Fleming et al (2022) Improving acceptance of natural capital accounting in land use decision making: barriers and opportunities. *Ecological Economics*. Accepted for publication 6 June 2022.

Improving acceptance of natural capital accounting in land use decision making: Barriers and opportunities

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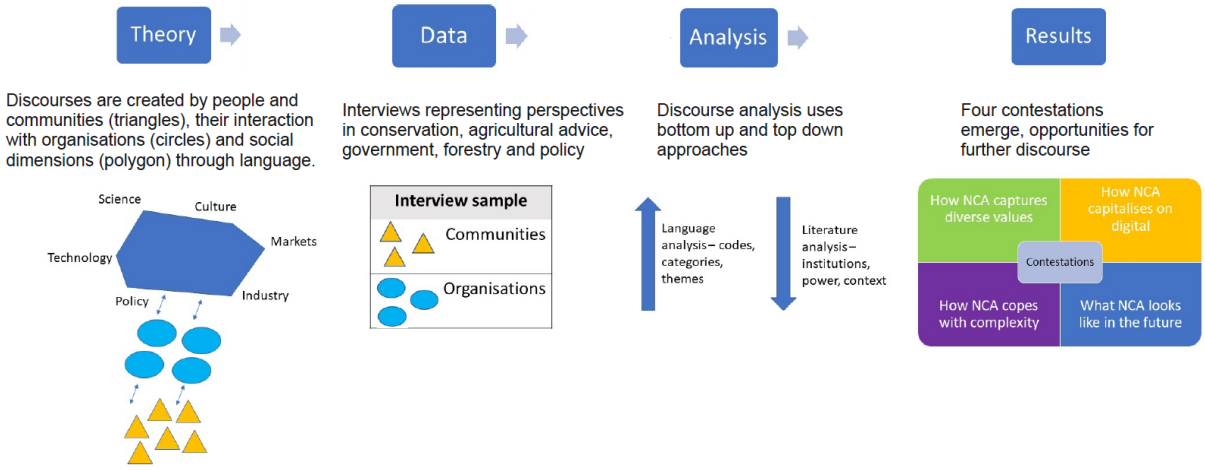
Abstract

Environmental issues are becoming more urgent. Biodiversity loss, climate change, extreme events and global pressures on resources place increasing importance on decision making about how natural resources should be managed. Natural capital accounting (NCA) is gaining popularity as a systematic approach to recognise the full value of natural resources such as soil, vegetation, animals, water, and biodiversity. To understand perceptions and opportunities for awareness and behaviour change relating to the use of NCA, we conducted a discourse analysis of 57 interviews with stakeholders across Australia. Our aim is to promote discussion and reflection about perceptions of natural resources as forms of capital, and the role of NCA to underpin management practice change and support sustainability. We identify four key areas of contestation that relate to values, complexity, digital technology, and the desired future vision of NCA in society. Findings include conflicting views around whether NCA should have a diversity of tailored approaches or a consistent approach for all and that digital technology has and will continue to shape the way NCA is conducted. To our knowledge, this is the first paper to take a discourse analysis approach to perceptions of natural capital accounting.

Graphical abstract

Figure 1. Schematic overview of the paper.



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Introduction

'There are many land managers that are great stewards of their land and are constantly trying to improve their natural capital but it's not easy to capture those practices and the outcomes of those practices at the moment.' (Int 14)

Land-use sustainability is of increasing importance to the global community. Climate change, unsustainable resource use and biodiversity loss are intersecting with population growth and increasing social pressure for accountability of decision making in relation to impacts on the earth's natural systems. Future-focused decisions on sustainable natural resource management need to be made urgently (Bergstorm et al. 2021), and based on multiple, integrated sustainability criteria. Global investments are needed to improve environmental performance and environmental conservation and better balance the growing tension between economic growth and environmental sustainability (Waldron et al. 2017). While there is a growing pool of financial and intellectual capital available to tackle these challenges, deployment will require both scalable investments and accountability (GIIN 2019).

One approach that is emerging as a method to more holistically account for natural resources and environmental performance is natural capital accounting (NCA). NCA is presently defined in multiple ways and has a scholarship that crosses economic, environmental and sector specific disciplines (e.g. agriculture, forestry, ecology) and literature (e.g. Missemer 2018). With contributions from the social sciences and humanities more recently emerging regarding the contribution of cultural ecosystem services, such as aesthetic, cultural, health, recreational and life support systems of the planet (Bartelmus 2009). Bateman & Mace (2020) define natural capital as:

"those renewable and non-renewable natural resources (such as air, water, soils and energy), stocks of which can benefit people both directly (for example, by delivering clean air) and indirectly (for example, by underpinning the economy). These stocks yield flows of 'ecosystem services' such as energy, water, plant and fibre growth, from which people derive benefits." (p.776).

One approach to natural capital accounting that is gaining momentum is the SEEA (System for integrated Environmental and Economic Accounting) (UNCEEA, 2021) for the purpose of including natural capital in macroeconomic analysis and policy making at national and subnational levels. The SEEA follows the system of national accounts to present information about the contribution natural capital makes to economic activity. While primarily focussed on national scale environmental accounting, there is growing interest in the application of this framework to enterprise scale NCA, driven by a desire among industry for consistent, robust and comparable measurement frameworks (van Putten et al. 2021).

We define NCA as the process of identifying the stocks of natural assets, assessing their condition, and estimating, in physical and/or monetary terms the flow(s) of services that they produce over time. Natural capital accounting tends towards 'an anthropogenic framing' (Bateman & Mace 2020, p.776), which views natural capital in terms of what it can

provide to humans (Virto et al. 2018). However natural capital accounting can also be used to value the stocks and condition of abiotic and biotic natural assets, in and of themselves, and therefore can include their import to non-humans, and future generations of people and animals (Bateman & Mace 2020). When considered in this way, NCA is important for decisions about production, conservation and sustainability, but intrinsic values are hard to capture and to account for (e.g. Costanza 2020; Stromberg et al. 2021). Nevertheless, sustainability and accountability are increasingly demanded by investors and equity is also valued by the community. NCA offers a potential way for governments, industry, and business to improve transparency and accountability and hence increase social license, trust, and sustainability (van Putten et al. 2021).

Increasingly, natural capital is being viewed as a material issue (Wu 2018). Materiality is a concept used widely in accounting. In a formal accounting sense, an issue is material if its omission, misstatement or non-disclosure has the potential to adversely affect decisions about the allocation of scarce resources made by users of financial accounts or reports or, the discharge of accountability by management of the governing body of the entity (AASB, 1995). The rising importance of sustainability within corporate reporting and society more generally is seeing an extension of the formal accounting materiality definitions to include natural capital (Geldres-Weiss 2021; Rudgley 2020). The natural capital protocol (Natural Capital Coalition 2016, p.123) defines materiality as; "an impact or dependency on natural capital is material if consideration of its value, as part of a set of information used for decision making, has the potential to alter that decision". Natural capital is particularly important in primary industries as it produces important inputs into primary production and concerns over growing scarcity or degradation of natural capital and increasing demand for agricultural outputs make natural capital a material concern for decision making.

Land managers have decision-making capacity over their land, and increasingly need to balance economic and environmental factors in decision-making. While decisions about agricultural production land can substantially improve or degrade environmental outcomes, tools are not readily available to allow farmers or other land managers to incorporate, or be acknowledged for, environmental outcomes in their decision-making (other than compliance with regulation) although demand for investment is building (GIIN 2019). Explicit recognition of the natural capital outcomes of land use decision-making will improve the sustainability and range of public and private benefits that accrue from land use decisions. NCA has the potential to be a key tool to help the wide range of stakeholders, from agricultural finance and insurance companies through to end-consumers to reach a common understanding about the impacts of land use decision-making on environmental outcomes and agricultural sustainability.

While NCA is demonstrably beneficial in accounting for sustainability, so far, the concepts have not been widely implemented by land managers and society more broadly. If NCA is to support a broader social shift towards accounting for the full value of nature (Costanza 2020), questions arise around how to build the capacity required to mainstream awareness of natural capital. Currently there is a significant gap between the need for NCA and its acceptance and mainstream application. We explored the barriers and opportunities to mainstreaming NCA in Australian land use decision making. This paper helps address these

questions through discourse analysis to examine the whole social system through language. In this paper, our key area of interest is in the barriers and opportunities for mainstreaming NCA into broader social decision-making and so our analysis focuses on key areas or 'themes' of contestation – where the discourse is still unsettled and in development – and key language – where words have particularly important, multiple or value-laden meanings. The main aim for this analysis is to expose and interrogate otherwise implicit assumptions and ideas which drive behaviour and are behind perceptions of natural capital, and NCA, to promote discussion and reflection about environmental decision making, and how NCA can underpin social change to be more sustainable.

Methods

Discourse analysis

Discourses are particular uses of language in different situations, with special attention given to **the effects** of that language use, such as the thoughts or actions that each discourse enables or restricts (Hammersley 2003). Discourse analysis seeks to understand the relationship between language, social institutions and individual subjectivity and agency. Discourse analysis is a varied field, traversing different disciplines and focusing on different areas such as media, grammar and syntax, actors and agency, or power (Jorgensen and Phillips 2002). Discourse analysis, or related approaches looking at narratives, frames or heuristics, is common in environmental policy, especially for climate change (Hajer & Versteeg 2005; Dryzek 2006). In the field of resources and environment, discourse analysis is often employed to understand decision-making and inform policy (Hajer & Versteeg 2006; Feindt & Oels 2005). To our knowledge, discourse analysis has not been conducted in the context of NCA, perhaps because natural capital is an emerging field of interest and the focus has predominantly related to financial accounting or ecological conservation rather than social science. The novel contribution of this paper in linking discourse analysis relevant to inform thinking and discussions around future stakeholder decision-making and public policy. Discourses are useful to explore for NCA because discourse analysis examines language as both the cause and the result of the social structures that shape the systems we operate within (Fleming et al. 2018). In this way, social discourses interact with individual thinking and behaviour where both are continually in a dynamic process of forming and being formed by, each other. Discourse analysis as an applied tool to support behaviour change views awareness of discourse as a crucial first step in enabling change (Fleming et al 2018).

Data collection

To understand the discourse of NCA amongst experts and practitioners and how it might be scaled out to broader social use, the target group included a broad sample of stakeholders involved in developing, applying or using natural capital accounting, including: financial managers and farm advisors, NGOs, investors and researchers (see Table 1). These stakeholders were specifically targeted because these groups are beginning to think about NCA and were interested and able to talk about natural capital concepts. Farmers were excluded from this study because they had previously been the focus for a related study (see Fleming et al. 2019), and as that work shows, farmers do not typically use the terminology 'natural capital'. In addition, this work aims to look at multiple sectors, not just

agriculture. The interviewees were sourced through formal and informal industry associations, referrals from partners in the project and via snowballing (participants suggest others). Due to the impacts of COVID-19 and social distancing requirements, the interviews were conducted over video conference or phone. On average, interviews were 40 minutes. The interviews were conducted in a semi-structured manner, suitable for eliciting people's feelings and perceptions. The questions examined interviewee interpretations of NCA, including approaches used, perceived natural assets, and barriers and opportunities for improving NCA across Australian landscapes. See Appendix 1 for a full list of interview questions.

Restrictions on travel and social distancing imposed by the Australian government as a result of the COVID-19 outbreak, precluded the use of attending face to face industry events, meetings and conferences. These factors constrained recruitment, but 22 participants were secured for online interviews from November 2020 to March 2021. To supplement the sample, 35 scoping interviews previously conducted in 2017 were also included in the analysis. These interviews asked similar questions: What does natural capital accounting mean to you? Do you know of methods to assess natural capital? What opportunities or barriers exist for natural capital to improve decision making, reporting or engagement with stakeholders? These interviews were not audio recorded but had typed notes which were included in the analysis and provided a means to strengthen and validate the coding structure. Results of these scoping 35 interviews (without discourse analysis) are also available in O'Grady et al. (2020) and van Putten et al. (2021).

Across the two data sets, we interviewed 57 participants. The sample size is larger than average for a qualitative study of this nature (Sim et al. 2018). In terms of including data across two different time frames, this provides an additional benefit of triangulation of our findings. Discourse is not a static concept and so qualitative approaches with variable contexts are beneficial, rather than detrimental to the analysis (Moon et al. 2019). Together these views produce the discourse/s of NCA we discuss in the results, the study was not designed to segment or compare sectors.

Table 1. Participant detail

Sector	Number (Men-Women)	Data set
conservation (6) advisors (4) finance (3) government (2) research (2) forestry (2) agriculture (1)	22 (12men, 10 women)	Full interview transcript, used for discourse analysis.
forestry (13) investment (7) research (4) advisors (4) conservation (3) policy (2) regulation (2)	35 (28men, 7 women)	Interviewer notes, used for coding.

Analysis

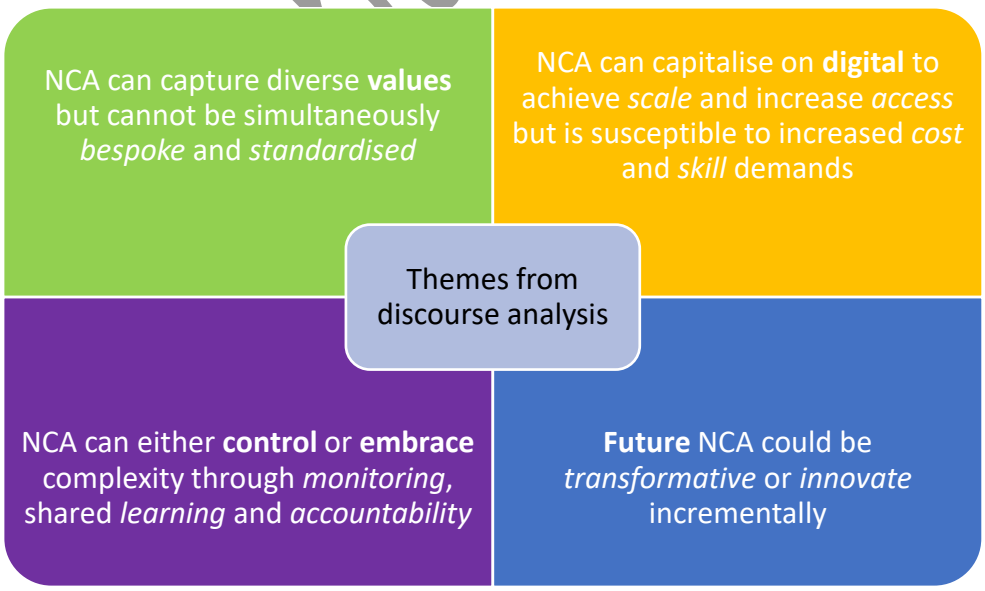
The recorded interviews were transcribed, entered in an NVIVO database (to facilitate analysis) and examined using a constructivist grounded theory approach to coding (Charmaz

2006). The analysis used theories of discourse analysis and included close attention to language use and meaning (Fleming et al. 2019). The analysis involved the researcher inductively assigning (bottom-up) and grouping codes—small, explicit ideas – and then categories — groups of related codes – into themes— groups of related categories. Coding focuses on qualitative interpretations of meaning and allows the analysis to be fully grounded in the data. While the codes, categories and themes could be organised in different ways, the focus for this paper was barriers and opportunities to further adoption of NCA and so the organisation is structured around this central research question. The interview notes were coded along with the transcribed interviews and were useful to validate the coding hierarchy and the results of the discourse analysis, but they are not used for example quotes (because they were not captured verbatim). See Appendix 2 for a table of the coding hierarchy.

Results

The results of the bottom-up coding and discourse analysis were grouped into four themes of ideas related to NCA. The ideas are contested because there are different (implicit) values and assumptions about what could or should happen in relation to natural capital accounting. Areas of contestation in discourse are sites of opportunity because there are multiple potential pathways. How something is framed within a discourse will change how it is thought about and what actions are enabled. If that framing is not yet set, there are more options. Therefore, these areas of contestation are important to explore to improve potential outcomes. We describe these below with an overview (Figure 2) with more discussion of the implications of the findings for different sectors in Table 2. We use example quotes to demonstrate how language use constructs different ways of thinking and has different implications. (See Appendix 3 for further quote examples).

Figure 2. A schematic of thematic results. Each quadrant shows one topic of contestation, with bold and italic text highlighting key words from the discourse analysis. .



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Natural capital accounting is values driven

The first theme or area of contestation in the data is whether NCA should have a diversity of tailored approaches or a consistent approach for all. Participants recognised that values shape perceptions of what natural capital and NCA is seen to be, as well as views on how it should be used for decision-making. For some respondents, the fact that natural capital is intrinsically linked to values was a key opportunity to make NCA relevant and useful, by achieving different purposes in different situations. Key language in this theme includes: bespoke, (recognition of) context, different perspectives, priorities.

'I think natural capital means different things to different people… I think each of those industry bodies themselves are prioritising what's really important to that sector. I don't think we have a one size fits all.' (Int 12)

For other participants, the need to tailor NCA to different values and contexts was a potential barrier to achieving consistent and rigorous approaches. Different values driving different sectors of industry or policy were perceived as constraining agreement and collaboration and scaling out change. Key words include: systematic, consistent, common, rigorous, agreed, credible.

'I think you've got to do it everywhere. I don't think you can choose one or the other it needs to happen across the board, right. I think, […] if we can actually coalesce the private and public sector around a common set of natural capital metrics, and everybody is asking for the same thing, then we can get hopefully some more momentum and break down some of those barriers.' (Int 14)

Some participants saw the indigenous perspective as a way to integrate values with a holistic perspective and an important window to better understanding risk and sustainable outcomes. Others thought that farmers should be recognised for stewardship of the public good. Key language here is: connection, (across) scale, public good.

'I'm sure that also goes for farming families that have been, for generations, that have had that really strong connection in place. Yeah, and so probably the same for conservation organisations or naturalists with long-standing associations in place. But obviously, Indigenous knowledge is such a different, more in depth, more complex, and I guess interconnected way of thinking about looking after nature and the importance that it has within our lives.' (Int 15)

Barriers resulting from values that were noted in this theme were around negative perceptions of agriculture (as clearing and degrading land) or forestry (as planting monocultures) and how they were often in conflict with each other. In addition, values conflicts based on politics were highlighted as a barrier, especially in terms of funding, election cycles and short term and economic focused objectives. Key words include: (lack of) political leadership, tension, pressure, division.

'We've got to have leadership and we've got to have the people who understand what the issues are, in a position to champion it[…] We've got to take the polarisation out of the issues of trees on farms and environmental farms away[…] That's – the issue is the division. We've got to normalise having trees on farms.' (Int 8)

Complexity – embrace or control

The second theme is how, while all participants recognised NCA as a complex task, some participants responded to the complexity as an opportunity to embrace while others responded to it as a risk to be controlled. Embracing the complexity of natural capital meant focussing on the important outcomes, the well-being of the beneficiaries (human and non-human), and the big picture of environmental condition, rather than accounting for any single component of natural capital in isolation. This overlaps with the holistic viewpoint discussed in relation to values above as individuals may differ in their preferences to think about things holistically and generally, or separately and specifically.

For the participants who thought that complexity was a barrier to overcome, issues were careful selection of what to include in natural capital accounts and making sure that it was simple enough to be used in a systematic and scalable way. A point raised was the need to track progress over time to be useful for decision making and to make evidence-based assessments about whether objectives had been achieved. Biodiversity was often discussed as a useful way to take a whole of eco-system lens and think about multiple components of ecosystems, and their connections. Key language in this theme is: interaction, acceptance (of complexity), biodiversity, outcomes.

'And so what we miss is the interaction between things and nature is complicated, it's messy, it has lots of different interactions and we need to live with that kind of go, okay, well, it is what it is, we can't and shouldn't be reductionist about it because, as soon as we start doing that, we lose the fundamental, I guess importance of what that is, and we've learned those lessons, right? We've learned that if you pull water out and allocate water in a particular way and don't think about the rest of the landscape, it's all going to come crashing down at some point. The same if we do it with soils or we do it with particular species. If we pull bits out, it's eventually going to cause problems. So I think we need to just accept that nature works in a complex way, and we need to live with that.' (Int 15)

Included in this theme is the recognition of the added complexity created by climate change and the impact on increased extreme events, including fire, drought, and flood. This was perceived as another reason why NCA was needed to help inform decision making, as well as to record and assess impacts and proactively and accountably manage risks. Key words include: actively manage, management decisions, impacts.

'How do we actively manage those biodiversity requirements? And the thing that we ask, we struggle with is fire management, or appropriate fire management and wildlife management, these two layers, they are constantly there. We're also seeing the climate layer. So, now that effect of drought. And then fire, they add complexities to try to come up with a system, you really need monitoring at the base of so much of it to be able to make management decisions so it's quite a big beast really.' (Int 4)

An opportunity exists that if NCA can truly account for complexity and interconnection, it will achieve better results. Key words are: improve, reward, measure change.

'And if that somehow was recognised, of course, we have talked before about the economic reward, yes, but if there was a sort of a social recognition to do that, I think that would be an opportunity.' (Int 10)

Barriers are around the cost and complexity of accounting for benefits over the time frames involved. Key words are: long-term, cost, not recognised.

'What is the relationship between natural capital and financial outcomes, and broader societal outcomes? And because we don't have, I guess, data from the farm scale through to the catchment scale over any length of time, making that connection is really, really difficult.' (Int 2).

The promise of digital technology, and its limitations

The third theme is around the contestation of digital technology, whether it will be the 'solution' to achieving NCA by synchronising multiple platforms and enabling different scales of autonomous assessment, or whether it is a barrier to achieving widespread change because only some will have access or capacity to use it. Some participants saw digital technology and the need for specialised skills as a potential way to attract and retain staff and be an employer of choice. Others saw the need for additional skills as a barrier to potential users of natural capital accounting, especially if they lacked other training to underpin it, for example in business, computer use, or general literacy. Access to essential infrastructure (such as access to internet or historical data) or funds were also perceived as potential barriers to participation in digital components of NCA. Although digital technology was described as an expensive upfront cost, it was also seen as the only way to afford on-going data collection. Key language in this theme is: expensive, pay-back, capacity, solution.
'And the advantage of digital technologies or the promise, is that it will lower the cost and expand our ability to monitor and track these things over time. So it absolutely has to be part of the solution.' (Int 2)

Opportunities related to digital technology include the potential for digital technology to allow remote, more frequent, and consistent monitoring and use of larger data sets for better decision making, either individually or across sectors. At the same time however, data sharing was raised as also a potential issue, in terms of how the benefits of data were shared and how data was stored, managed, and used. Bringing platforms and tools together and harmonising and standardising the results was seen as an opportunity to achieve consistency and scale open to all. Key language here is: stored, controlled, bringing data together.

'So it's sort of this idea of how do you store and control the exchange of data, and, again, if we had some common platform for doing that there'd be huge benefits to that as well.' (Int 14)

New developments in digital technology were also seen to be full of promise for some, with

satellite imagery, geospatial mapping, drones and sensors. Agriculture was seen to be a sector that had already strongly adopted technology and would continue to do so. Others were concerned that too much reliance on digital technology for autonomous or large-scale assessments (such as satellite imagery measuring land cover) could result in errors. For these participants, there was more development needed to build trust in the systems, as well as the way they were used and validated. Key language here is: ground truthing, not there yet.

'I think remote sensing plays a role, but I also think ground truthing information is really critical as well for tech.' Int 16

Two visions for natural capital accounting – fundamental shift or continuation of the status quo

The final area of contestation is around two differing views of how NCA operates in the future. For some participants, NCA was seen to be part of a fundamental shift in how society makes decisions, at all levels, including the public and government, to account for nature more explicitly (social transformation). This involves significant changes to accounting processes and financial decision-making being widely adopted (e.g. sustainability linked loans, true cost accounting). For others, NCA was seen to be more seamlessly integrated into business as usual, as innovation, but not a significant change (e.g. disclosures). In this view, NCA was related more to individual businesses and industry, rather than to governments and the wider community. In the fundamental shift version of the future, raising awareness, building momentum and driving wider social change through the farming sector, government and involving the public were seen to be important. Key words here are: information, understanding, realisation, education.

'I think it's just about giving people information which is a really great opportunity that natural capital accounting can do.' (Int 16)

To create a fundamental shift in society, government was seen to have a key role to play to incentivise and drive change, including internally changing government systems (e.g. accounting, grants, assessments). Furthermore, the farming sector was seen to be a key player in driving the transformation. Key words: leading, incentivising, regulation, government, industry.

'I think that's where government, for the greater social good, environmental good, public good, could drive that through some sort of incentivising that, and creating and investing in programs that work.' (Int 16)

The public was also seen to have a crucial role to play, via social license and consumer markets. As environmental awareness increases, and natural capital becomes more broadly recognised as essential to human well-being, natural capital impacts more on consumer behaviour and changes how businesses are required to operate more transparently and responsibly. Media and social media are some examples of how public awareness can be raised and in turn lead to increased pressure on business. Key words: market, social license, demonstrate outcomes.

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'I think natural capital accounting has the ability to drive a non-regulated market for better conservation outcomes, environmental outcomes, sustainability outcomes.' (Int 16)

NCA was perceived to be useful to guide decisions and for reporting and engagement with stakeholders, shareholders and the community (including NGOs) as evidence of corporate social responsibility - where businesses are required to contribute to the public good to demonstrate legitimacy, in practice, often superficially. Key words: demand, decisions, responsibility, investors.

'So we have a corporate responsibility and a social responsibility to deeply understand environmental impacts and natural capital impacts to our environment.' (Int 12)

In the future vision of NCA as part of the status quo in Australia, the benefits of NCA are not settled yet, and there is still a high administrative burden to participating, for unclear returns. The carbon trading scheme is often cited by participants as a way that natural capital payments could be developed, but the low financial return, and difficulty in adoption of the programs was also noted. Key words: burden, onerous, process, settle.

'The ultimate goal is that it does become a requirement over time but I think there's a lot of work to be done between now and when that happens because in terms of getting – easier non onerous ways for land managers to measure natural capital and then a system for them to be actually be able to report on it formally, either at the natural capital measures level or at a financial accounting level, there's still a bit of a way to go there.' (Int 14)

These results are intended to help different sectors understand each other's perspectives and work together to collectively mainstream NCA. Table 2 captures the implications of each theme for different sectors and highlights priority areas for each sector to action to better coordinate efforts.

Table 2. Summary discussion of the implications of the four contestations found in this research for different sectors with priority areas shaded

	Value driven	Complex	Digital	Future ideal
Accounting	Explicitly tailor accounts to reflect different values and enable these to be aggregated for analysis to support community, regional and national scale resource management.	Design NCA to manage complexity and so that it can be adopted at different levels for different purposes.	Explore opportunities to automate and verify data from digital technology at individual and aggregated scales.	Accounts and reports of business and government are enabled and required to include natural capital.
Industry	Different values are enabled for	Explore case studies and	New technology transparently	Increased productivity and

	different individuals but able to aggregated to a broader scale at industry level.	example accounts e.g. soil health and biodiversity to grapple with complexity.	tested to build trust. Skills developed and access supported to avoid inequity.	increased recognition and return from efforts to improve and sustain natural capital.
Conservation	Public goods such as biodiversity, cultural and intrinsic values are recognised and enabled alongside other values.	NCA supports decision makers to account for the whole system.	Better and more cost-effective ways to measure biodiversity and to support new approaches to cultural knowledge.	Increased accountability and pressure for all sectors on sustainability decision-making.
Government	Facilitation of co-production and collaboration across sectors of natural capital accounts that are able to be adapted and tailored.	Fund on-going programs that start despite uncertainty and actively build in learning by doing and on-going adaptation.	Fund development of new approaches that progress ways to scale up and make more inclusive natural capital assessments.	Commitment to the facilitation of a broad, cross-industry national natural capital account process to be used within government as well.
Research	Explicitly explore different values and ways to capture these in accounts, including with co-design and collaboration with multiple groups.	Continue to explore and reduce uncertainties and improve methods for measurements and validation and increase interdisciplinary and transdisciplinary approaches.	Continue to co-design technology that is trusted and improves efficiency and accuracy of measurements at scale.	Faster, more dynamic interplay between research and practice, adoption and innovation and more conceptual development of the connections between public good and natural capital.

Discussion

This paper contributes a unique perspective to the literature about natural capital accounting by providing a focus on the language key stakeholders use and what this means for how natural capital and natural capital accounting is perceived and could be more broadly adopted. To increase the application of natural capital accounting as a mainstream foundation for informing decision-making, the four contestations show that there are currently tensions (or opportunities) that will need to be navigated. The tensions are around how to manage values, how to deal with complexity, how to harness digital technology and

what the ideal vision of the future should be. Contributions from industry, government and community are required for addressing these social questions and tensions.

Other studies have looked at how to integrate diverse knowledge systems based on different values, such as indigenous and western perspectives to improve land management outcomes (e.g. Tengö et al. 2014; McLean et al. 2021). Similarly, the 'boundary work' of science to policy has been explored by multiple studies looking at how to integrate and harmonise thinking that has different purposes (e.g. Cash et al. 2003; Cornell et al. 2013). What is common across these types of discussions is how important it is to engage in open, respectful and equal dialogue to 'listen with empathy' and bring assumptions into the open (Tengö et al. 2014, p.586; Harrison et al. 2021). It is important to realise at the outset that every individual has a range of personally held values and assumptions about 'what should be done' and making this explicit is a key first step toward negotiating action. In terms of valuing natural capital, this discussion is still very dynamic and new, with a tendency toward politicisation that must be openly addressed (Tengö et al. 2014). State based programmes are being developed in Australia whose accounting systems are not consistent with each other, reflecting how returns tailored to different values are currently progressing NCA.

Systems thinking approaches designed to deal with complexity and uncertainty in understanding the drivers and resolutions of threats to natural capital management are common in both land and marine settings (see Judd & Lonsdale 2021 for an example in the marine sector, and van Kerkhoff et al. 2019 and CMP (2018) for conservation management practice). In agriculture, best management practices have been developed to reduce complexity and support decision-makers to avoid damage to natural resources (for example see MLA Grazing Land Management https://www.mla.com.au/research-and-development/Grazing-pasture-management/, and: Reef 2050 Water Quality Improvement Plan (reefplan.qld.gov.au). The Capitals Coalition has developed guidance and protocols to assist businesses to analyse their dependence on natural capital and how their operations may impact (negatively or positively) the type and condition of natural capital (see www.capitalscoaltion.org). NCA and the UN SEEA could support these protocols. They are drawing on national accounting and financial accounting principles that have been designed to help stakeholders detect and avoid undesirable outcomes resulting from 'consuming' their financial and produced capital and are extending and adapting these to enable stakeholders to minimise consumption of natural capital (Ogilvy 2020; Hein et al., 2020). They may be able to provide further support to resolve complexity-related barriers to better natural capital management if they are designed to keep records along the chain of cause and effect that the system thinking approaches have identified as links between natural capital (or Ecosystem Assets) to financial, cultural, and other economic resources.

We showed in Table 2 that the interview participants highlighted different priority needs and values of the use of digital technologies for NCA. This underscores a need for multi-party participatory co-design processes for the future use of NCA, as outlined by Harrison et al. (2021).

Digital technology has and will continue to shape the way NCA is conducted. Interactive, web-based platforms that integrate spatial and real time data, audio, video and user-

entered information enable virtual modelling of natural capital, allowing users to remotely access and visit sites, collaboratively discuss management and visualise future changes could potentially revolutionise this space (AECOM 2020; Preininger & Hafner 2021). Through appropriately encrypted digital dashboards, such platforms will enable co-creation of NCA with other sustainability metrics, such as gains in biodiversity. Recent innovations may even enable *in silico* quantification of the number and locations of plants, wildlife, ecological condition, as well as predictions of how such variables change over time, and their influence on soil, air and water quality (Ara et al. 2020; AECOM 2020).

Where data is unavailable, machine learning (e.g., for satellite imagery) and biophysical modelling (for temporal process-based changes) can be applied to interpolate measured data – thus backfilling the virtual gap – providing users with a more comprehensive and complete virtual picture of natural capital. Such advancements are a significant leap forward from traditional static and/or published analyses that are often only legitimate to expert technical audiences (AECOM 2020). In contrast, new digital tools allow processing and quantification of natural capital by the layperson, increasing both cost and time efficiencies for land managers, but also increasing the ability for a diverse array of stakeholders to have input.

While the technology and capacity for cloud-based big data gathering are rapidly gaining momentum, the institutions that support (efficient and equitable) use and exchange of data are very much in their infancy. Institutions here may include rules, organisations and expectations that determine how people interact to use the data (Sanderson et al. 2017). Data ownership, trust and transparency and benefit sharing (Jakku et al. 2020) are foremost and pressing issues in digital technology developments, including for the ethical use of natural capita data. By way of example, farmers may be loath to share their data if it could be used against them, e.g., via penalties for land clearing (Sanderson et al. 2017) or to benefit others further along the supply chain (Jakku et al. 2020). 'Data markets' may be useful platforms to connect data owners with other users and encourage dialogue (e.g. Poppe et al. 2015). Various ownership models have been proposed (e.g., 'the sensor as a service' and 'the farmer owned sensor'; see Box et al. 2017). Overall, however, policy frameworks for data ownership and ethical use lag significantly behind technology aspects in NCA.

NCA is not the only way of improving decision-making around natural resource management in Australia. There are other mechanisms for motivation and enablement of continual improvement of landholder management practices (for example Environmental Management Systems) and informal communities of practice such as Landcare in Australia and the Food Agility Cooperative Research Centre, see https://www.foodagility.com/). However, NCA is likely to be a significant part of the solution for these other mechanisms because it allows natural capital to be defined in production, conservation and sustainability terms to reflect the multiple dimensions of its economic value and for decisions about natural capital to be accountable to these values. In terms of achieving mainstream social change, it is essential that we start to better realise and represent the role of nature in our

decisions, at all sectors and scales. NCA is a promising way to achieving that social change (Costanza 2020; Bateman and Mace 2020) and it was consistently supported by participants as a worthwhile area to continue to build and grow.

The incorporation of natural capital into financial and management accounting appears practical and useful to integrate management decisions with analysis and reporting of financial, environmental and economic performance. In addition to the UN SEEA EA, Ogilvy (2020) demonstrated ways in which the present corporate financial accounting standards can draw on existing methods of natural resource measurement and management in agriculture to provide a conceptual framework for natural capital accounting in broadacre agriculture. Ways in which the Natural Capital Protocol (Capitals Coalition 2021) and the UN SEEA EA can be harmonised have been proposed (IDEEA Group 2017) and ways in which financial accounting can make nature's values more visible have been demonstrated (Dickie et al, 2020).

Conclusion

Global action to conserve and improve the environment is required, given current trajectories of climate change and biodiversity loss. Natural capital accounting is one approach to improve how decisions are informed by the (complex) valuation of natural resources with potential application at the individual, organisational and policy scales. From interviews with 57 participants, we explored how natural capital and natural capital accounting was perceived and the barriers and opportunities to natural capital accounting be adopted to underpin broader social change. Using discourse analysis we identified four areas of contestation around values, complexity, digital technology and future visions of natural capital accounting in society. These four disputed themes represent key aspects of natural capital accounting for industry, research and policy decision makers to reflect on and address, to scale out natural capital accounting.

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