. Generation of woody biomass which could be used as fuel is a characteristic of most categories of land use. Comprehensive planning of fuelwood supply should be part of integrated land management planning. The technique of Whole Farm Planning, developed and implemented in Tasmania, could be adapted for use on Tongatapu. This procedure aims to identify the optimum land use system for a defined area of land in terms of ecological stability and economic profitability. The natural resources of the area are assessed and the land's capability for agricultural production examined in order to identify natural land management units. Areas affected by particular constraints are defined and existing improvements taken into account before management strategies are constructed (Waugh 1990). The Whole Farm Planning technique could be modified to assist Tongatapu farmers in planning their management of single allotments, but would probably be most beneficial if applied to larger areas. For example, it could be used to guide a reassessment of the utilisation of an entire tract of land under the control of a village community. Such an assessment should cover unmanaged land, such as coastal strips, as well as town and bush allotments. As with the fuelwood strategy the procedure would be best carried out at the community level but would require centralised coordination and support. Information and plans arising from any such evaluation of land management would be a very valuable contribution to the design and selection of options for the fuelwood strategy.

Options for reducing demand for fuelwood on Tongatapu

The brainstorming and lateral thinking methods suggested for generating possible options for increasing supply will be useful again for determining the range of technically feasible options available for achieving reductions in demand. To summarise the situation with regard to fuelwood demand on Tongatapu in 1986, virtually all the approximately ten thousand households required at least some wood to fuel cooking appliances; for the majority of households fuelwood was the only source of energy for cooking; approximately 90 percent of households used fuelwood for non-cooking purposes; woody biomass provided fuel for industrial and commercial enterprises, and for institutions such as schools (Plate 6). Technical options for reducing fuelwood demand will operate in one of three ways: by reducing demand for the functions which fuelwood fulfils; by enabling those needs to be met through the consumption of a smaller quantity of fuelwood; or by the provision of other sources of energy to satisfactorily substitute for fuelwood.

Possible ways of reducing demand for the contributions made by fuelwood to its most common function, cooking, would include persuading people to eat less, reducing the population of Tongatapu, limiting the cooking of food to one meal per day, changing foods to those requiring less cooking time, reducing the number of feasts or the numbers of people attending, promoting the patronage of restaurants which cooked on gas or electric stoves.

Continuing to meet current requirements while using less fuelwood would necessitate improving the efficiency of conversion from the stored, chemical energy in the wood to useful heat. The most obvious example of a technological attempt to achieve this is the design of improved domestic, wood burning cooking stoves. Improved understanding of combustion processes has assisted the design of efficient woodheaters in Western countries (King 1989). Utilisation of this technical expertise in association with careful assessment of local requirements could lead to the development of acceptable cooking stoves which require significant less fuel. The widespread dissemination of such stoves throughout Tongatapu would almost certainly lead to a significant fall in fuelwood consumption. Similarly, better management of existing appliances would result in higher efficiencies being attained. Techniques such as placing heated food in a super-insulated box to complete the cooking process could also be employed to reduce the length of time a wood burning appliance would be required to be alight. Any planned changes to cooking appliances should take account of other desirable improvements to kitchen facilities.

Provision of substitute sources of energy would be the most straightforward of methods for reducing fuelwood demand: comprehensive adoption of alternatives would simply halt consumption. Electricity, gas, and kerosene are all available on Tongatapu and their expanded use would be technically quite feasible. Possible non-conventional energy sources include solar radiation, which could be used to cook food on reflector stoves, to generate electricity to power a stove, or perhaps to heat a liquid medium for cooking food via a secondary heat exchanger.

(d) Discussion of recognisable advantages, disadvantages, idiosyncrasies, and potential influences of the range of feasible contributions, within the defined system boundaries

Given that there is a vast array of possible ways of assisting the achievement of a fuelwood balance on Tongatapu, a mechanism is required for evaluating and comparing potential contributions. Traditionally, new activities have been introduced because they were expected to provide benefits within the framework of existing systems. Changes have been incremental, and in recent years to a large degree prompted by desire for financial gain. As in most other societies this imperative to increase monetary wealth has overridden the protection of many processes essential to the maintenance of ecological stability. In many countries economic development has occurred at the expense of traditional cultural values and institutions. In order to ensure a comprehensive evaluation of changes suggested to bring about a balance between fuelwood supply and demand, ecological and cultural as well as socio-economic criteria must be considered.

All members of a community have experience of economic, ecological, and cultural aspects of their environments. Some have deeper knowledge of particular areas, and have perhaps received training in how to evaluate aspects of the environmental factors which influence their lives. It follows that there can be considerable variation in the values held by individual members of the same community. For example, a mat weaver is likely to value a stand of pandanus trees more highly than a commercial farmer who wants to clear the land to plant pumpkins or water melons. Similarly, a householder short of fuelwood is likely to see different values in remnant coastal forest trees which provide shelter to another villager's bush allotment. Such variation in perception is inevitable and must be recognised if equitable and sustainable solutions are to be reached with regard to fuelwood supply.

To allow the greatest possible input to the decision making process it is suggested that all local people likely to be affected by changes required by proposed contributions to gaining a fuelwood balance should have the opportunity to comment on proposals and ideally to discuss them with others. Tongan communities' village meetings, <u>fono</u>, could be the venue for initial explanations of the concept of preparing a local fuelwood strategy. the forum for all affected parties to voice their opinions on the overall desirability of the strategy and on particulars of the procedure, should be provided by meetings called especially for that purpose. Discussions of the technical aspects of a proposal will require input from those with the relevant specialist knowledge but this should serve to illuminate and inform, and not to outweigh the perceptions of the local people. Similarly, if a proposal is expected to benefit all members of a community, with both gain and cost being relatively uniformly distributed, potential impediments to even-handed discussion which might arise from unequal social status would have to be resolved. For example, if a proposal involved each household in a village relinquishing one tenth of a hectare of land for the purpose of communal tree-planting, a household with only a town allotment could stand to lose half or more of their land. The same area would probably represent a very small proportion of the total area controlled by a commercial farmer. A situation where the householder without control of a bush allotment had no opportunity to complain about the imbalance in the hardship caused by the proposal would obviously be grossly unfair. While the Tongan people are the only ones who can decide whether their society should promote fairness, the lack of information about the reaction of any affected party would prevent a comprehensive and objective evaluation of the impacts of any proposal being made.

It is assumed here that it is desirable for the full range of predictable advantages and disadvantages of intended alterations to the fuelwood to be explored and assessed. It is suggested that this investigation be initiated by use of de Bono's 'PMI' technique for identifying 'plus', 'minus', and 'interesting' attributes of a proposal. Listing these characteristics will provide an indication of direct advantages and disadvantages, and also features which might complement or detract from other changes within the community.

Applying this technique to the two extreme scenarios suggested as technically feasible solutions, leads to the following observations. The immediate cessation of fuelwood consumption would have several 'plus' characteristics. Wood would not have to be collected and prepared; woodsmoke would no longer irritate a cook's eyes; the potential danger of open fires would be removed; and so on. On the other hand, many minus factors would result. Those households who could not afford other fuels would not be able to cook their food; the reinforcement of traditional culture regularly provided by use of the 'umu would be lost; monetary income from copra would drop because biomass fired dryers could not be used; commercial sellers of fuelwood would lose their livelihood. 'Interesting' repercussions would be to see: whether other uses were found for waste coconut shells and husks; how quickly the coastal forest areas regenerated once fuelwood collection was stopped; whether cultivated plots on bush allotments became overrun by vegetation that would previously have been controlled by fuelwood collection.

'PMI' observations for the second extreme scenario, the production of ample fuelwood, include the following. Collection of adequate quantities of wood would be much easier; impacts of poaching fuelwood from others' land would be negligible; it would be easy to maintain stacks of drying wood so that wet wood would not be burnt. 'Minus' points would include: woodsellers would not be able to charge such high prices; unless carefully managed, fuelwood production might take up valuable agricultural land; much of the incentive to use more efficient appliances would be lost. It would be interesting to observe: whether over-cutting of the best fuelwood species continued; whether users of commercial fuel stoves changed back to wood; whether the frequency of feasts increased.

While these two extreme scenarios are very unlikely ever to be achieved, some of the thoughts generated by the 'PMI' assessment could highlight areas where extra consideration would be needed. For example: if the work of commercial woodsellers were to be preserved as a valuable supply mechanism, the impact of changes to the production system on market prices would have to be evaluated; if the efficiency incentive to change to improved stoves were lost, a promotion programme should be launched to reduce the health hazards of woodsmoke.

One technically feasible option for increasing fuelwood production on bush allotments is used here as an example to illustrate the utilisation of this technique.

The proposal considered is the management of salt-affected sections of bush allotments adjacent to the windward, liku, coast for fuelwood production. 'P' (plus) features could include: planting trees for fuelwood would protect crops on adjacent land from salt-bearing winds; tree plantations would suppress noxious weeds which could spread onto agricultural land; if nitrogen fixing, fruit bearing, medicinal, or handicraft trees were planted, additional benefits would accrue; selling fuelwood would provide an income; having plenty of fuelwood available would stop poachers from damaging protected trees on agricultural land; tree cover could provide suitable habitats for endangered flora and fauna; looking after trees as well as crops would keep men out of the house for longer and so give the women more freedom. 'M' (minus) characteristics might include: the time required to look after the trees might prevent social activities; other households might cut the trees before the owner had a chance to harvest them; getting the money required to set up a plantation might require cutting back on essential requirements such as food or clothing; if a loan were taken out to pay for establishing a woodlot, defaulting on future repayments could result in court proceedings; flying foxes might take to roosting in the new trees and damage fruit on the adjacent agricultural land; allowing dead wood to rot on the ground would encourage rats and rhinoceros beetles, both of which are pests to local crops; using the land for trees might prevent it supporting grazing animals; the tree species chosen might be unsuitable and the investment be lost. 'I' (interesting) points could include: it would be interesting to see which trees survived and thrived and which did not; it would be interesting to see if other villagers also took up the idea; it would be interesting to see if the fuelwood produced had different characteristics to that produced by naturally regenerated trees; it would be interesting to see if tourists found the adjacent beach less or more attractive with a fuelwood plantation behind it.

Some of the issues raised by such spontaneous remarks would clearly be essential to the success of the proposal. Benefits from production of handicraft materials, fruit, and medicinal ingredients could make the difference between a woodlot being feasible and totally unattractive. Such an issue would require further investigation to ascertain what combinations of trees would (a) provide these benefits, and (b) survive the harsh coastal environment. Similarly, if farmers have been complaining about the degradation of the coastal vegetation which used to protect the crops, a technically and economically viable proposal to grow trees for fuelwood could fulfil the environmental protection role as well. Again, due consideration of both sets of requirements would have to be given during the plantation design process. For the project to be successful the 'M' points would have to be addressed. The plantation design would have to suit the level of management skills and enthusiasm offered by the land-holder. Financial problems could be settled in three ways: the market place would ensure that only individuals with capital were able to establish fuelwood plantations; groups of residents would combine resources to facilitate communal projects; the government or overseas organisations would provide grants or guarantee loans. Some potential indirect effects were identified by listing the 'I' characteristics. Establishing the first woodlot would provide information to benefit subsequent enterprises. Other landholders or community groups would almost certainly take up the initiative to grow fuelwood if the success of woodlots were demonstrated. Incidental impacts, such as attracting or deterring tourists, could significantly influence the siting of future plantations.

In addition to the 'PMI' process, evaluation of any proposal should assess how successfully the aim and objectives prepared in the first step of the design and selection procedure are addressed. In relation to the broad aim, the establishment of fuelwood plantations would certainly have great potential for increasing fuelwood production. Objective 1. would benefit by information about production rates and environmental impacts becoming available. The question arises though whether this information, particularly about potential environmental effects, should not be available before woodlots start to proliferate. There would almost certainly have to be some investigation to identify where plantations could be detrimental to the environment, and regulations imposed to prevent their location in such areas.

Components of fuelwood supply mechanisms would also need to be addressed. The benefits of a fuelwood plantation would be severely limited if the land-holder did not allow any other households to have access to the wood, or charged exorbitant prices for it. Unless the plantations were established to provide primarily non-fuelwood products, commercialisation of fuelwood would almost inevitably increase. While some households would not have effective access to commercial fuelwood, having that wood available for those who could afford to buy it would reduce pressure on non-commercial collection sites. Woodlots would not only improve the availability of fuelwood but also, indirectly, reduce the adverse environmental impacts of fuelwood collection.

Plantation establishment on land close to the liku coast is unlikely to be the optimum way of satisfying objectives 6. and 7. The number of sites suitable for plantations would be limited and thus this proposal alone would put both the responsibilities and profits of increased fuelwood production into the hands of a few landholders. Such a programme in isolation would not substantially increase the ability of fuelwood using households to control the supply of their fuelwood, nor would it make any significant contribution to redress the imbalances between urban, peri-urban, and rural households. Objective 7. suggests that the co-production of fuelwood and other commodities and services should be encouraged. The liku sites would not be well suited to this, except with regard to the environmental protection afforded to adjacent cultivated land. While systems could be developed to make best use of these sites, much greater opportunity for the production of multiple crops would exist on the more fertile soils inland, where closer integration of trees and crops in appropriate agroforestry regimes would be desirable.

The multi-level systems model adopted to construct the study area profiles would provide a valuable tool for the collation of material generated by the 'PMI' exercise and by checking the fulfilment of objectives. The implementation of contributions towards balancing fuelwood supply and demand will have effects on natural, domestic, cultivated, commercial, and social systems within the study area. Methodical evaluation of the advantages and disadvantages of impacts on each system will require the application of specialist techniques for both monitoring and analysis. Data resulting from this research will provide valuable contributions to guidance for the construction of strategies and also to the assessment of the overall suitability of proposals.

(e) Assessment of the compatibility of the various contributions identified, and the construction of options which could provide routes for achieving the aim and objectives

Pursuing the example used above, of fuelwood plantations being established on uncultivated land near the liku coast, contributions in the areas of harvesting, distribution, and preparation are required to construct a complete fuelwood supply mechanism. One possible manner of harvesting would be for local residents to have common access to the plantation to collect wood in the way they would from any other common land. This would clearly be incompatible with the optimum management of the plantation if live wood were cut, and even accidental damage to trees during collection of dead wood would mitigate against allowing general access. The suggestion that harvesting could be mechanised would be most appropriate to even age plantations, where trees of similar size could be cut by a standard process. If the management technique were to coppice on a short rotation system, machinery to cut, trim, and bundle stems might be viable. Such a procedure would further centralise control of the fuelwood supply system, in contravention of objective 6. An alternative might be to sell rights to the standing trees and allow individual households to harvest their wood themselves.

Possible modes of distribution suggested above included the use of barges. This might appear attractive given that the proposed planting sites are close to the coast. However, the configuration of the reef and the likelihood of adverse sea conditions are such that berthing on this coast would be very hazardous. If the plantation were to be run commercially the owner would almost certainly want to transport much of the wood produced to Nuku'alofa, where the highest prices could be gained. Of the vehicles available on Tongatapu in 1986 a large utility or small to medium sized truck would be the most likely mode of transport. Advantages would include being able to move relatively large quantities of wood at a time, and avoiding the difficulties of manoeuvring a large truck on narrow bush tracks and into the selling sites at Talamahu market.

The type of preparation would depend on the use to which the wood was to be put. The billets required for cooking on an open fire could be provided by the conventional use of axe and cane knife, or alternatively, if tree stems of relatively uniform thickness were to be processed, by a mechanical splitter. If the fuelwood produced were to be used in an industrial system it might be appropriate to use a mobile chipper on the plantation site to provide fuel suited to mechanical feeding into a furnace or gasifier.

While combinations of some of these processes would vary from existing mechanisms only slightly, other combinations would constitute original fuelwood supply systems. Assessment of the compatibility of contributions such as these towards increasing fuelwood supplies, and strategies for reducing demand will have to be carried out on a case by case basis. How well components work in association with one another will depend not only on the technologies used but also on their acceptance by the people operating the fuelwood system. The degree to which any given combination satisfies the aim to provide sustainable improvements in the fuelwood situation will depend on not only technical and social factors but also, and most significantly, on factors determining environmental impacts, particularly on physical and biological features of affected ecosystems. If sustainability is to be achieved, objective appraisal of the potential long term environmental consequences of proposed changes must be undertaken. A full complement of local, technical, and institutional information will be required to permit decisions to be made.

(f) Investigation of likely implications of suggested changes in relation to factors outside the defined system boundaries

The sustainability of fuelwood supply and consumption mechanisms could well be significantly influenced by interactions with ecosystems external to the system boundaries defined in stage two of the design and selection procedure. For example, with regard to the proposal for fuelwood plantations close to Tongatapu's coasts, the application of fertilisers to promote tree growth or insecticides to reduce pests could adversely affect the littoral and reef ecosystems.

While flushing on the liku coast would be rapid, runoff into shallow lagoons or swamps could cause eutrophication which would affect species diversity. Changing the distribution of flora and fauna in these coastal ecosystems could in turn have detrimental effects on other ecological communities. Arguments presented for the protection of these natural systems on the basis of the organisms' intrinsic right to existence should be adequate to instigate human action to prevent damage. Arguments based on human utilitarian values, when viewed objectively, will be seen to have similar justification to those based on intrinsic rights. However, because humans consider themselves to be more important than other components of the environment, damage which affects them directly is more likely to result in remedial action. If leachates and runoff from fuelwood plantations have adverse effects on economically valuable fish stocks or pollute drinking water reservoirs, calls for action will come relatively swiftly. In this case the lack of sustainability of the fuelwood plantation system will be more readily apparent than when the ecological damage is more remote from day-to-day human experience.

Impacts in the predominantly cultural segments of the environment will also extend beyond the immediate system boundaries used for study purposes. For example, if all the currently unutilised land on Tongatapu were to be used for tree plantations, as soon as their fuelwood became available the importation of fuelwood from 'Eua would almost certainly cease. If building timber were to be produced as well as fuelwood then imports from Fiji would be reduced. If wood production were proven to be a viable commercial operation, Tongans working in New Zealand, Australia, and the U.S.A. might well return to enjoy their home lifestyle with economic security provided by tree plantations. Even if tree-planting never grew to these dimensions, information about methods of combining trees planted for fuelwood with traditional land management systems would have some impact on land managers in other parts of Tonga and in other countries searching for improved ways of utilising their own resources. If adverse effects of tree-planting schemes were to materialise, these could also have significant impacts on cultural systems. In 1986 there was a healthy, and apparently growing enthusiasm for growing culturally important trees (King 1987b). Any detrimental outcomes of fuelwood plantations could have a dampening influence on desires to plant trees for other purposes.

(g) Assessments of the suitability of possible options

Strategies constructed by the amalgamation of contributions to improve fuelwood systems will need to be assessed in terms of the aim and objectives set in the first stage of this procedure. Before this can be done, the aim and objectives themselves should be re-evaluated. The pursuit of the design process will have brought to light information not previously available, and, perhaps even more importantly, will have changed the facilitator's and decision-makers' perceptions of interconnections between various aspects of the systems studied. The aim and objectives could be seen to be deficient in a variety of ways. Perhaps the needs of people who would be disadvantaged by the implementation of changes were not given adequate consideration because they had not been consulted prior to the aim and objectives being established. Maybe preliminary investigations into likely ecological impacts suggest that much greater problems could be caused than originally anticipated. The reassessment of the aim and objectives should be guided by the facilitator and carried out through consultation with the local people. If technical factors are to lead to alterations to objectives, broad ranging discussion, perhaps stimulated by 'brainstorming' or the use of lateral thinking techniques, could well bring to light approaches to overcoming problems which would not be apparent from a purely technical perspective. Simply presenting technical reports to local representatives is clearly inadequate. Full advantage of both technical research and local knowledge will only be gained if in-depth interaction between the various parties is achieved.

While such an approach is more likely to achieve satisfactory results than the imposition of changes solely because they are technically feasible, optimisation of outcomes will still be difficult. Contributing to the difficulties are apparent dichotomies in what is to be achieved. Increasing fuelwood supplies and reducing fuelwood consumption will require prompt and decisive action; the attainment of sustainability is a long-term goal which will demand a varied range of actions over time, and changes in attitude with regard to many aspects of the Tongatapu environment. Adverse environmental impacts are to be minimised but the adoption of intensive production methods to increase fuelwood supply as quickly as possible would caused major changes to the natural environment. Objective 6 calls for fuelwood supply to remain largely under the control of fuelwood users but intensive production techniques would appear to be best suited to large scale commercial undertakings. The range of apparent conflicts is likely to increase as information on expected impacts of various proposals is collated. The character of the aim precludes the adoption of simplistic criteria for the assessment of suitability such as 'whatever system makes the most money must be best'. To achieve the sustainability called for, the interactions between the physical, biological, and cultural components of the inclusive environment must be understood as fully as possible. Only then will a meaningful evaluation of the suitability of proposals and the selection of the most appropriate options be possible.

6.5.3.3 Implementing the selected options

The nature of options and requirements for implementation will vary according to the local environment and decisions made in the design and selection procedure. The appropriate bodies and individuals to implement options will vary accordingly. As a basis for determining the aim and objectives for improving the fuelwood situation on Tongatapu, two fundamental assumptions were made: that fuelwood production should be, as far as possible, under the control of fuelwood users; that a sustainable balance between supply and consumption should be achieved. If these assumptions are accepted, the implementation stage will be characterised by: maximum involvement of fuelwood users in all aspects of improvement activities; and the adoption of mechanisms which enhance rather than degrade the natural environment. These two characteristics would be compatible with the involvement of non-government organisations in implementation programmes which emphasize the personal rather than the institutional approach to development activities.

Community groups ranging from Scouts and Guides to churches and village based working groups could be valuable vehicles for the transfer of information and organisation of practical activities. They could operate in the context of community projects, such as coastal forest rehabilitation, or as conveyors of advice to individual practitioners. Schoolchildren around the world are increasingly aware that maintaining a healthy environment is of paramount importance to their future well-being. Providing good environmental education will thus underpin any activities selected to contribute to the achievement of a sustainable balance between fuelwood supply and demand.

7. A CRITICAL REVIEW OF THE RESEARCH METHODOLOGY AND ITS POTENTIAL TO ASSIST THE DESIGN OF SOLUTIONS TO FUELWOOD PROBLEMS IN DEVELOPING COUNTRIES

The approach taken in this research programme has two main distinctive features: the development of a theoretical framework to facilitate holistic modelling, and the adoption of a thematic approach to guide data collection and analysis. The whole approach is underpinned by the conviction that the well-being of non-human as well as human entities should be afforded meaningful consideration. Assessment of the effectiveness of the overall methodology thus requires evaluation of:

1. the appropriateness of a non-anthropocentric philosophical basis;
2. the suitability and practicability of holistic modelling; and
3. the effectiveness of the thematic approach.

Each of these criteria are discussed here in relation to the specific environment in which the Tongatapu study was undertaken, and in the context of the range of conditions applying in other developing countries where fuelwood problems need to be addressed.

Superficially, the adoption of a non-anthropocentric approach could appear totally inappropriate for the study of development issues. However, including consideration for the well-being of non-human components of the environment in approaches to development planning, is becoming increasingly accepted in varied societies around the world. Even in countries most committed to the pursuit of material goals, recognition is given to maintaining those aspects of the natural environment which are perceived as providing direct benefits to humans. As the impacts of human activities on global life support systems have become better understood and widely known, the need to reduce the detrimental effects of humans on the natural environment has been acknowledged.

The conventional approach to the study of ecological systems is anthropocentric: natural phenomena are studied in order to satisfy human wants. Generally, the 'natural environment' is perceived as a backdrop to human activities, providing both concrete and abstract resources, and holding value only by way of benefits provided for human-beings. A non-anthropocentric approach acknowledges that non-human entities have value in their own right, and attempts to balance this with the values inherent in human systems. Gaining an adequate understanding of the interactions between the human and non-human components of the global system would permit the adoption of long-term sustainability as a practical criterion for project design and selection.

There are currently, however, many serious difficulties with regard to using non-anthropocentric approaches to development issues. These difficulties can be categorised as problems of acceptance and problems of implementation. The main impediment to widespread acceptance of a non-anthropocentric basis for development is that it would undermine the central dynamic of capitalism: self-interest. The world economic system is founded on the right of humans to sequester material from the natural environment for the satisfaction of human desires. The allocation of rights for such material to remain in its natural state would contradict basic assumptions of economic development theory. Given that the governments of most developing countries are continuing to extend their dependence on the capitalist system, it would seem highly unlikely that moves to base official development policies on non-anthropocentric philosophies could occur in the foreseeable future.

One very significant aspect of the self-interest which underlies capitalism is adherence to self-centred value systems. Classical economics, which seeks to describe and explain transactions within the capitalist system, holds as a fundamental tenet that individuals behave in ways which maximise benefit to themselves. The highest values are placed on goods and services which give the greatest satisfaction to those humans who have control of adequate resources to participate in the market. No value is allocated to the role of components of non-human ecosystems in the maintenance of those systems unless some direct human use is implied. Attempts to develop methods of placing monetary values on non-human phenomena reinforce not only anthropocentric bias but also the pre-occupation of capitalist societies with the enumeration of values. The assumption that any component of the natural world can be allocated a monetary value which adequately describes its worth, demeans humanity. Nevertheless, it is consistent with the system that the vast majority of humans utilise to regulate the distribution of goods and services. As long as value systems concentrating on utility provided to individuals prevail, non-anthropocentric approaches to development are unlikely to gain more than narrow acceptance.

The second set of difficulties involves problems with the implementation of non-anthropocentric approaches. The central problem is that it is effectively impossible for any individual to totally overcome all human bias. While one could never actually view the world '... through the eyes of a dog, frog, scorpion, badger, seagull, buttercup, etc. ...' (Fenton 1987, p.28) it is possible to gain relevant information to construct a perspective which enhances understanding of the impacts of human behaviour on the natural environment. The main practical difficulty in achieving such a perspective is the large amount of research required to obtain and process the necessary volume of data. However, simply accepting that such perspectives on the implications of a proposed activity need to be considered makes a useful contribution.

Difficulties with the collection of large amounts of data also apply to the utilisation of holistic models. This problem can be minimised by use of techniques such as progressive contextualisation which assist the identification of essential areas of investigation. However, for a researcher to be able to gain a holistic perspective on the focus of a study requires the assimilation of information to characterise all factors impinging on the subject matter. Only then can judgments be confidently made about which routes of possible investigation can be abandoned. As discussed in Chapter 1, the practical application of truly holistic models has been said by some not to be viable. The task of fully identifying all interactions between all components of complex systems is indeed not practicable; the approach used for this study has been, therefore, to adopt a conceptual model which provides a broad framework without making demands for a particular degree of detail to be attained. This framework was found to be a useful construct to guide both collection of descriptive material and investigation of interactions. It also provided a constant reminder that non-human components of the environment were significant to the focus of the research.

The value of such a holistic model to research to assist the design of solutions to fuelwood problems in other developing countries will to some extent depend on local conditions, and on the perspective and objectives of the initiators of the study. An advantage which a comprehensive approach has in relation to any fuelwood issue is that it can accommodate consideration of factors only indirectly associated with the central focus of the study. This is particularly important for addressing fuelwood problems because causes of difficulties often lie outside the immediate supply and consumption processes, and solutions always involve the utilisation of resources which could be used for other purposes. For example, in the case of charcoal production in southern Thailand, a narrow approach to the assessment of stocks of mangrove trees might suggest that cutting could continue for, perhaps, five years before the charcoal industry would be seriously threatened. Adopting a broader approach to such research would rapidly show that problems already exist in the physical, biological, and cultural spheres of the environment external to the charcoal production process. In many cases, such as in this example, recognition of detrimental impacts to both anthropocentric and non-anthropocentric values would be prompted by the use a holistic model to guide investigations. This approach will be valuable no matter which value system underlies the distribution and allocation of resources in the study area. If a non-anthropocentric approach is to be taken, the utilisation of a holistic model to guide the research will be essential.

Within the context of a holistic study the use of a thematic approach is highly recommended. For the study of fuelwood issues on Tongatapu the theme was composed essentially of the field research aims. In other circumstances the theme could be more general or more specific in nature, but, in this context, a theme will almost certainly consist of more than the statement of a singular problem which requires a solely technical solution. In applications of the thematic approach to fuelwood problems the nature of the theme itself will be further explained as the research continues. In some cases it might be appropriate to redefine the theme once background information or material substantially clarifying the nature of the problem has been gathered. If the theme has been devised in isolation from the practical features of the problem being addressed, its appropriateness should be continually reassessed.

The main value of the thematic approach is that every aspect of the study can be related to the theme; this provides a simple yet powerful mechanism for collating material from varied sources. Ways of dealing with the different types of data generated by a holistic study will vary. Suitable structures will have to be introduced to handle the various sets of information and to relate them to the theme. The forms these might take will depend on the nature of the study. For the Tongatapu research the information gleaned about the study areas was organised according to types of system which were perceived to be components of the study area environments of greatest relevance to the fuelwood theme. It was then considered most appropriate to conduct the main discussion about the theme by comparing and combining the study area results. A valuable feature of the thematic approach is its flexibility that will allow the treatment of data in accordance with idiosyncrasies of the subject of the research.

The information gathering techniques related to the thematic approach to the Tongatapu study could be critically assessed from a number of perspectives. Listing 'Plus', 'Minus', and 'Interesting' points (de Bono 1982) highlights a broad range of features of the fieldwork programme. Positive aspects include: the educational benefits gained by the field researchers; the direct contribution made to creating awareness among villagers and government officers about fuelwood problems; the indirect benefits of having written records of a detailed study of the role of fuelwood in Tongatapu villages; a small input of foreign currency into the Tongan economy. Negative aspects might include: the intrusions into people's everyday lives which the surveys involved; the fact that information was collected from only a small sample of villages; not all the desired information was obtained; the presence of any foreigner has some detrimental impacts on the local culture. 'Interesting' issues include noticing the different attitudes towards the project; experiencing the contrasting lifestyles which exist side-by-side in developing countries; gaining greater awareness about difficulties in making the achievement of practical goals compatible with academic objectives. It was also 'interesting', though disappointing, to see confirmed the assertion made by a Tonga Government officer that Ph.D. students take years to produce full reports on their fieldwork, thus greatly reducing the practical value of the results of their research. These preliminary observations indicate that a wide range of criteria could be used as the basis for an appraisal of the research techniques.

To contribute to the critique of the effectiveness of the research approach, evaluation of the information gathering techniques is best focused on how well they fulfilled the requirements of the theme. This task is undertaken here by reference to the objectives, listed in Chapter 1, that were set out to guide the collation of information to satisfy Field Research Aims 1 and 2. These objectives specify how stages two, three, and four of the thematic approach were related to the Tongatapu study.

Objective 1 promoted the collation of all information that would be relevant to the Tongan study. This construction of a general description of the study area environment was required in order to satisfy stage two of the thematic approach. The major research method employed to obtain material on various aspects of the situation in Tonga was searching the literature. This was supplemented by gathering information through interviews, discussions, and direct observation during the author's preliminary visit to Tongatapu. The holistic, conceptual model introduced in Chapter 1 (Figure 1.3) proved a useful guide to organising and presenting this information. While the goal of characterising the general environmental context in which the fuelwood study was conducted, is considered to have been largely achieved, some difficulties and deficiencies are evident.

The main difficulty was related to the volume of background information needed to provide a comprehensive characterisation. To fully describe every aspect of the Tongatapu environment is clearly impossible, but a basic tenet of the holistic approach to this study is that decision-makers need an adequate awareness of the human and non-human context; without it they will not be able to identify which options are most likely to be sustainable and offer the greatest long-term benefits. The breadth and detail required in the characterisation therefore depends on who are the decision-makers, on their levels of awareness, and on the perspectives they adopt. The collation of information for this study was based on the assumption that among those wishing to follow the application of the thematic approach to the Tongatapu study would be individuals with no prior knowledge about Tonga. The inclusion of detailed information about the environment in which the study took place is, therefore, considered appropriate in this case. In other situations, when decision-makers are already aware of the background to a study, a less detailed characterisation will be appropriate. Difficulties exist in making assessments of not only the volume of material to be included in background descriptions, but also the nature of that information. Even in situations where all decision-makers are local people, extra information, perhaps reporting results of specialist research, will be available to describe their environments. Such information must be properly interpreted and its worth carefully evaluated, but it should not be disregarded just because the local people believe they already have adequate knowledge. As de Bono's lateral thinking techniques have illustrated, approaching the same issue from a different perspective can be extremely enlightening (de Bono 1982).

The main deficiency identified in this study's characterisation of the environmental context, is that features of the Tongatapu environment which were changing only slowly have been more comprehensively described than those subject to greater fluctuation or development. Three main factors contributed towards this imbalance: first, the rapid rate of change in Tongan society; second, the relatively sparse coverage of Tongan events in the academic literature; and third, the inadequate allocation of time in the fieldwork programme specifically for gathering general background information. There was a tendency for all data collection activities in the field to concentrate on the completion of the programme of interviews and bush allotment surveys. While this was probably essential for gaining the information needed for the core theme, it did force lower priorities to receive less than optimum attention, or, in some cases, to be virtually ignored. This illustrates a difficulty with the thematic approach that will require experience and careful pre-planning of fieldwork to overcome.

The second objective, to devise suitable methods of integrative study, was, similarly, broadly achieved but not to the optimum extent. The integrative nature of the study ran from the information gathering procedures, such as household interviews, through the data processing to the presentation of results. The technique of dealing with information about the study areas in terms of natural, domestic, cultivated, commercial, and social, as well as fuelwood, systems, worked well. Nevertheless, it could have been improved by conducting a full pilot study of a single village. The broadly-based research carried out during the preliminary visit was extremely valuable for guiding the design of the main interview and bush survey programme. However, it is felt that focusing on just one community to gain in-depth information about all systems would probably have been better preparation. Generating the full range of material about one study area would have permitted a trial run through proposed data processing procedures. This would have provided a more complete test of the integrative techniques proposed for data collection, collation, analysis, and presentation. With a fuller understanding of the requirements of integrative processing of information, the tendency of the fieldwork to rely excessively on the main data collection procedures could have been avoided.

While detailed research in just one community would have been beneficial, this single study could not have met all requirements of the preliminary research programme. An assessment of the diversity of conditions within the area to be included in the main study was also needed, in combination with an evaluation of priorities. For studies of this type, the optimum balance between a locally focused study and the collection of general information depends on environmental conditions, the nature and requirements of the research programme, and the availability of reliable and up-to-date information from indirect sources.

The next three objectives, 3, 4, and 5, relate to the core of the field research programme: gaining adequate information to describe consumption, supply, and resources of fuelwood in the study areas. These requirements were addressed by the main fieldwork activities, and were the ones to which the vast majority of data relate.

The central fieldwork technique, the household interview survey, generated a wealth of data about the role of fuelwood in household activities, and to that extent was very successful. The schedule of questions about household characteristics sought to gain a broad range of information to enable the construction of profiles on household activities. While the results from the sample households cannot be claimed to cover the full range of variation within a study area, it is believed that they give a valid indication of typical households. As discussed in Section 6.3.2, the estimates of fuelwood consumption obtained from the interview survey can only be considered as approximations. While Objective 5 sought an evaluation of fuelwood requirements, the fact that the data gained are approximate is not felt to diminish the overall value of the survey results.

Methods used to obtain information about fuelwood production and supply included all three main research activities. Respondents to the household characteristics interviews described how they obtained their fuelwood; bush allotment interviewees provided information about quantities of fuelwood collected from agricultural land; and the bush allotment surveys recorded the types, numbers, and sizes of potentially fuelwood generating trees. Together, these sources of information provided an adequate description of production procedures from bush allotments, and the bush surveys contributed towards a fuller understanding of the resource base. A deficiency in data on fuelwood resources and supply systems occurs in the area of wood production on non-agricultural land. The preliminary surveys conducted near 'Ahau and at Tukutonga indicate that fuelwood collection has had a severe impact on natural coastal ecosystems, effectively destroying the basis for a sustainable fuelwood production system. The fieldwork conducted by the author was deficient in that it did not pursue investigations of this degraded fuelwood resource.

Objective 4 specified that data on fuelwood resources should be quantitative. Apart from some tentative calculations of volume indicators for some bush allotment trees (Section 6.2.6) no attempt has yet been made by the author to quantify resources or potential sustainable yields of fuelwood. It is hoped that once data on biomass volumes from fieldwork undertaken by a research student with the University of the South Pacific become available, estimates of fuelwood stocks on surveyed allotments will be calculated.

Information required to build profiles of study areas came mostly from household interviews and informal discussions with residents. Relations between fuelwood systems and other systems within the study area environments are considered to have been adequately characterised. Additional material relating to the requirements of Objectives 6 and 7 would have been valuable to add further detail to the profiles. The approach to gaining comprehensive information to contribute to the profiles could have been improved by designing research methods specifically for this purpose. Due to constraints on time in the field, gathering such information was not given all the attention it perhaps deserved. It is recommended that when the thematic approach is adopted for future research, the full requirements of stage 3, to describe factors within local systems, should be carefully evaluated not only at the start of the study but also subsequently. Once the strengths and weaknesses of the main research techniques are known, the need for additional information gathering can be better defined.

Objectives 8 and 9, to identify factors affecting fuelwood systems and assessing likely implications of changes in fuelwood supply, have only partially been fulfilled. As stressed throughout the thesis, fuelwood systems, and factors influencing them, vary markedly between locations. Having identified variations in fuelwood supply mechanisms across Tongatapu only general factors have been discussed. Limitations on components of fuelwood systems have been examined in Section 6.4. Changes to local systems will depend on local conditions and should, therefore, be investigated in the context of the specific community under review. While observations can be made about the potential seriousness of fuelwood shortages on Tongatapu, in terms of both ecological damage and reductions in fuel supplies, implications for individual households and communities need to be evaluated at the community level. Once this has been done, and residents are fully aware of how fuelwood shortages are likely to affect their own lives and those of their children, then activities within local communities and across the island can be undertaken to ensure that long-term implications are not detrimental. Such a process can only be successfully completed by local residents. To the extent that this study has failed to meet Objectives 8 and 9, it is considered that this is because those objectives were not wholly appropriate for an outsider's research programme.

Objective 10, to develop guidelines to assist design and selection of techniques for improvement, has been fulfilled by the presentation of the procedure incorporated into the strategy described in Section 6.5. The utilisation of the guidelines to suggest specific ways of improving the fuelwood supply/consumption balance has not been undertaken in the way intimated in Objective 11. Possible methods of increasing wood production and of reducing consumption have been presented and discussed, but the procedure required by the guidelines cannot be undertaken in isolation. The design and selection of programmes of change to reintroduce balance into local fuelwood systems must be controlled, and enthusiastically pursued, by the fuelwood producers and users themselves.

In most developing country situations woody biomass is collected and burnt because it is the only fuel available at no monetary cost. The market economy cannot provide a good at no cost, so people with no surplus wealth in the form of monetary funds are marginalised. It is often these very people who most need access to fuel. Because conventional economic development strategies cannot deal with non-commercial goods, another approach is needed to assist the development of those who have no money to buy everyday requirements such as cooking fuel. As discussed in Chapter 3 proponents of basic needs approaches do not deny that economic development gained through industrialisation can bring worthwhile benefits, they are keen to ensure that the rich do not grow richer at the expense of the poor. The consensus about how the living conditions of the poorest can be improved, is that they must be empowered to make decisions for themselves. As Samana explained, village people have to be able to develop their own resources '... to service their own needs on a scale that they can afford financially and politically, without losing control of their destiny' (Samana 1988, p.93). In many situations they will require some outside assistance to instigate development programmes, but they will undoubtedly have the human resources within their own communities to plan and coordinate activities. In other locations, such as on Tongatapu, the average wealth of households is such that they have control of the resources essential for meeting everyday needs. However, pressure on resources, generally brought about by increasing population pressure and a desire to utilise resources for financial gain as well as for subsistence needs, is often very great. In such circumstances programmes of change to stimulate development must take into account possible impacts on the environment which provides all resources. To gain sustainable benefits, well-informed decisions about development activities are required at both personal and institutional levels. National and international organisation have acknowledged the need for change to relieve fuelwood shortages; they must now work to achieve local solutions.

It is in this context that the strategy developed in this study is proposed as a way of stimulating and supporting people in small communities in developing countries to make their own decisions about how to develop. There is much to be done if the impacts of the fuelwood crisis are to be reduced. While outsiders can provide information, suggestions, and support, it is those directly involved with fuelwood systems who have to decide to make those systems sustainable. To do so they must be permitted and encouraged to take control of their own development. The strategy for the design and implementation of programmes of change is presented here in the belief that its utilisation could stimulate positive attempts to create sustainable solutions to local fuelwood crises.

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APPENDIX 1 HOUSEHOLD CHARACTERISTICS INTERVIEW SCHEDULE

Village:-
Hingoa 'o e Kolo:-
Household Reference:-

No.(s) on Cadastral Map:-
Selected for Bush Survey?:-

SECTION 1 MEMBERS OF THE HOUSEHOLD

1.1.1 What is the name of the head of this household?
Kohai nai 'a e hingoa 'o e 'ulu pe taki 'o e 'api ni?

1.1.2 Male/Female
Tangata pe Fefine

1.1.3 What is his/her resident status?
'Oku nofo fonua'i fe pe'oku 'i fe he taimi ni?

R - Permanent Resident	V -	Visitor
R- Nofo Fonua 'i Tonga ni.	V -	'A'ahi
O - Permanently Overseas	T -	Temporarily away from the household (specify where)
O - Nofo Fonua 'i Muli.	T -	Mamao fakataimi mei he famili (fakamahino'i pe ki fe.)

1.1.4 Where is his/her home town?
Ko fe nai hono Fonua totonu?

C - Current town; C - Kolo he taimini;
N - Nuku'alofa;
T - Elsewhere in Tongatapu; T - Ha feitu'u pe 'i Tongatapu
E - 'Eua; H - Ha'apai; V - Vava'u;
U - Niuas; O - Overseas (specify where)
U - Niuas; O - Muli (fakamahino'i pe 'i he Fonua fe 'i Muli.)

1.1.5 How long has he/she been living on this town allotment? (yrs)
Ko e ta'u nai 'eni 'e fiha ho'o nofo he 'api ni?

1.2.1 How many male and female adults are there in this household?
(<16yrs = C; >15yrs = A)
Ko e ha nai hono toko lahi 'o e kakai tangata pe a mo e kakai fefine lalahi 'i he 'api ni.?

1.2.2 How many male and female children are there in this household?
Ko e tamaiki tangata mo e tamaiki fefine iiki nai'e toko fiha 'oku nofo 'i 'api ni?

1.3.1 How many day and boarding students are there in this household?
Ko e ha nai hono tokolahi 'o e fanau ako 'alu pea mo ako nofoma'u 'i 'api ni.?
What ages are they? C - <16; A - >15; AM - >24.
Ko e ha honau ta'u motu'a? C - <16; A - >15; AM - >24.

1.3.2.1 What occupations do members of the household have which earn an income (either cash or goods)?
Ko e ha nai 'a e ngaue 'oku fai 'e he kakai 'o e 'api ni 'o ma'u mei ai 'enau moui(Pe ko e silini pe ko ha koloa pe.

1.3.2.2 Do any children work for an income?
'Oku 'iai ha taha 'i he fanau 'oku ngaue pa'anga?

1.3.3 How much is the total yearly earned income of this household?
Ko e ha nai 'a e lahi 'o e pa'anga hu mai 'a e 'api ni he ta'u?

1. T$ 0 - 100	5. T$1001 - 2000
2. T$101 - 250	6. T$2001 - 5000
3. T$251 - 500	7. T$5001 - 8000
4. T$501 -1000	8. More than T$8000

1.3.4 How much do people in this household receive each year from relatives living abroad?
Ko e ha e lahi 'o e pa'anga 'oku mou ma'u mei ha kainga mei muli?

1.4.1 What transport facilities does the household own?
'Oku 'iai nai ha me'alele "a e 'api ni pe ko ha to e fa'ahinga me'a pe 'oku fai 'aki 'enau fefononga'aki?

B - Bicycle; H - Horse; S - Cart; C - Car; M - Minimoke;
B - Pasikala; H - Ho'osi; S - Saliote; C - Ka; M - Minimoke
V - Van; T - Truck; W - Boat; O - Other (specify).
V - veeni; T - Loli; W - Vaka ; O - Me 'a kehe (fakamahino'i)
BS - Bus; X - Taxi; MB - Motorbike.

1.4.2 What transport facilities do members of the household pay to use?
Ko e ha e me'alele pe ha fa'ahinga me'a 'oku totongi 'ehe kakai 'oku nofo 'i api ni ki ho'omou fefononga'aki?

SECTION 2 LAND

2.1.1 In whose name is this town allotment ('api kolo) registered?
Ki hai 'oku lesisita ai 'a e 'api ni.?

2.1.2 What size is this town allotment ('api kolo)?
Ko e ha nai hono lahi 'o e 'api kolo ni.?

2.1.3 What types of food do you produce in this town allotment ('api kolo)?
Ko e ha nai ha fa'ahinga ngoue me'akai pe 'akau fua 'oku mou ma'u mei he 'api kolo ni; moha fanga monumanu 'oku mou tauhi heni?

2.1.4 What other products do you get from plants and animals on this allotment?
'Oku to e 'iai nai hano to e 'aonga 'e taha 'o e 'akau 'oku ke to 'i 'api ni pea mo e fangamanu 'oku ke fafanga makehe mei hono to mo hono fafanga ki he me'atokoni?

2.2 Does any member of this household have a town allotment ('api kolo) anywhere else? If so, please give details.
'Oku to e ma'u 'api kolo ha taha'i 'api ni 'i ha feitu'u kehe? Kapau 'oku 'iai pea ke fakamahino'i mai mu'a 'a e tukunga 'o e 'api ni.

2.3.1 How many bush allotments ('api 'uta) does this household have access to?
Koe 'api 'uta nai 'e fiha 'oku mou ngaue 'aki?

2.3.2 Where is it/are they?
'Oku tu'u nai 'i fe/ pe 'oku nau tu'u nai 'i fe?

2.3.3 How far is that from here? (miles)
Ko e ha nai hono mama'o mei 'api ni?

2.3.4 Do you own this land?
Ko e 'api 'uta ko 'eni 'o'ou?

2.3.5 What size is the bush allotment? (Acres)
Ko e ha nai hono lahi 'o e 'api 'uta?

2.3.6.1 Is the bush allotment registered in the name of a member of this household? (R)
'Oku lesisita pe 'a e 'api 'uta 'i ha taha 'i 'api ni? (R)

2.3.6.2 Is it held under customary tenure by a member of this household? (C)
Ko e 'api ni nai ko e foaki atu pe 'ehe Ma'u tofi'a ma ha'a taha 'i ho mou 'api.? (C)

2.3.6.3 Do you share the allotment ('api 'uta) with the registered or customary holder? (S)
'Oku ke vahevahe nai mo e toko taha 'o ku 'o'ona 'a e 'api pe koe tokotaha na'e foaki kiai 'a e 'api 'uta.'Oku 'uhinga 'eni ki hono ngoue'i? (S)

2.3.6.4 Do you have an agreement with the holder to use the whole allotment? (A)
'Oku 'ia 'i nai ha'amo felotoi mo e tokotaha 'oku 'o'ona e 'api 'uta ki ho'o ngaue'aki.(A)

2.3.6.5 If so, is the allotment holder in Tonga or overseas? (T/O)
Kapau 'oku pehe 'oku 'i Tonga ni nai pe 'oku 'i muli 'a tokotaha 'oku 'o'ona 'a e 'api 'uta? (T/O)

2.3.7 How much of the allotment do you have permission to use? (Acres)
Ko ha nai hono lahi 'o e 'api 'uta 'oku ngofua keke ngaue'aki?

2.3.8 Who is the registered or customary holder of the bush allotment?
Ko hai nai oku ne ma'u pe lesisita 'a e 'api ni ,pe koia 'oku na'e foaki kiai 'a e 'api ni.

2.3.9 How much do you pay the registered or customary holder for the use of the allotment? (T$ per year)
Ko e ha nai hono lahi 'o e totongi pe ko e me'a 'oku ke totongi ki he tokotaha 'oku 'o'ona 'a e 'api ki ho'o ngaue ai?

2.3.10 To what general use is the bush allotment ('api 'uta) put?
Ko e ha nai 'a e tefito'i me'a 'oku mou ngaue 'aki kiai 'a e 'api 'uta?
F=food crops (subsistence); C=commercial; L=fallow; G=grazing;
O=other - specify

2.3.11 How long have you had access to this bush allotment ('api 'uta)? (Years)
Ta'u 'eni 'e fiha hono fakangofua atu e 'api uta ke mou ngaue 'aki?

2.3.12.1 How many households use this 'api 'uta to grow food crops?
Ko e famili pe 'api 'e fiha 'oku nau ngoue'i e 'api 'uta?

2.3.12.2 How many households collect fuelwood from this 'api 'uta?
Ko e famili 'e fiha nai 'oku nau fa'a ta mo tufi fefie mei he 'api 'uta ni?

SECTION 3 DOMESTIC FACILITIES

3.1 How many buildings do you have on your town allotment?
Ko e fale nai 'e fiha he 'api kolo ko 'eni?

3.2.1 What types of building are they?
Ko e fale ha nai 'a e 'u fale ko 'eni?
Use: L - Living/Sleeping (Fale nofo'anga)
K - Kitchen (Fale peito)
B - Boys' Sleeping (Fale 'o e taimaiki tangata)
T - Toilet (Fale malolo)
W - Washroom (Fale fo)
S - Storeroom (Feleoko pe fale tuku 'anga me'a ngaue)
Walls; Roof; Floor; Windows; Doors:
Holisi; 'Ato; Faliki; Matapa sio'ata; Matapa:
R - Rough Wood
W - Prepared Wood
T - Thatch (poloa)
M - Sheet Metal (kapa)
K - Cardboard/Hardboard (pepa)
P - Plastic Sheet (milemila)
L - Coconut Leaves (louniu)
B - Concrete Blocks (piliki)
C - Cement (sima)
E - Earth (kelekele)
G - Glass (sio'ata)
Style:
Fa'ahinga fale:
T - Traditional Tongan (faletonga)
MT- Modified Traditional (Fale konga ngaahi mei he niu pea papa palangi)
ME- Modified European
E - European (fale palangi)

3.2.2 Which buildings are connected to the electricity grid?
Ko e fe fua 'a e ngaahi fale 'oku hoko ki ai e uhila?

3.2.3 What types of water supply do you have?
Ko e ha nai 'a e fa'ahinga vai 'oku ke ngaue 'aki?
P - Piped (paipa)
X - External Standpipe
T - Rainwater Tank (tangike)
W - Well (vaitupu)
N - Neighbour's
O - Other (Specify) (To e 'iai ha to e me'a kehe fkmahino'i)

3.3 What sorts of lighting facilities do you use?
Ko e ha nai 'a e fa'ahinga maama 'oku ke ngaue 'aki?
EI=Electric Incandescent (fo'i 'uhila fuopotopoto.)
EF=Electric Flourescent ('uhila tiupi)
K =Kerosene (kalasini)
B =Benzine (penisini)
C =Candle (te'elango)
O =Other-specify (To e 'iai ha me'a kehe fkmahino'i)

3.4 What sort of iron do you use?
Ko e ha nai 'a e fa'ahinga haiane 'oku ke ngaue 'aki?
E=Electric ('uhila)
C=Charcoal (malala)
B=Benzine (penisini)
N=None (hala)

3.5.1 How much was your last month's electricity bill?
Na'e fiha nai ho'o mo'ua 'uhila he mahina kuo 'osi?
Note: Ask to see the latest bill.
* Manatu'i ke kole ange keke sio mu'a ki he 'enau tohi mo'ua 'uhila. (fakamuimui taha).

3.5.2 Was this larger, smaller , or about the same as usual?
Ko ho'o 'uhila ko eni he mahina kuo 'osi me'a ni na'e lahi ange , si'i ange pe tatau pe mo e ngaahi 'uhila fuoloa.

3.5.3 Do you use more, less, or about the same amount of electricity now as one year ago?
'Oku lahi ange, si'i ange, tatau pe 'a e lahi koia 'oe 'uhila 'oku ke ngaue 'aki he taimi ni fakatatau moe ta'u 'e taha kuo hili?

3.6.1 Do you use batteries?
'Oku ke ngaue 'aki ha makakasa?

3.6.2 How many do you have to replace each week?
Ko e fo'i maka nai 'e fiha 'oku fetongi he uike takitaha?

3.7.1 Do you use hot water?
'Oku ke ngaue 'aki 'a e vai mafana?

3.7.2 For what purposes? Koe ha fua e ngaahi?

W=Personal Washing	Kaukau
D=Dishwashing	Fufulu peleti
L=Laundry	Fo
H=Handicrafts-specify	Ngaue fakamea'a
P=Pandanus boiling	Haka lou'akau
O=Other specify	To e 'iai moha me'a kehe

3.7.3 What type of fire/stove do you use to heat water?
Ko e ha nai 'a e fa'ahinga afi pe sitou 'oku ke ngaue 'aki ki ho'o vai mafana?
O=Open fire (tafu pe 'i tu'a)
H=Homemade woodstove (sitou fefie ngaahi pe 'i 'api ni)
C=Charcoal stove (Sitou malala)
J=Electric jug/kettle (Sioki pe tikatele 'uhila)
K=Kerosene stove (sitou kalasini)
W=Commercial Stove (fa'ahinga sitou pe na'e fakatau mai)
E=Electric Stove (sitou 'uhila)
G=Gas stove (sitou kasa)

3.7.4 How much extra wood do you use to heat water?
Ko e ha nai 'e lahi 'o e fefie 'oku ke ngaue 'aki ki ho'o vai mafana ?

3.8.1 Have you made any alterations to your home within the last year? If so, please specify.
Na'e 'iai nai ha to e liliu 'i 'api ni lolotonga 'a e ta'u kuo maliu atu. Kataki ka ke fakamahino'i ange mu'a.

3.8.2 Do you have plans to make alterations to your home? If so, please specify.
'Oku 'iai nai ha'o palani ke 'iai ha ngaahi liliu ki ho 'api ni pe 'ikai. Kataki kake fakamahino'i ange mu'a pe ko e ha 'a e ngaahi liliu ko ia.

3.9.1 Do you make copra?
'Oku ke fakamomoa niu?

3.9.2 How do you do this?
'Oku anga fefe ho'o fakamomoa ho'o niu?
S=Sun (La'aa)
W=Wood in own drier (fefie he fale niu pe 'o'ou)
D=Dried in a neighbour's or commercial drier (Fakamomoa he kaunga'api pe koha fale fakamomoa niu totongi)
HS=Husk & Shell in own drier (pulu mo e ngeesi niu 'i ho fale niu pe 'o'ou.
O=Other - specify (to e 'iai ha me'a kehe)

SECTION 4 COOKING PRACTICES.

4.1 How many meals do you cook each day?
'Koe houa kai nai 'e fiha 'oku ke feime'atokoni kiai he 'aho takitaha?

4.2.1 Which cooking appliances do you use?
Ko e ha e fa'ahinga sitou pe afi 'oku fai ai ho'o feime'atokoni?
O - Open fire (afi tafu pe 'i tu'a)
H - Homemade woodstove (sitou ngaahi pe 'i 'api)
W - Commercial Woodstove (Sitou fakatau ha faahinga sitou pe)
U - Earth 'umu (ngoto'umu kelekele)
D - Drum 'umu (ngoto'umu talamu)
J - Electric jug/kettle (sioki pe tikatele 'uhila)
C - Charcoal stove (sitou malala)
K - Kerosene stove (sitou kalasini)
G - Gas stove (sitou kasa)
E - Electric stove (sitou 'uhila)
T - Toaster (me'a tunu tousi)
F - Electric frypan (fakapaku 'uhila)

4.2.2 Where are these cooking appliances located?
'Oku tu'u pe tuku nai 'i fe 'a e uu me'a ko 'eni?
M - Mainbuilding (fale lahi)
S - Separate kitchen (fale peito makehe)
X - External ('I tu'a pe)

4.2.3 How long have you been using these types of cooking appliances?
Ko e ha hono fuoloa ho'o ngaue'aki e ngaahi me'a ni ke fai ai ho'o feime'atokoni?

4.3 Which cooking methods do you use?
Ko e ha e founga feime'atokoni 'oku ke ngaue'aki?
H - Haka
B - Other Boiling
K - Baking (ta'o keke mo e ngaahi me'a pehe)
F - Frying (fakapaku)
T - Toasting (tousi)
R - Roasting in coals
S - Spit roasting (tunupuaka)
U - Umu
O - Other specify (To e 'iai moha me'a kehe)

4.4 How long is the fire/stove alight? (hrs per meal)
Ko e ha nai hono fuoloa 'a e 'ulo ho'o afi pe sitou pea toki 'osi e ngaahi me'a 'oku ke fiefu'u he afi pe sitou?

4.5 How many people are cooked for? Kakai lalahi Fanau 'i'iki.
Ko e toko fiha nai 'oku fai kiai ho'o feime'atokoni?

4.6 Which cooking methods would you like to use which you cannot use on your present fire/stove?
Ko e ha ha toe founga feime'a tokoni 'e taha 'oku ke fie fai, 'oku ikai lava ho'o afi pe sitou?

4.7 Would you like to make any alterations to your kitchen? If so, please describe.
"Oku ke loto nai ke fai ha liliu ki ho peito? Fai ange mu'a ha'o fakamatala ki he te u liliu ko ia.

4.8 What sorts of cooking stove would you use if you could choose any type?
Ko e ha nai ha fa'ahinga sitou 'oku ke fie ngaue'aki kapau teke fili pe ha fa'ahinga sitou?

SECTION 5 FUELWOOD CONSUMPTION

5.1 Approximately how much fuelwood do you use each day?
Ko ha nai ha'o fakafuofuo ki he lahi 'o e fefie koia 'oku ke ngaue 'aki he 'aho, ki he feime'atokoni?
(Wood; H & S; Fronds; Charcoal; Other.
Mon-Fri; Sat; Sun)
Note: Record in units given by interviewee; measure and weigh at least one unit to allow approximate conversions.

5.2.1 Which are your 5 most important types of fuelwood?
Fakahokohoko mou ange 'a e fefie pe me'a tu'ukimu'a 'e nima 'oku lahi taha ho'o mou ngaue'aki?

5.2.2 Which other types of fuelwood do you use?
Ko e ha nai moha to e fefie pe me'a 'oku mou ngaue'aki?

5.3.1 Which types, of the ones available to you now, are best for use on an open fire?
Ko e ha nai 'a e fa'ahinga fefie 'oku ke ma'u heni he taimi ni 'oku ke pehe 'oku sai taha ki he tafu haka 'i tu'a?

5.3.2 Why?
Ko e ha nai hono 'uhinga?

5.4.1 Which types, of the ones available to you now, are best for use in an umu?
Ko e ha nai 'a e fefie he kalasi 'oku ke ma'u heni 'oku ke pehe 'oku sai ki he 'umu?

5.4.2 Why?
Ko e ha nai hono 'uhinga?

5.5.1 Which types that you used in the past are no longer available?
Ko fe nai ha kalasi fefie na'a ke ngaue 'aki he kuohili ka 'oku 'ikai ke toe ma'u ia?

5.5.2 Which types of fuelwood that are no longer available would you prefer to those that are available?
Ko fe 'a e kalasi fefie 'oku 'ikai ke to e ma'u ka 'oku ke fi'e ngaue'aki lahi ange 'i he ngaahi fefie 'oku ke ala ma'u?

5.5.3 Why?
Ko e ha nai hono 'uhinga?

5.6.1 Does your use of fuelwood vary much during a year?
'Oku 'iai nai ha ngaahi mahina pe mahina 'oku lahi ange pe si'i ange ho'o ngaue 'ahi e fefie?

5.6.2.1 In which months do you use most?
Ko fe nai 'a e mahina 'oku lahiange ai ho'o ngaue 'aki?

5.6.2.2 Why is this?
Ko e ha nai hono 'uhinga?

5.6.2.3 How much more than normal do you use? (per month)
Ko e ha nai hono lahi ange he anga maheni 'a e fefie koia 'oku ke ngaue'aki?

5.6.3.1 In which months do you use least?
Ko e mahina fe 'oku si'i taha ai ho'o ngaue'aki 'a e fefie?

5.6.3.2 Why is this?
Ko e ha nai hono 'uhinga?

5.6.3.3 How much less than normal do you use? (per week)
'Oku si'isi'i fefe 'a e fefie 'oku ke ngaue'aki he uiki 'e taha mei he anga maheni?

5.7.1 For what purposes other than cooking do you use fuelwood?
Ko e ha ha to e fa'ahinga me'a 'oku ke ngaue'aki ki ai ae fefie 'o makehe mei ho'o ngaue 'aki ki he feime'a tokoni?

- C - Coconut oil (ngaahi lolo)
- D - Drying copra (fakamomoa niu)
- F - Fish drying (fakamomoa ika)
- I - Insect repellant (fakaahu namu)
- P - Pandanus leaves (ngaahi louakau)
- O - Other (to e me'a kehe)

5.7.2 How much fuelwood do you use per month for these purposes?
Ko e ha nai hono lahi 'oe fefie he mahina 'oku ke ngaue 'aki ki he ngaahi me'a ni?

5.8.1 Do you use charcoal as fuel? How much do you use per week?
'Oku ke ngaue'aki e malala? Ko e ha hono lahi 'oe malala 'oku ke ngaue 'aki he uike?

5.8.2 In what sort of appliance do you use charcoal?
Ko e ha nai 'a e fa'ahinga me'a oku ke ngaue 'aki kiai 'a e malala?

- F - Open fire (tafu pe 'i tu'a)
- W - Woodstove(Sitou)
- C - Charcoal stove (sitou malala)
- I - Iron (haiane malala)
- O - Other - specify (to e iaimoha me'a kehe)

5.8.3 Where do you get this charcoal?
Ko e ma'u nai e malala ko 'eni mei fe?

5.9.1 Has your use of fuelwood increased or decreased since 1981?
Talu mei he 1981 me'a ni 'oku lahi ange pe si'isi'i ange ho'o ngaue 'aki 'a e fefie?
I - Increased (lahi ange)
D - Decreased (si'isi'i ange)
S - Same (tatau pe)
5.9.2 If so, why? (Ko e ha nai hono 'uhinga?)
5.9.3 Which types of fuelwood have been affected?
Ko e ha fua e kalasi fefie 'oku lahi ange / si'i ange ho'o ngaue'aki?

5.10.1 Has your use of fuelwood increased or decreased in the last year?
'I he ta'u kuo 'osi ko ho'o ngaue 'aki 'a e fefie na'e lahi pe si'i si'i?
5.10.2 If so, why? (Ko e ha nai hono 'uhinga)
5.10.3 Which types of fuelwood have been affected?
Ko e ha fua e kalasi fefie 'oku lahi ange / si'i ange ho'o ngaue'aki?

5.11.1 Would you prefer to use less fuelwood?
'Oku ke sai'ia ange ke si'i ange ho'o ngaue 'aki e fefie?
5.11.2 If so, why? (Ko e ha nai hono 'uhinga?)
5.12.1 Are you interested in making or buying a stove that burns wood fuels?
'Oku ke sai'ia nai ke ngaahi pe fakatau mai ha'o sitou tafu?
5.12.2 If so, which fuels would you want to burn in it?
Kapau ko ia ko e ha nai e fa'ahinga me'a oku ke fie tafu 'aki?
W - Wood (fefie)
H&S - Coconut husk and shell (pulu mo e ngeesi niu)
FRO - Coconut fronds (palalafa)
OCF - Other coconut fuels (to e fefie niu pe)
CHA - Charcoal (malala)
AGR - Agricultural residues (fefie mei he ngoue 'anga)
5.12.3 How much would you be prepared to pay for a woodstove?
Ko e pa'anga nai 'e fiha teke fie fakamoleki ki ha'o sitou tafu?

SECTION 6 FUELWOOD SUPPLY

6.1.1 Where do you collect fuelwood from? (In order of importance)
'Oku ke tufi pe ta fefie nai mei fe?
T - Own town allotment ('api kolo pe 'o'ou)
OT - Other town allotment
B - Own bush allotment ('api tukuhau pe 'o'ou)
AB - Abandoned bush allotment (to e 'api tukuhau pe)
OB - Other bush allotment (to e 'api tukuhau pe)
OC - Other cultivated agricultural land (mei ha to e 'api tuku hau ngaue'i)
OU - Other uncultivated agricultural land (mei ha to e 'api tukuhau ta'e ngoue'i)
CD - Copra drier (fale niu)
C - Coastal forest (inc. swamp forest)(Fefie mei he matatahi)
M - Mangrove (tongo)
D - Driftwood (fefie ma'u mei he tete mai 'i tahi)

R - Roadsides (fefie tanaki pe he hala)
S - School land ('api 'o e lautohi)
CH - Church land ('api 'o e siasi)
N - Noble's land('api 'o e nopele)
G - Government land('api 'o e pule'anga)
K - King's land (tofi'a 'o e tu'i)
O - Other - specify (to e iai moha feitu'u kehe)

6.1.2 How long have you been collecting fuelwood from each of these areas? (years)
Ko e tau nai 'eni 'e fiha ho'o ta pe tufi fefie mei he ngaahi feitu'u ko 'eni?

6.1.3 From which areas did you collect fuelwood in the past but do not now?
Ko fe ha ngaahi feitu'u na'a ke fa'a ta mo tufi fefie mei ai he kuo hili ka 'oku 'ikai keke to e ta fefie mei ai?

6.1.4 Do you have to pay for access to any of the areas where you collect fuelwood now?
'Oku ke totongi nai ki ho'o 'alu ki he ngaahi feitu'u ko 'eni 'o ta fefie mei ai?
If so, how much do you pay per year?
Ko e fiha nai oku ke totongi he ta'u?

6.2 Which types of fuelwood do you collect from each of these areas?
Ko e ha nai 'a e kalasi fefie 'oku ke/mou ta mei he ngaahi feitu'u takitaha ko 'eni?

6.3 How often do you collect wood from each area? (per month)
'Oku tu'o fiha nai ho'o ta fefie mei he ngaahi feitu'u ko 'eni ?

6.4 How far from your home is each collection site? (miles)
Ko e ha nai hono mama'o mei ho mou 'api 'a e ngaahi feitu'u ni ?

6.5.1 Who collects the wood?
Ko hai nai 'oku ne ta 'a e fefie?
M - Male (tangata)
F - Female (fefine)
A - Adult Tokotaha lahi)
C - Child (fanau)
O - Outside this household (tokotaha kehe ia mei 'api ni)

6.5.2 How much do you pay for labour for collecting fuelwood? ($ per month)
Ko e fiha nai 'oku ke totongi ki hono ta ho'omou fefie?

6.6.1 How much time is spent collecting fuelwood? (man hours per month)
Ko e ha nai hono loloa 'o e taimi 'oku ke ta fefie ai?

6.6.2 Is this less or more time, or about the same as: 1. 1 year ago?
(L;M;S) 2. 5 years ago?
Pehe nai 'oku loloa ange 'eni pe si'isi'i ange 'a e taimi ki ho'o tufi pe ta fefie? tau e taha kuo hili tau e nima kuo hili

6.7 What sort of equipment is used to cut the wood?
Ko e ha nai 'a e fa'ahinga me'a ngaue 'oku ke ngaue 'aki ki ho'o ta fefie?
K - Cane knife (helepelu)
A - Axe (toki)
S - Handsaw (kili)
C - Chainsaw (misini tutu'u 'akau)
O - Other - specify (to e iai mo ha me'a ngaue kehe)

6.8.1 How is the fuelwood transported home?
'Oku anga fefe hono fetuku ki 'api ho'o fefie?
P - Person (tangata pe)
B - Bicycle (pasikala)
H - Horse (hoosi)
S - Horse and cart (saliote mo e hoosi)
C - Car (ka)
V - Van (veeni)
T - Truck (loli)
X - Taxi (tekisi)
BS - Bus (pasi)
MB - Motorbike (motopaiki)
W - Boat (vaka)
O - Other - specify (to e iai ha me'a kehe)

6.8.2 How much do you pay for the transport of each load? (T$)
Ko e ha nai ho'o totongi ki he uta fefie 'e taha?

6.8.3 How much do you pay for the transport of fuelwood per month? (T$ per month)
Ko e ha nai hono totongi 'o e uta fefie ki he mahina?

6.9.1 Is live wood cut, or just dead wood collected? (L/D)
Ko e 'akau mate pe mata, 'oku ta?

6.9.2 If live wood is cut specifically for fuel, is the tree felled, coppiced, pollarded, or lopped? (F/C/P/L)
Ko hono ta mata'i hifo o e 'akau 'oku fakataumu'a nai 'eni ki he fefie , pe oku tuu'si pe ke mate, pe tu'usi pe ki lalo pe a to e huli hake, pe ko hono tutu'u ko toa 'o e ngaahi va'a, pe ko e tata holo pe ha ngaahi va'a ha ngaahi fu'u 'akau?

6.9.3 Which species are cut live?
Ko e ha nai 'a e fa'ahinga 'akau 'oku ta mata'i pe?

6.9.4 Which species are killed by ringbarking or burning?
Ko fe nai 'a e fa'ahinga 'akau 'oku mate hono fakahele pe ko hono tutu?

6.10.1 What size is the wood when it is brought home?
'Oku lalahi fefe 'a e fefie 'oku 'omi ki 'api ni?

6.10.2 What size(s) of wood do you burn?
'Oku lalahi fefe 'a e fefie 'oku ke ngaue'aki, ki he tafu afi, feiumu pea moha toe fa'ahinga mea pe?

6.10.3 How is it cut down to size? (K/A/S/C/O)
'Oku anga fefe hono tutu'u ke iiki ki ho'o ngaue 'aki?

6.10.4 Who cuts it down to size?
Ko hai nai 'oku ne ta 'a e fefie ko ia ke iiki?

6.11 Where do you store wood?
'Oku ke tuku pe tauhi nai 'i fe ho'o fefie?
1. All the time Taimi kotoa pe
2. Frequently Faka taimi pe
3. Occasionally Taimi pe'e ni'ihi
B - Bush; 'api 'uta
T - Town; 'api kolo
IM - Indoors - main building ('i loto 'i he falelahi)
IK - " - kitchen (falepeito)
IS - " - store (feleoko)
OC - Outside - covered ('i tu'a pe 'o 'ufi'ufi'i)
OU - " - uncovered ('i tu'a kae 'ikai ke 'ufi'ufi

6.12 How long after the wood is cut is it used as fuel? (weeks)
Ko e ha e fuoloa mei hono ta 'o e 'akau pea toki kamata ngaue 'aki ki he fefie.

6.13 Where do you buy wood from?
'Oku ke fakatau mai mei fe ho'o fefie?
0 - None bought ('ikai ke faiha fakatau fefie)
1 - Householder(s) in the same village (casual sales)
(Ko ha fatau pe mei ha taha mei hokolo.
2 - Commercial distributor in the same village (fakatau mei
ha taha fakau fefie mei ho kolo.
3 - In another village - specify (mei ha to e kolo pe)
4 - Talamahu market, Nuku'alofa (mei talamahu mei maketi)
5 - An industrial organisation - specify (pe mei ha to e
fa'ahinga kautaha pe.)
6 - Other - specify (to e iai moha me'a kehe)

6.14.1 Which types of fuelwood do you buy?
Ko e ha nai e fa'ahinga fefie 'oku ke fakatau mai?
6.14.2 How often do you buy fuelwood? (times per month)
'Oku tu'o fiha nai ho'o fakatau fefie he mahina?
6.14.3 How much do you buy at a time?
Ko e ha hono lahi 'o e fefie 'oku ke fakatau mai tu'o taha?

6.15.1 How much do you pay per load?
Ko e fiha nai 'oku ke totongi kihe uta?
6.15.2 How much do you pay per month?
Koe fiha nai 'oku ke totongi he mahina?

6.16.1 How do you transport this wood home?
(P/B/H/S/C/V/T/X/BS/MB/W/O)
'Oku anga fefe nai ho'o ave 'a e fefie ko 'eni ki ho mou 'api?
6.16.2 How much do you pay for transport per load?
Ko e fiha 'oku ke totongi ki he me'alaele ki he fe'iata 'e taha?
6.16.3 How much do you pay for transport per month?
Ko e fiha 'oku ke totongi he mahina ki hono 'uta me'alele mai ho'o fefie?

6.17 Do you need to prepare the wood before you can use it?
'Oku ke to e fai nai ha me'a ki he fefie, kimu'a pea ke toki ngaue 'aki?

6.18 For what purpose(s) is this bought wood used?
Ko e ha fua e ngaahi me'a 'oku ke ngaue 'aki ki ai e ngaahi fefie fakatau ko 'eni?

6.19 Where do you get coconut fuels?
'Oku ke mau nai mei fe ho'o fefie niu?
C - Nuts used for cooking (niu faka'aonga'i ki he haka)
P - Nuts fed to pigs (niu ki he fangapuaka)
D - From copra drying (mei he fakamomoa niu)
A - From 'api 'uta (mei he 'api 'uta)
BT- Bought from TCB (fakatau mei he TCB)
BE- Bought elsewhere - specify (fakatau mei ha feitu'u)
O - Other - specify (To e feitu'u pe)
6.20.1 Which types of coconut fuel do you buy?
Ko e ha nai 'a e fa'ahinga fefie niu 'oku ke fakatau ?
6.20.2 How often do you buy coconut fuels? (times per month)
'Oku tu'o fiha nai ho'o fakatau fefie niu he mahina?

6.20.3 How much do you buy at a time?
Ko e ha hono lahi 'o e fefie niu 'oku ke fakatau tu'otaha?

6.21.1 How much do you pay per load?
Ko e fiha nai 'oku ke totongi ki he uta?
6.21.2 How much do you pay per month?
Ko e fiha nai 'oku ke totongi ki he mahina?

6.22.1 How do you transport it home?
'Oku anga fefe ho'o 'ave ki 'api
6.22.2 How much do you pay for transport per load?
Ko e fiha nai 'oku ke totongi ki he me'alele ki he fo'i uta 'e taha?
6.22.3 How much do you pay for transport per month?
Ko e fiha 'oku ke totongi he mahina ki he me'alele ki hono 'uta mai ho'o fefie?

6.23 Do you need to prepare the coconut fuel before using it?
Te ke toe fai ha me'a ki he fefie 'oku ma'u mei he niu ki mu'a ho'o ngaue'aki?

6.24 For what purpose(s) is the coconut fuel used?
Ko e ha nai 'a e ngaahi me'a 'oku ke faka'aonga'i ki ai ho'o fefie niu?

6.25.1 Do you spend more, less, or the same amount of money on getting fuelwood now compared to: 1. 1 year ago? 2. 5 years ago?
'Oku ke pehe nai 'oku lahi pe si'isi'i ange 'a e silini 'oku ke fai 'aki ho'o fakatau fefie : Ta'u 'e taha kuo hili Pe ko e ta'u 'e nima kuo hili.
6.25.2 If your spending on fuelwood has changed, please describe how it has changed.
Kapau 'oku 'i ai ha liliu 'i ho'o fakamole ki he fefie, kataki mu'a kake fakamahino'i ange ki he anga 'o e liliu ko ia?

6.26 Which of these levels of supply apply to your 5 most important types of fuelwood?
Ko e ha e tu'unga 'oku 'ia i 'a e kalasi fefie 'e 5 'oku lahi taha ho'o ngaue'aki?

P Plentiful now — Lahi 'aupito he taimi ni
PP Will remain plentiful — Lahi 'aupito he kaha'u
A Adequate supply now — Lahi lahi pe he taimi ni
S Will be scarce 5 years from now — 'E ma'u ngata'a he ta'u 5 kaha'u
SS Will be scarce in less than 5 years
SN Scarce now — Ma'u ngata'ahe taimi ni
I Availability increasing — Lahi ange hono ma'u
D Availability decreasing — Holo pe si'isi'i hono ma'u

6.27 If fuelwood is, or will be, scarce, what do you plan to do?
Ka faifai ange kuo si'isi'i pe 'e honge fefie ko e ha nai ho'o palani ki ha'o me'a 'e fai?

1. Switch to other woodfuels - specify — Liliu ki ha kalasi fefie 'e taha - fakamahino'i
2. Switch to non-wood fuel - specify — Liliu ki ha me'akehe 'ikai ko ha fefie - fakamahino'i
3. Plant trees - specify type — Teke to 'akau - kalasi fe
4. Other - specify — To e iai ha me'akehe - fakamahino'i

6.28.1 Do you sell fuelwood?
'Oku ke fakatau atu ha fefie?
6.28.2 If so, which types?
Ko e ha nai 'a e fa'ahinga fefie 'oku ke fakatau atu?
6.28.3 How much on average do you sell per week?
Ko e ha nai 'a e avalisi 'o e lahi 'o e fefie 'oku ke fakatau he uike?
6.28.4 Where do you sell it?
'Oku ke fakatau atu ia 'i fe?
6.28.5 Where do you collect it?
'Oku ke ta pe ma'u nai 'a e fefie ko 'eni mei fe?
6.28.6 How much do you charge for it?
Koe ha nai 'a e mahu'inga 'oku ke ngaue 'aki?
6.28.7 Approximately how much money do you receive from selling fuelwood per week?
Ko e ha nai 'a e lahi'o e seniti 'oku ke ma'u he uike?(fakafuofua pe)

SECTION 7 ATTITUDES TOWARDS TREES

7.1.1 Which trees should people be encouraged to protect?
Ko e ha nai 'a e fa'ahinga 'akau 'oku ke pehe ke fakalotolahi'i a e kakai ke malu'i 'o 'oua 'e ta?
7.1.2 Why?
Ko e ha nai hono 'uhinga?

7.2.1 Which trees should people be allowed to cut down?
Ko e ha nai 'a e fa'ahinga 'akau 'oku ke pehe ke ngofua pe hono ta 'e he kakai?
7.2.2 Why?
Ko e ha nai hono 'uhinga?

7.3.1 What are the most important uses of trees?
Ko e ha nai'a e ngaahi faka'aonga'i mahu'inga taha 'oe 'akau?
7.3.2 What other reasons are there for protecting trees?
Ko e ha nai ha to e 'uhinga ki hono malu'i 'oe 'akau?

7.4.1 Are the trees on your town allotment a benefit or a nuisance?
Ko e 'akau ko e ho 'api kolo 'oku 'aonga pe ko e tu'u noa pe?
7.4.2 In what way?
'O anga fefe?

7.5.1 Have you planted any trees on your town allotment?
Kuo ke to nai ha 'akau 'i ho 'apikolo?
7.5.2 If so, what types?
Ko e ha nai 'a e kalasi ko ia?
7.5.3 When?
Fakaku nai?
7.5.4 For what reason did you plant them?
Ko e ha nai hono 'uhinga ho'o to 'a e 'akau ni?

7.6.1 Do you intend to plant any trees on your town allotment within the next year?
'Oku ke palani nai ke to ha 'akau i ho 'api kolo ki he ta'u kaha'u?
7.6.2 If so, what types?
Ko e ha nai 'a e fa'ahinga 'akau teke to?
7.6.3 For what reasons?
Ko e ha nai hono 'uhinga teke to ai 'a e 'akau ko ia?

Thankyou very much for your cooperation.
Malo 'aupito ho'o loto 'aufuato ke ke fie fakamoleki ho taimi ke tokoni'i 'a e ki'i fekumi 'oku faii.

I need to gather more information about the places where fuelwood is collected, and the types of trees which are providing this fuel. Could I come back in about a week's time to talk to you about the sites where your fuelwood comes from?

'Oku ou fiema'u ke u tanaki ha to e fakamatala fekau'aki mo e feitu'u 'oku ta mei ai 'a e fafie, mo e fa'ahinga 'akau fefie ko ia. 'Esai pe nai ke u to e foki mai 'i he 'osi ha uike mai heni ke ta talanoa ki he feitu'u oku ma'u mei ai 'a e fefie?

APPENDIX 2 BUSH ALLOTMENT INTERVIEW SCHEDULE

Village:- Household Reference:-
No.(s) on Cadastral Map:- Town / Bush
Location of Bush Allotment:- Map Ref:-

SECTION 1 GENERAL INFORMATION

1.1.1 Is this your own bush allotment?
Ko e 'api 'uta pe 'eni 'o'ou/'omoutolu?
1.1.2 Is this bush allotment registered in your name?
'Oku lesisita nai ho hingoa 'ae 'api 'uta ni?
1.1.3 If not, in whose name is it registered?
Kapau 'oku 'ikai, koe hingoa nai 'o hai 'oku lesisita ai?
1.1.4 If the allotment is not registered, who is the customary holder?
Kapau 'oku te'eki ke lesisita, ko hai nai 'ae ma'utofia?
1.1.5 How long have you been using this bush allotment? (yrs)
Ko e ha nai hono fuoloa ho'o ngaue 'aki 'a e 'api 'uta ni? (ta'u)

1.2.1 How far is this bush allotment from your town allotment?
Ko e ha nai hono mama'o 'o e 'api 'uta ni mei ho 'api kolo?
1.2.2 How long does it normally take you to travel here from your town allotment?
Ko e ha nai hono fuoloa ho'o 'alu mei heni ki 'uta
'Oku ke 'alu ha ki 'uta?
1.2.3 What sort of transport do you use? (B,H,S,C,M,V,T,W,MB,BS,X,O)
Ko e ha nai 'a e fa'ahinga me'alele 'oku ke ngaue 'aki pe koha toe me'a pe?

1.3.1 What size is this bush allotment?
Ko e ha nai hono lahi 'o e 'api 'uta ni?
1.3.2 How much of this allotment do you use?
Ko e ha nai hono lahi 'o e konga 'oku ke faka'aonga'i/pule'i?
1.3.3 How large is the area on which you currently have crops planted?
Ko e ha nai hono lahi 'o e 'elia 'oku ke lolotonga to ai ho'o ngoue?
1.3.4 How many other households cultivate crops on this bush allotment?
Ko e famili nai 'e fiha 'oku nau toe ngoue'i e 'api 'uta ni?

1.4.1 How many buildings are there on this bush allotment?
Ko e fale nai 'e fiha 'i 'uta ni?
(T - Traditional Fale Tonga
MT - Modified Traditional
ME - Modified European
E - European Fale palangi)
1.4.2 What sort of water supply is there to this bush allotment?
Ko e ha nai 'a e ma'uanga vai 'i 'uta ni?
N - None Hala
P - Piped Paipa (vaitaki)
T - Rainwater tank Tanike
W - Well Vaitupu
O - Other - specify Toe mea kehe (fakamahino'i)

1.5.1 How many meals do you cook on this bush allotment per week?
Ko e houa kai nai 'e fiha 'oku ke fa'a feime'atokoni ki'ai he uike 'i 'uta ni?
1.5.2 How much fuelwood do you use for cooking here per week?
Ko e ha nai ha'o fakafuofua ki he lahi 'o e fefie 'oku ke ngaue 'aki heni ki ho'o feime'atokoni ki he uike?

SECTION 2 CROP CULTIVATION

2.1.1 What are the main crops you grow on this bush allotment?
Koe ha nai 'a e fa'ahinga ngoue 'oku lahi taha ho'o to heni?

2.1.2 What other crops do you grow here?
Ko ha nai moha toe ngoue 'oku ke to heni?

2.2.1 How many coconut trees are there on this bush allotment?
Koe fu'u niu nai 'e fiha 'i 'uta ni?

2.2.2 How many coconut trees are there on the section of the allotment which you manage?
Ko e fu'u niu 'e fiha 'oku tu'u 'i he konga 'oku ke tokanga'i?

2.3 What ages are the coconut trees on this allotment?
Koe ha nai 'a e ta'u motu'a 'o e 'ulu niu 'i 'api ni?
(<5yrs;5-9;10-19;20-29;30-39;40-49;50-59;60-69;>69)

2.4.1 Do you use a crop rotation system?
'Oku ke ngaue 'aki 'a e ngoue hikihiki holo?

2.4.2 What combinations of crops are included in the rotation?
Ko e ha nai 'a e fa'ahinga ngoue 'oku ke kau ki ai?
Year 1
Year 2
Year 3
Year 4
Year 5

2.4.3 How long is the land under fallow?
Ko e ha nai hono fuoloa hono fakavaoa 'o e konga kelekele?

2.4.4 Do you plant any crops in the fallow?
'Oku ke to ha fa'ahinga ngoue 'i he konga 'oku fakavaoa?
If so, which?

2.5.1 How fertile is the soil on this bush allotment?
'Oku mo'ui nai 'a e kelekele 'o e 'api 'uta ni?

2.5.2 What do you do to maintain the fertility of the soil?
Ko e ha ha'o me'a 'oku fai ke pukepuke 'aki 'a e mo'ui 'o e kelekele?

2.5.3 What can be done to improve the fertility of the soil?
Ko e ha nai ha me'a 'e fai ke fakautuutu ai 'a e mo'ui ange 'a e kelekele?

2.5.4 Have you been able to improve the fertility of the soil on this bush allotment?
Kuo ke lava nai ke fakalelei'i pe fai hono fakautuutu 'a e mo'ui 'o e kelekele he 'api 'uta ni?
If so, how did you do this?
Kapau 'oku 'io, 'oku anga fefe nai?

2.6.1 What sorts of equipment do you use to cultivate this land?
Ko e ha nai 'a e fa'ahinga me'a ngaue 'oku ke ngaue 'aki ki hono ngoue'i 'o e 'api 'uta ni?

2.6.2 Which pieces of equipment do you borrow or hire from other people? (Clearing; tilling; planting; crop protection; harvesting; post-harvest)
Ko e ha nai ha fa'ahinga me'a ngaue 'oku ke totongi pe/kole mei ha taha keke ngaue'aki?

2.7.1 How do you control weeds on your cultivated land?
'Oku anga fefe ho'o tauhi 'a e ma'ala 'i ho'o ngoue'anga?

2.7.2 How do you protect your crop plants from pests and diseases?
'Oku anga fefe ho'o malu'i ho'o ngoue mei he mahaki moe 'inisekite maumau?

2.8.1 How many people work on your piece of land?
Ko e toko fiha nai 'oku mou fa'a ngaue 'i 'uta ni?

2.8.2 Are the other people who work here members of your household (H), members of your family (F), or members of a farming co-operative (C)? (O - Others)
Ko e kakai ko'eni 'oku ngaue heni koe kakai pe mei homou 'api, kautaha, toe fa'ahinga kakai pe?

SECTION 3 PRODUCE

3.1 What are the most important products from your cultivation of this land?
Ko e ha nai "a e fa'ahinga ngoue 'oku mahu'inga taha kia koe 'oku ke to 'i'api ni?

3.2 Which of the products that you grow here do you sell?
Ko e ha nai 'a e fa'ahinga ngoue 'oku ke to heni 'oku ke fakatau atu?

3.3.1 Which of the products that you grow here are used by your household?
Ko e ha nai 'a e ngoue 'oku ke to heni 'oku faka'aonga'i ho mou 'api?

3.3.2 Which of the products that you grow on this piece of land do you give to other members of your family or to other people?
Ko e ha nai ha fa'ahinga ngoue 'oku ke to heni 'oku ke tufa atu ki ho ngaahi kainga pea mo e kakai kehe pe?

3.4.1 How many coconuts does your piece of land produce each year?
Ko e fo'iniu nai 'e fiha 'oku ke mau mei ho 'api 'uta he ta'u?

3.4.2 How many of these coconuts do you use in your household each week?
Ko e fo'i niu nai ai 'e fiha 'oku ke/mou ngaue 'aki ho mou 'api he uike?

3.4.3 Who do you sell whole coconuts to?
Ko hai 'oku ke fakatau atu ki ai e fo'i niu?

3.4.4 How much copra do you produce each year?
'I ho'o fakamataka he ta'u koe tangai nai 'e fiha 'oku ma'u?

3.4.5 How is this copra dried?
'Oku anga fefe hono fakamomoa?

3.4.6 How much fuelwood from this bush allotment is burned to dry your copra?
Ko e ha nai hono lahi 'o e fefie 'oku ke ngaue 'aki mei ho 'api 'uta 'oku faka'aonga'i ki ho'o fakamomoa niu?

Coconut Shells; Nge'esi niu:
Coconut Husks; Pulu:
Wood; Fefie 'akau:

3.5.1 What types of coconut fuel do you take from here to your town allotment?
Ko e ha nai ha fa'ahinga fefie ma'u mei he niu mei ho 'api 'uta 'oku ke 'ave ki ho 'api kolo?

3.5.2 How much coconut fuel do you take from here to your town allotment per week?
Ko e ha nai hono lahi 'o e fefie ma'u mei he niu 'oku ke 'ave mei heni ki ho 'api kolo he uike?

3.5.3 How much wood do you take from here to use as fuel on your town allotment per week?
Ko e ha nai hono lahi 'o e fefie 'akau 'oku ke 'ave mei ho 'api 'uta ki ho 'api kolo 'o faka'aonga'i ke fefie?

3.5.4 How do you transport these fuels?
'Oku anga fefe hono 'ave/'omai?

3.6.1 Which products other than food and fuel do you get from this bush allotment?
Koe ha nai ha to e fa'ahinga me'a kehe 'oku ke toe ma'u mei ho 'api 'uta 'o makehe mei he 'aonga ki he fefie moe me'a tokoni?
(H - Handicraft Material, ngaahi me'a fakamea'a;
C - Cultural, 'akau tu'u fonua; M - Medicinal, 'akau faito'o;
T - Construction Timber, 'akau ngaahi fale; O - Ornamental, 'akau teuteu)
3.6.2 Which of these products have important uses in your household?
Koe fe leva ai 'a e me'a 'oku lahi taha hono faka'aonga'i ho 'api?
3.6.3 Which of these products do you sell?
Koe ha leva 'a e me'a 'oku ke fakatau atu?

SECTION 4 TREES

4.1.1 Which species of tree grow on your bush allotment?
Ko e nai 'a e fa'ahinga 'akau 'oku tu'u 'i ho 'api 'uta?
4.1.2 Which of these trees are beneficial?
Ko e fe nai 'ai 'a e fa'ahinga 'akau 'oku aonga?
4.1.3 In what way are they of benefit to you?
Ko e ha leva nai hono 'aonga kia koe?
4.1.4 Which of the trees growing on your bush allotment are a nuisance?
Ko e ha nai 'a e fa'ahinga 'akau 'oku 'ikai ke 'aonga 'ene tu'u 'i ho 'api 'uta/pe fakakina?
4.1.5 In what way are they a nuisance?
Ko e ha leva 'a e me'a 'oku ta'e 'aonga ai?
Ko e ha fua e fa'ahinga 'akau 'oku ke fakahaofi 'i ho'o huo ha konga vao na'e fakavaoa?
4.2.1 Which plants do you protect when you clear fallow?
'Ihe taimi koe 'oku ke faka'aonga'i ai 'a e konga vao na'a ke fakavaoa 'oku 'iai nai ha fa'ahinga 'akau 'oku ke fakahaofi?
4.2.2 Which of the plants that you have not planted do you protect when you are weeding?
Ko e fe ha fa'ahinga 'akau na'e 'ikai teke to ka ka na'a ke fakahaofi he taimi 'oku huo ai?
4.2.3 What uses do these self-regenerated plants have?
Ko e ha nai hono aonga 'o e ngaahi 'akau tupu ko eni?

4.3 What influence do the trees on your land have on the crop plants? (good and bad influences?)
Ko e ha nai ha fa'ahinga 'uesia 'oku fai 'ehe 'akau he ngoue 'oku ke to? (kaunga lelei/kaunga kovi)

4.4.1 Do you have plans to destroy any of the trees on your land?
'Oku ke fakakaukau ke ta ha fu'u 'akau 'i ho 'api 'uta?
4.4.2 If so, why?
Koe ha nai hono 'uhinga?

4.5.1 Have you planted any trees on your bush allotment?
Kuo ke to nai ha 'akau 'i ho 'api 'uta?
4.5.2 If so, what types?
Ko e ha nai 'a e kalasi ko ia?
4.5.3 When?
Fakaku nai?
4.5.4 For what reason(s) did you plant them?
Ko e ha nai hono 'uhinga ho'o to 'a e 'akau ni?

4.6.1 Do you intend to plant trees on your bush allotment within the next year?
'Oku ke palani nai ke to ha 'akau 'i ho 'api 'uta lolotonga 'a e ta'u ka hoko mai ki ho 'api 'uta ki he ta'u kaha'u?
4.6.2 If so, what types?
Ko e ha nai 'a e fa'ahinga 'akau teke to?
4.6.3 For what reasons?
Ko e ha nai hono 'uhinga teke to ai 'a e ngaahi 'akau ko 'eni?

4.7.1 To whom do the trees on this land belong?
Ko hai 'oku 'a'ana (ma'u) 'a e ngaahi 'akau ko eni?
4.7.2 Do you have the right to use all the trees on this land in any way you wish?
'Oku 'iai nai ha'o totonu ke ke ngaue'aki 'o e 'akau ni 'i ha founga pe teke fiema'u?
4.7.3 Which people have the right to take the following products from trees on this land?
Ko hai e kakai oku totonu ke nau 'ave 'o ngaue'aki 'a e 'akau ki he ngaahi me'a ni?
Fuelwood Fefie
Timber Papa
Food Me'atokoni
Animal fodder Me'atokoni ma'a e monumanu
Medicinal ingredients Fouito'o
4.7.4 Who has the right to plant trees on this land?
Ko hai 'oku totonu kene to e 'akau 'o e 'api ni?
4.7.5 Who has the right to destroy trees on this land?
Ko hai 'oku ne ma'u e totonu ki hono faka'auha 'o e 'akau he 'api ni?
4.7.6 How have these people acquired rights over these trees?
Anga fefe 'a hono ma'u 'e he kakai ko 'eni 'a 'emau totonu ki he 'ulu'akau ni?

APPENDIX 3 CODES USED FOR FUELWOOD TYPES AND OTHER TREES

Code	Tongan Name	Botanical Name	Name in English
AGR			agricultural residues
AHI	ahi	*Santalum yasi*	sandalwood
AII	'ai	*Canarium harveyi*	
AKV	'akauveli	*Indigofera suffruticosa*	indigo
APE	'apele	*Annona* spp.	
API	'apele 'initia	*Annona muricata*	soursop
APT	'apele tonga	*Annona reticulata*, or	bullock's heart, or
		A. squamosa	sweetsop
APU	'apu	*Anacardium occidentale*	cashew
AVO	'avoka	*Persea americana*	avocado
COC			coconut residue fuels (general)
*			
FAL	falahola	*Pandanus odoratissimus* var. *sinensis*	type of lou'akau (pandanus)
FAO	fao	*Ochrosia oppositifolia*	
FAU	fau	*Hibiscus tiliaceus*	beach hibiscus, giant hibiscus, hibiscus tree
FEH	fehi	*Bauhinia monandra*	Hong Kong orchid tree
FEK	fekika	*Syzygium* sp.	
FEO	fe'ofa'aki	*Euphorbia pulcherrima*	poinsettia
FET	feta'anu	*Excoecaria agallocha*	
FIC		*Ficus* sp.	
FIK	fiki	*Jatropha curcas*	physic nut
FIL	filimoto	*Xylosma orbiculatum*	
FIS	fisimoli		
FKP	fekika palangi	*Syzygium jambos*	rose apple
FKV	fekika vao	*Syzygium clusiaefolium*	
FOT	fotulona	*Hernandia ovigera*	
FOU	fo'ui	*Grewia crenata*	
FSF	fisi'ifafangi		
FTU	feta'u	*Calophyllum inophyllum*	
FUT	futu	*Barringtonia asiatica*	fish-poison tree, barringtonia
H&S	pulu mataka		coconut husk and shell
HAN	hangale	*Lumnitzera littorea*	
HEH	hehea	*Syzygium corynocarpium*	

*FAA	fa	*Pandanus* spp. particularly *P. tectorius*	pandanus

Code	Tongan Name	Botanical Name	Name in English
HIA	hiapo	*Broussonetia papyrifera*	paper mulberry
HIK	hikukuna		
HUL	hulu		coconut leaf
HUN	huni	*Phaleria disperma*	
HUS	pulu hoka		coconut husk
IFI	ifi	*Inocarpus edulis*	Tahitian chestnut
IFK	ifi'akuma		
KAH	kaho	*Miscanthus floridulus*	sword grass
KAK	kalaka	*Planchonella costata*	
KAL	kalosipani	*Plumeria* spp.	frangipani
KAN	kanume	*Diospyros ferrea*	
KAS	kasia	*Albizia saman*, *A. lebbeck*, *Cassia fistula*, *Cassia javanica*	rain tree, lebbek, golden shower or pudding-pipe tree, pink & white shower
KAU	kaute	*Hibiscus rosa-sinensis*	hibiscus, shoe flower
KFI	kofi	*Coffea arabica*	coffee
KIL	kilisimasi	*Lagerstroemia indica*	crepe myrtle
KLA	kalakala'apusi	*Acalypha wilkesiana*	beefsteak hedge
KLI	koli	*Syzygium neurocalyx*	
KLK	kalonikakala	*Quisqualis indica*	rangoon creeper
KOF	kofe	*Schyzostachym glaucifolium*	green-stemmed bamboo
KOK	koka	*Bischofia javanica*	red cedar
KOL	kola	*Citrus aurantium*	Seville orange
KOT	kotone	*Myristica hypargyraea*	wild nutmeg
KUA	kuava	*Psidium guajava*	guava
KUL	kauli		kauri
L&T	loholoho and toume		coconut flower spathe and sheath
LAL	lalatahi	*Vitex trifolia*	
LAN	langakali	*Aglaia saltatorum*	
LAU	laukaupo'uli	*Cestrum nocturnum*	night-blooming cestrum
LEK	lekileki	*Xylocarpus granatum*	cannonball tree
LEM	lemani	*Citrus* sp.	lemon
LEP	lepo	*Ricinus communis*	
LOA	lou'akau	*Pandanus* spp.	pandanus
LOH	loholoho		coconut flower spathe

Code	Tongan Name	Botanical Name	Name in English
LOL	lolie	*Nerium oleander*	oleander, nerium lily
LOP	lopa	*Adenanthera pavonina*	red bead tree
LOU	loupata	*Macaranga harveyana*	
MAI	maile	*Alyxia stellata*	
MAL	malolo	*Glochidion concolor, G. ramiflorum*	
MAN	mango	*Mangifera indica*	mango
MAP	mapa	*Diospyros laterifolia*	
MAS	masi	*Ficus tinctoria* (?)	
MAV	mavaitangi	*Duranta repens*	golden dewdrop
MEI	mei	*Artocarpus altilis*	breadfruit
MHH	mohemohe	*Serianthes myriadenia*	
MIL	milo	*Thespesia populnea*	
MKK	masikoka		
MNG	mangele	*Trema orientalis, T. amboinensis*	
MNU	manonu	*Tarenna sambucina*	
MOA	mo'onia	*Garcinia pseudoguttifera*	
MOH	mohokoi	*Cananga odorata*	
MOL	moli	*Citrus* spp.	
MOM	mo'otamea		
MOO	mo'ota	*Dysoxylum forsteri*	
MOS	mo'osipo	*Triumfetta bartramia, T. procumbens*	
MOT	motou	*Cryptocarya glaucescens, C. hornei*	
MSA	masi'ata	*Ficus scabra*	
MSK	masikona	*Pittosporum arborescens*	
MUI	manaui	*Garuga floribunda*	
NAT	nati		
NGA	ngatae	*Erythrina variegata*	coral tree, tiger's claw
NGI	ngingie	*Suriana maritima* or *Pemphis acidula*	
NGS	ngesi	*Manilkara dissecta*	
NGT	ngatata	*Elattostachys falcata*	
NIU	niu	*Cocos nucifera*	coconut stem wood
NON	nonu	*Morinda citrifolia*	Indian mulberry, beach mulberry
NUK	nukonuka	*Decaspermum fruticosum*	

Code	Tongan Name	Botanical Name	Name in English
OHA	'ohai	*Delonix regia*	flamboyant, poinciana
OKE	oke	*Grevillea robusta*	silky oak
OLI	'olive	*Murraya paniculata*	
OVA	'ovava	*Ficus obliqua*	strangler fig, banyan
PAI	paini	*Araucaria excelsa*	Norfolk Island pine
PAK	pakaka	*Erigeron sumatrensis* or *Synedrella nodiflora*	
PAL	palalafa		coconut frond spine
PIN	paini	*Pinus* spp. (especially *P. caribaea*)	pine (Caribbean pine)
PIP	pipitui	*Hernandia moerenhoutiana*	
PIS	piisi	*Prunus persica*	peach
PIT	pitu	*Bambusa vulgaris*	yellow stemmed bamboo
PLK	pulukamu	*Eucalyptus* spp.	eucalypts, gums
POL	polo tonga	*Solanum uporo*	
PTK	puataukanave	*Cordia subcordata*	
PUA	pua tonga	*Fagraea berteriana*	
PUK	puko	or puka *Pisonia grandis* (also synonym for fotulona, *Hernandia ovigera*)	
PUL	pula	*Solanum verbascifolium*	
PUO	puopua	*Guettarda speciosa*	
PUP	pupu		dried green coconut
PUU	pulu		coconut husk and shell, and coconut husk
SAL	salato	*Laportea harveyi*	
SHE	nge'esi niu		coconut shell
SIA	sialemohemohe	*Leucaena leucocephala*	leucaena
SII	si	*Cordyline terminalis*	cabbage tree
SIL	siale	*Gardenia jasminoides* and *G. taitensis*	gardenia
SIN	sinamoni	*Pimenta racemosa*	bay rum
SIT	sita	*Melia azedarach*	
SPI	sipaisi	*Pimenta doica* (syn. *P. officinalis*)	allspice
STP	sita palangi	*Cedrela odorata*	West Indian cedar, cigar-box cedar
TAG	tangato	*Pleiogynium solanderi*	
TAH	tayahi	*Rhus taitensis*	

Code	Tongan Name	Botanical Name	Name in English
TAK	takafalu	*Micromelum minutum*	
TAL	talatala	*Lantana camara*	lantana
TAM	tamanu	*Maniltoa amicorum* or *Calophyllum vitiense*	
TAN	tanetane	*Polyscias guilfoylei*	
TAT	tatangia	*Acacia simplicifolia*	
TAV	tava	*Pometia pinnata*	wild liichi, Pacific lychee
TEE	te'ete'emanu	*Ervatamia orientalis*	
TEH	te'ehoosi	*Sida rhombifolia*	
TEL	telie	*Terminalia catappa*	Indian almond
TEV	tevunga	*Amomum cevuga*	
TIM			timber
TIU	tiulipe	*Spathodea campanulata*	African tulip tree
TMT	tamatama	*Achyranthes aspera*	
TOA	toa	*Casuarina* or *Allo-casuarina* spp.	casuarina, sheoak, bull oak
TOF	totofisi	*Euphorbia fidgiana*	
TOH	touhuni	*Tournefortia argentea*	
TOI	toi	*Alphitonia zizyphoides*	
TON	tongo, tongolei, and tongo ta'ane	*Rhizophora mucronata, R. mangle, Bruguiera gymnorrhiza*	mangrove
TOT	toto	*Cerbera manghas*	
TOU	toume		coconut flower sheath
TPM	te'epilo'amaui	*Geniostoma* spp.	
TTL	tutu'uli	*Jasminum didymum, J. simplicifolium*	
TUI	tuitui	*Aleurites moluccana*	candlenut tree
UHI	uhi	*Euodia hortensis*	
VAV	vavae	*Ceiba pentandra*	
VII	vi	*Spondias dulcis*	
VIV	vivao		
VOL	volovalo	*Premna obtusifolia*	

APPENDIX 4 CODES USED FOR CROP PLANTS, WITH TONGAN AND ENGLISH NAMES

Code	Tongan Name	English Name
Ba	Siaine	Banana
Bn	Piini	Beans
Cb	Kapisi	Cabbage
Cp	Polo palangi	Capsicum
Cs	Manioke	Cassava
Ct	Kaloti	Carrots
Gn	Sinisa	Ginger
Hi	Hiapo	Paper Mulberry
Ho	Hopa	Plantain
Ka	Kape	Giant Taro
Kv	Kava	Kava
Lt	Letisi	Lettuce
Mn	Meleni	Water Melon
Mz	Koane	Maize
On	Onioni tonga	Spring Onion
Pa	Pata	Cooking Banana
Pe	Pele	Edible Hibiscus
Pi	Faini	Pineapple
Pm	Hina	Pumpkin
Po	Pateta	Potato
Pt	Pinati	Peanut
Py	Lesi	Papaya
Rm	Meleni maka	Rock Melon
Sa	Saafa	Guinea Grass
Sc	To	Sugar Cane
Sp	Kumala	Sweet Potato
T	Talo	Taro
Tf	Talo futuna	American Taro
Tm	Temata	Tomato
Tt	Talo tonga	Swamp Taro
Va	Vaine	Passion Fruit
Vg		Vegetables
Vn	Vanila	Vanilla
Ym	Ufi	Yam

Glochid.

APPENDIX 5 CODES AND TONGAN NAMES OF TREES CATEGORISED AS (i) SPECIAL PURPOSE AND (ii) INVASIVE SPECIES AND EARLY COLONISERS

Category (i) Special purpose trees

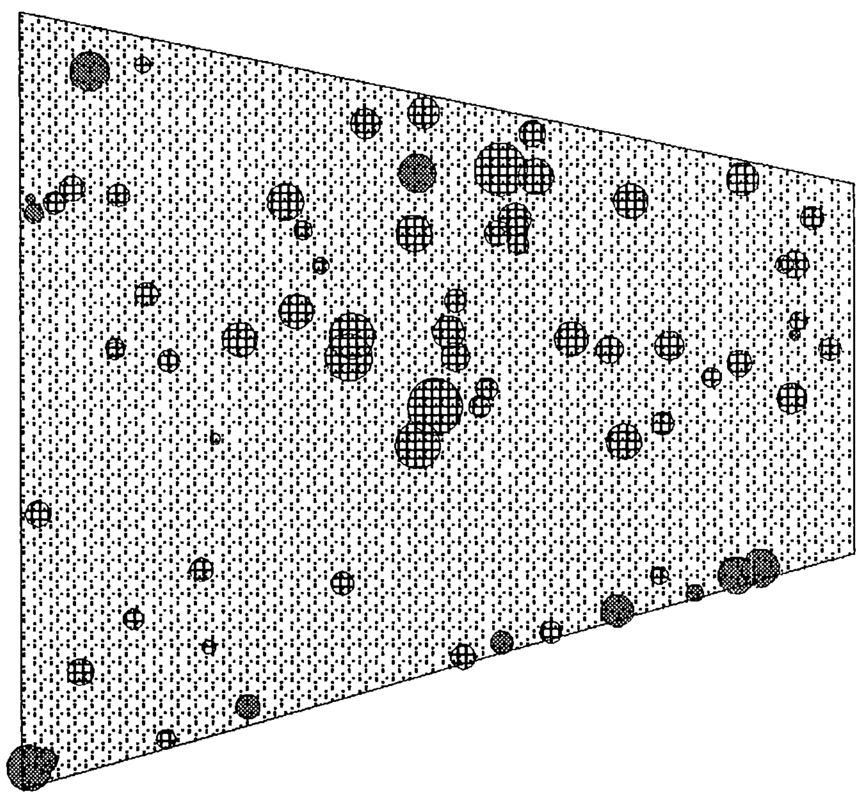
Code	Tongan Name	Code	Tongan Name
API	'apele 'initia	MAN	mango
APT	'apele tonga	MEI	mei
APU	'apu	MOH	mohokoi
AVO	'avoka	MOL	moli
FAL	falahola	NGA	ngatae
FEK	fekika	OHA	'ohai
FEO	fe'ofa'aki	OKE	oke
FIK	fiki	OLI	'olive
FKP	fekika palangi	PAI	paini
HEH	hehea	PIN	paini
HEI	heilala	PIS	piisi
HUN	huni	PIT	pitu
IFI	ifi	PLK	pulukamu
KAL	kalosipani	SII	si
KAU	kaute	SIL	siale
KFI	kofi	SIN	sinamoni
KIL	kilisimasi	STP	sita palangi
KLA	kalakala'apusi	TAN	tanetane
KOF	kofe	TAV	tava
KOK	koka	TON	tongo
LAN	langakali	TUI	tuitui
LEM	lemani	VAV	vavae
LOA	lou'akau	VII	vi
LOA	lou'akau		

Category (ii) Invasive species and early colonisers

Code	Tongan Name	Code	Tongan Name
AKV	'akauveli	SIA	sialemohemohe
KUA	kuava	TAL	talatala
PUL	pula		

APPENDIX 6 DIAGRAMMATIC REPRESENTATIONS OF SURVEYED BUSH ALLOTMENTS USED BY VAOTU'U, FOLAHA, LAVENGATONGA, PERI-URBAN, AND URBAN NUKU'ALOFA INTERVIEWEES

Allotment Vaotu'u 1



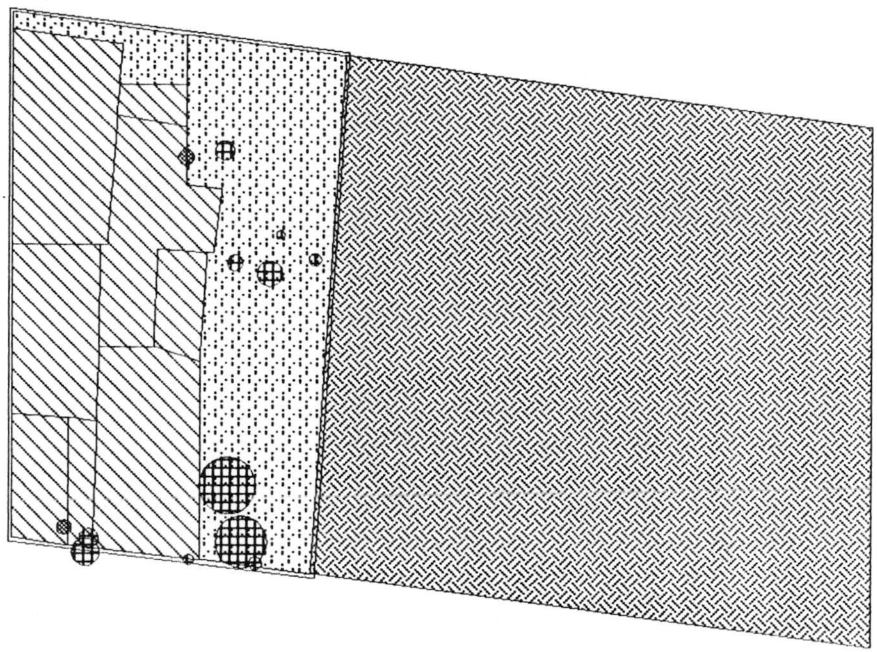
LEGEND

- Cultivated sections
- Fallow sections
- Uncultivated sections
- Area outside allotment
- School building
- Fruit trees
- Non-fruit trees

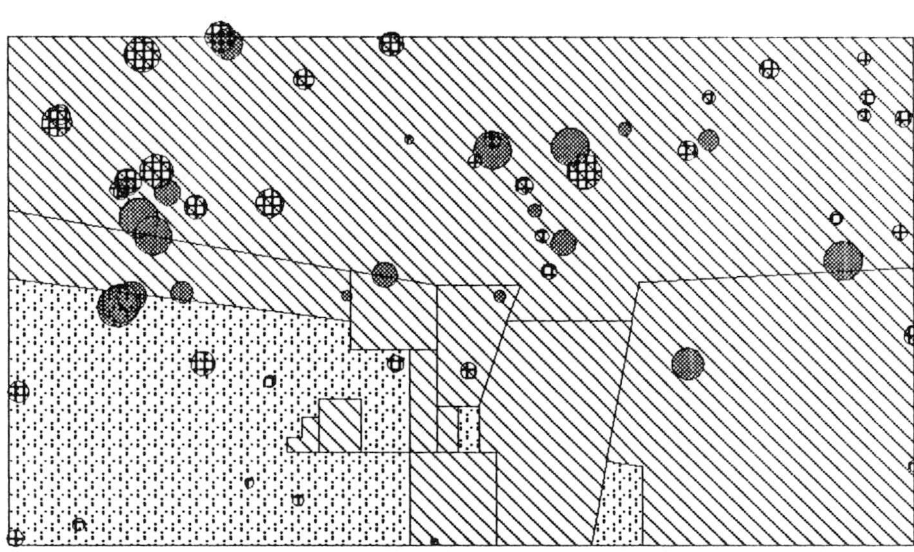
APPROXIMATE SCALE: 1:2000

0 50 metres

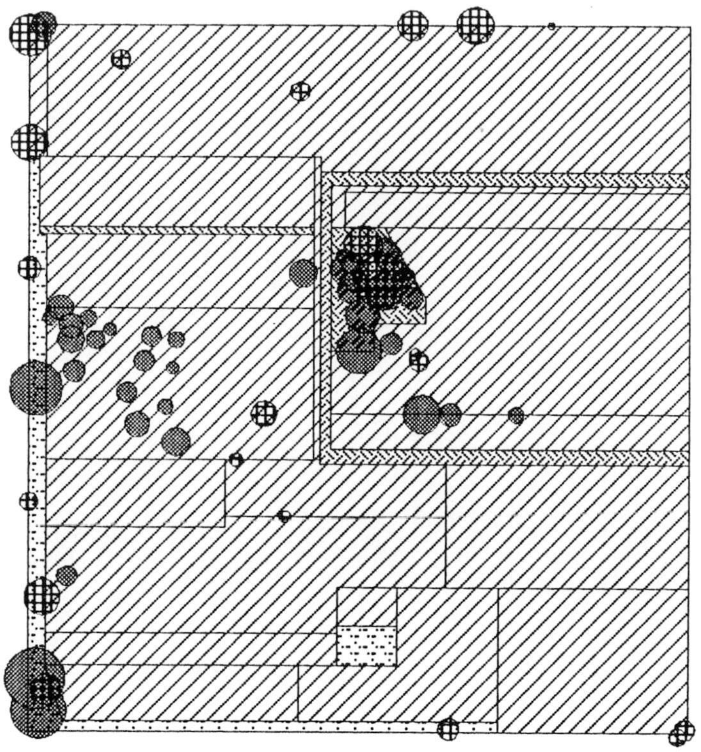
Allotment Vaotu'u 10



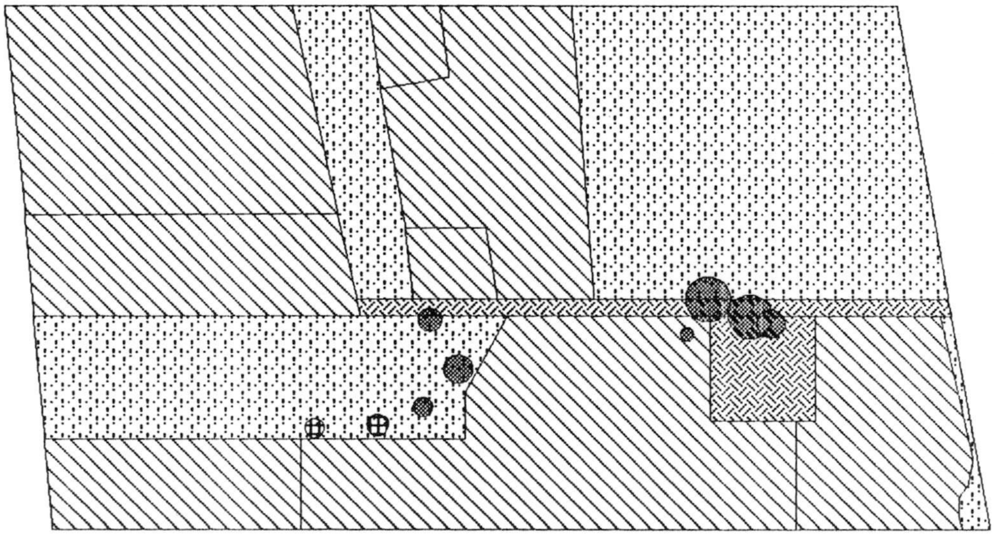
Allotment Vaotu'u 12



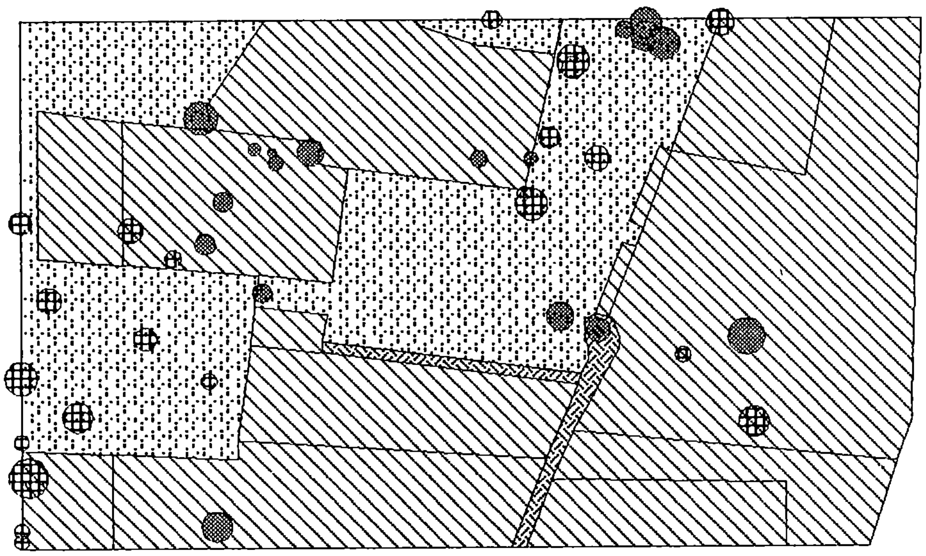
Allotment Folaha 1



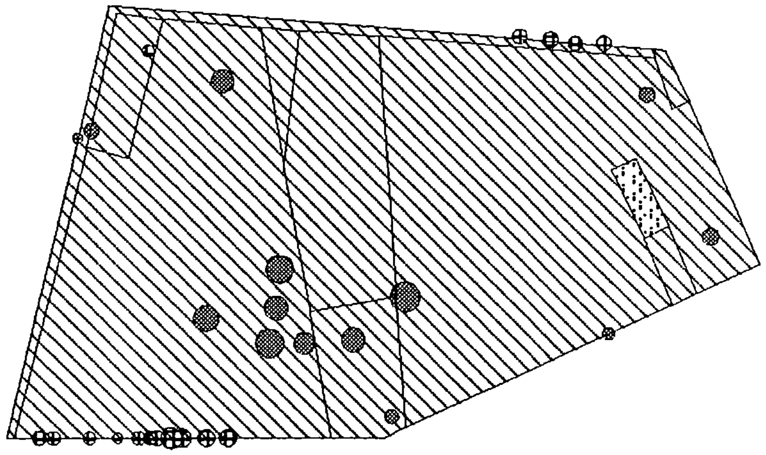
Allotment Folaha 7



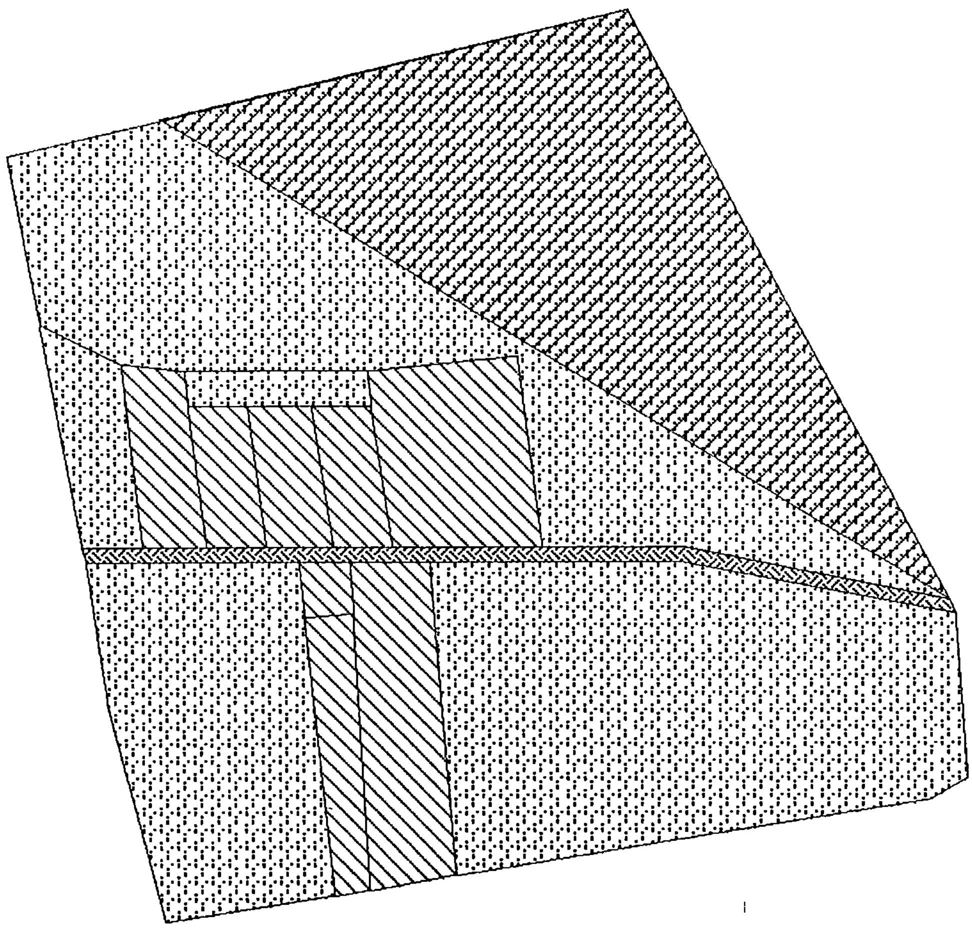
Allotment Folaha 9



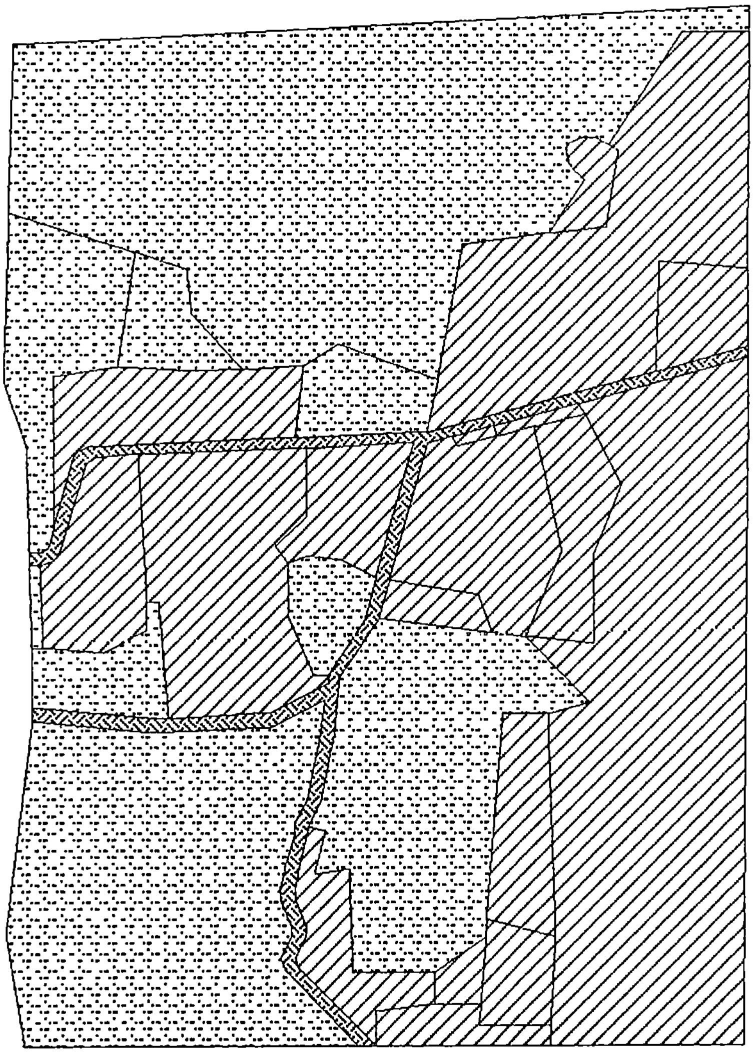
Allotment Lavengatonga 1



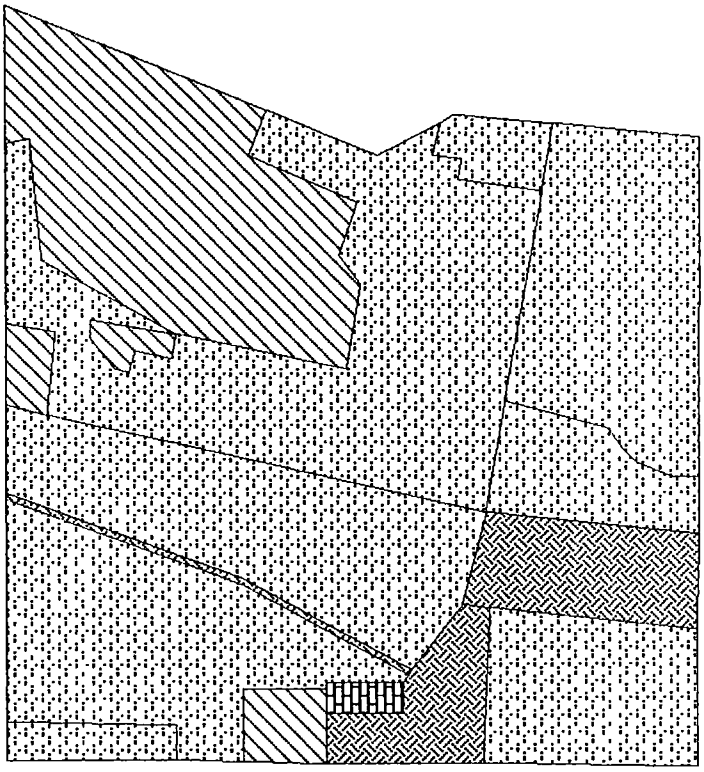
Allotment Lavengatonga 2



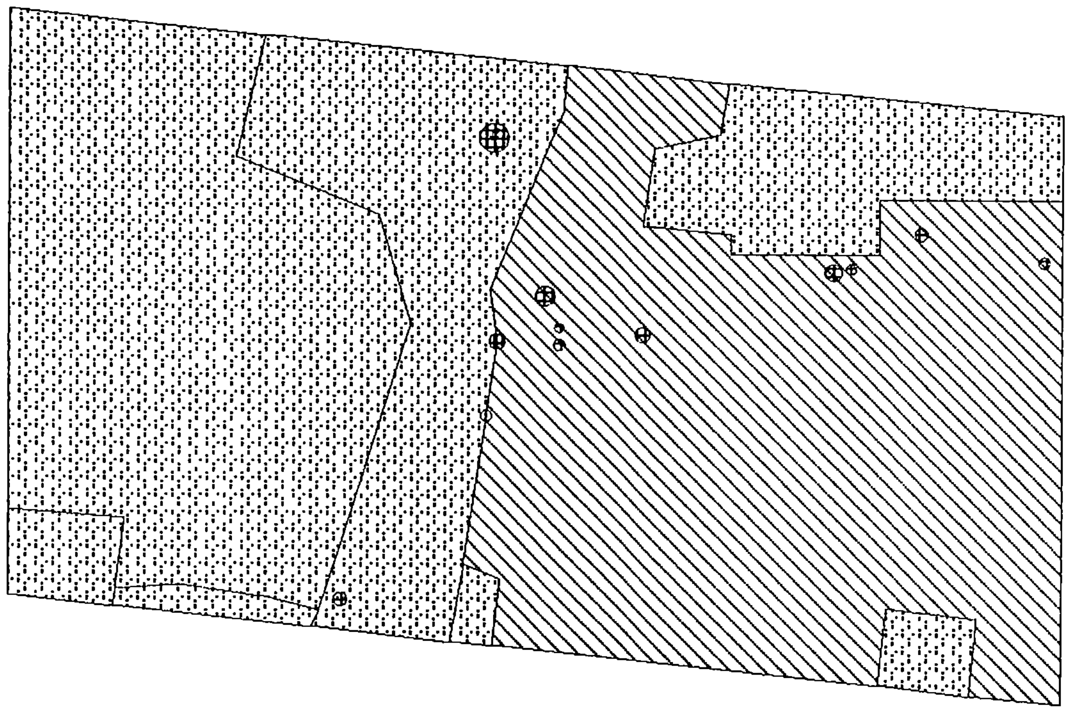
Allotment Lavengatonga 5



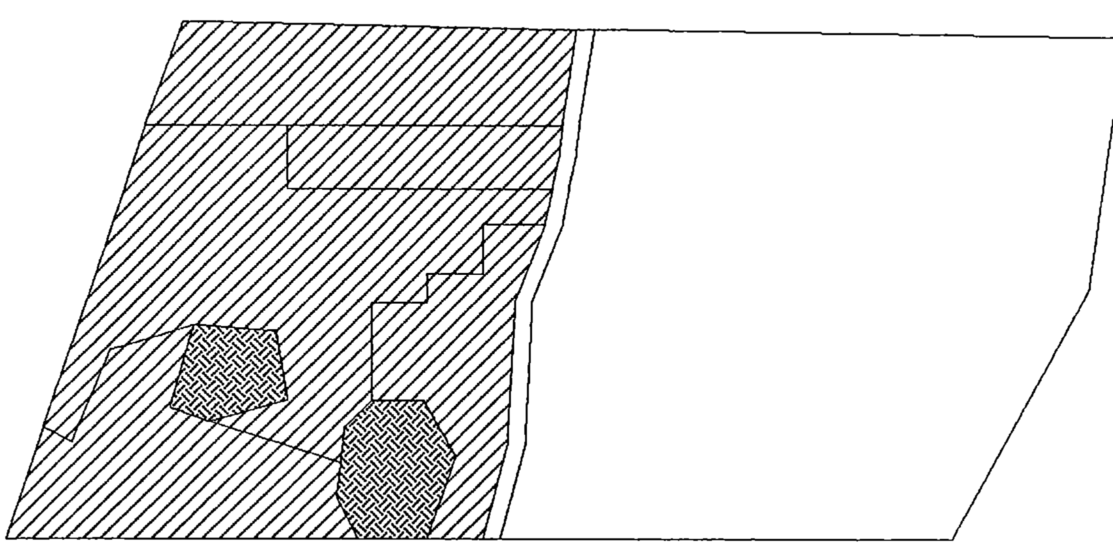
Allotment Peri-urban 2



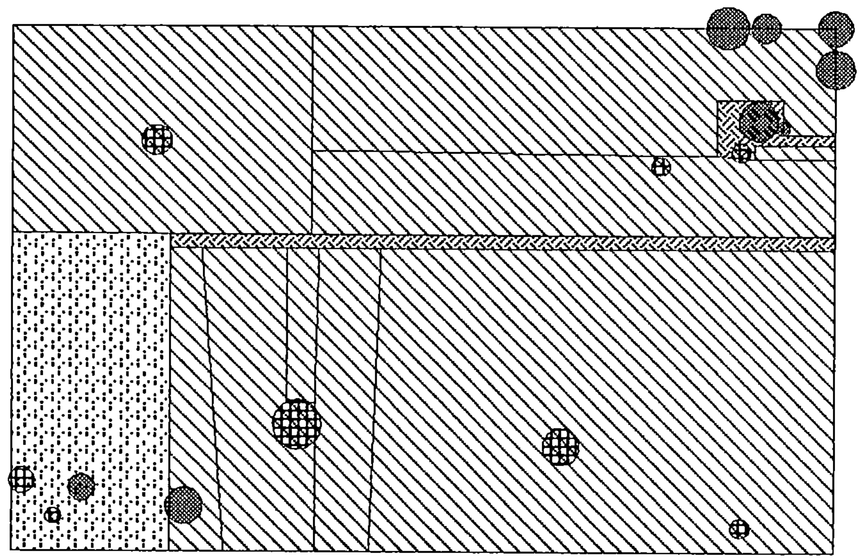
Allotment Peri-urban 5



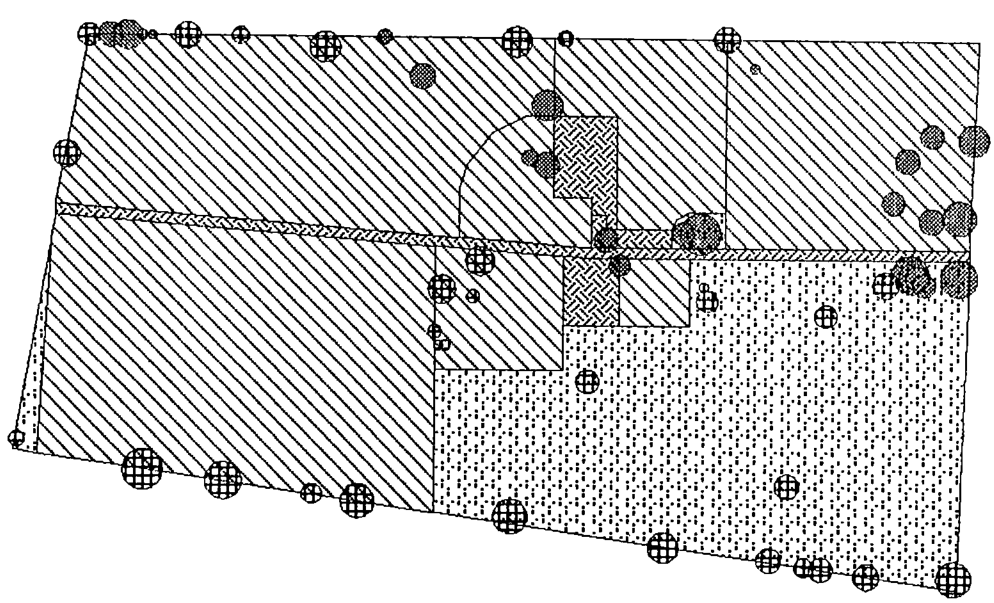
Allotment Peri-urban 15



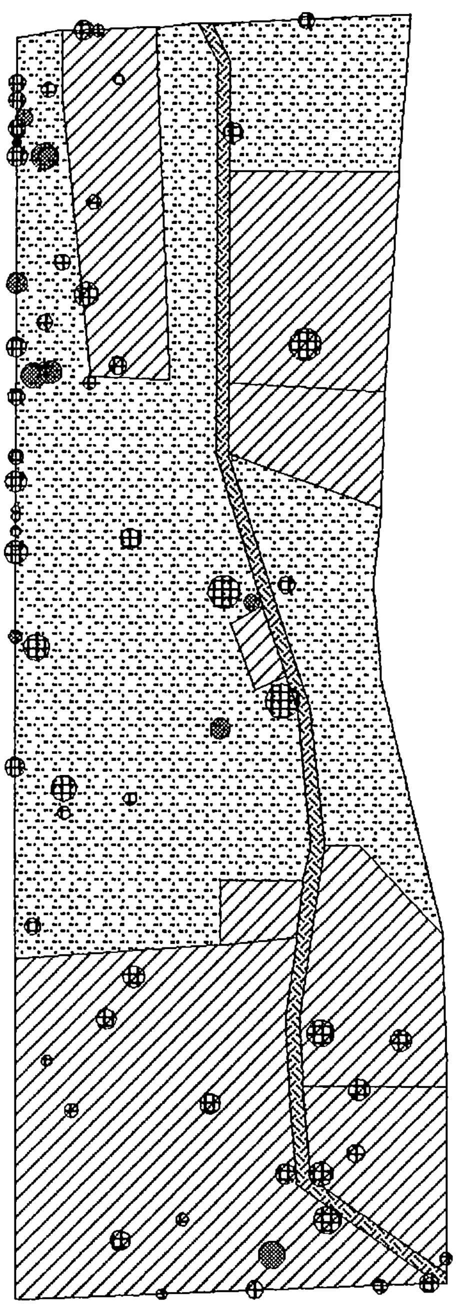
Allotment Urban 5



Allotment Urban 14



Allotment Urban 15



APPENDIX 7 CONVERSION FACTORS USED IN THE ESTIMATION OF FUELWOOD VOLUME, MASS, AND ENERGY CONTENT DATA[1]

Nominal Volumes of Standard Units

Unit of Measurement	Stack Volume (m^3)
Standard basket	0.0600
Standard bundle	0.1300
Standard bag	0.0500
50 kg flour sack	0.0722
Standard sack	0.1000
Standard piece of wood	0.0046
Standard tree	3.0000
Two arms full of wood	0.0600
Standard wheelbarrow	0.0900
Standard mini-moke load	0.4000
Standard cart-load	1.5000
Standard van-load	3.0000
Standard truck-load	10.0000

Volume to Weight Conversion Factors

Unit of Volume	Air-dry Weight (kg)
1 m^3 stacked wood	300.0
1 m^3 solid wood	600.0
1 m^3 coconut fuel	150.0

Nominal Standard Weights of Units of Coconut Fuel

Unit of Measurement	Air-dry Weight (kg)
Standard coconut husk	0.444
Standard coconut shell	0.168
Standard husk & shell	0.612

Nominal Energy Contents

Wood (25% m.c.w.b.)[2]	15 MJ/kg
Coconut fuel (25% m.c.w.b.)	15 MJ/kg

1. The approximations of unit volumes and weights presented here were derived from measurements of typical examples of each type of unit; deviations from these standard values were not evaluated.

2. The assumed wet basis moisture content of 25 percent was chosen to coincide with the 34 percent dry basis figure used by the UN Pacific Energy Development Programme (1985).