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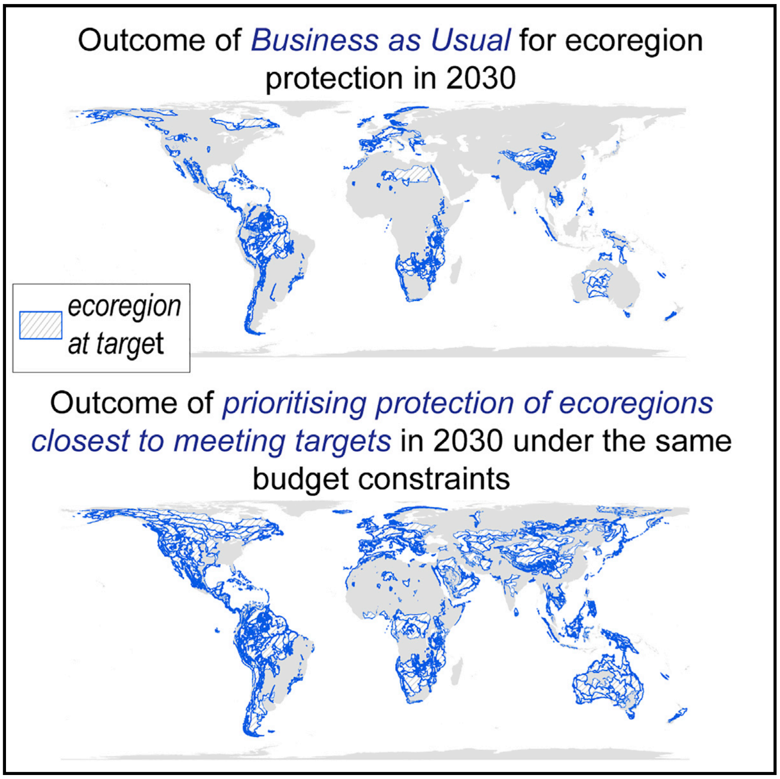
To Achieve Big Wins for Terrestrial Conservation, Prioritize Protection of Ecoregions Closest to Meeting Targets

Graphical Abstract



Highlights

- We develop a global strategy to prioritize ecoregions for protection over time
- Our strategy could protect twice as many ecoregions as business as usual by 2030
- Our strategy could halve the ecoregion protection gap compared with business as usual
- Considering the ongoing race between conversion and protection of habitats is key

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In Brief

Protected areas represent a significant investment from countries toward biodiversity conservation. Up until 2020, countries are expected to contribute to the global 17% terrestrial protected-area target, which will most likely increase in the post-2020 Strategic Plan for Biodiversity negotiations. Under the current strategy of area acquisition, almost 80% of ecoregions are unlikely to achieve this goal by 2030. We present a simple yet effective framework for prioritizing global ecoregion protection and meeting the likely future targets of the Strategic Plan for Biodiversity.

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To Achieve Big Wins for Terrestrial Conservation, Prioritize Protection of Ecoregions Closest to Meeting Targets

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SCIENCE FOR SOCIETY To save species from extinction, conservation is racing to establish new protected areas (PAs) before natural habitats are lost. We thus need a strategy to efficiently allocate conservation resources toward PAs. This strategy also has to be global to meet the international targets for PAs set by the Convention on Biological Diversity (CBD). One key aspect of these targets is that all broad ecosystem types (called ecoregions) should have a minimum level of protection equal to an area target. Here, we show that simply prioritizing ecoregions that are the closest to meeting the CBD's area target for PAs performs almost four times better than the "business as usual" approach: under the current annual budget for PAs, up to 260 more ecoregions that meet their targets by 2030. Our work addresses the ongoing race between habitat conversion and habitat protection, a factor seldom accounted for in the PA literature despite real-world implications.

SUMMARY

Most of the terrestrial world is experiencing high rates of land conversion despite growth of the global protected area (PA) network. There is a need to assess whether the current global protection targets are achievable across all major ecosystem types and to identify those that need urgent protection. Using recent rates of habitat conversion and protection and the latest terrestrial ecoregion map, we show that if the same approach to PA establishment that has been undertaken over the past three decades continues, 558 of 748 ecoregions (ca. 75%) will not meet an aspirational 30% area protection target by 2030. A simple yet strategic acquisition plan that considers realistic futures around habitat loss and PA expansion could more than double the number of ecoregions adequately protected by 2030 given current funding constraints. These results highlight the importance of including explicit ecoregional representation targets within any new post-2020 global PA target.

Table 1. Summary of the Acquisition Strategies between 2009 and 2030

Strategy	Description	Algorithm Ranking for Regions below Target
BAU	maintain acquisition and conversion rates observed between 1993 and 2009	none
Random (null model)	select ecoregions to protect randomly	random
Quick win	prioritize protection of ecoregions that are the closest to meeting target-level protection	according to amount of land needed to reach the target-level protection, from smallest to largest
Greatest need	prioritize protection of ecoregions that are the furthest from meeting target-level protection	according to amount of land needed to reach the target-level protection, from largest to smallest
Cheap land	prioritize protection of ecoregions where buying land is the cheapest (i.e., smallest opportunity cost, estimated as potential revenue per year per hectare for the most profitable crop)	according to the median cost of available cells in the ecoregion, from smallest to largest
Last chance	prioritize protection of ecoregions that are the closest to being too converted to reach the target	according to amount of land left to reach conversion level, from smallest to largest
Most threatened	prioritize ecoregions that are being converted the fastest to minimize the loss of area available	according to the rate of conversion, from largest to smallest
Quick and cheap	prioritize ecoregions that are the closest to meeting target-level protection and where buying land is the cheapest	according to the amount of land needed to reach the target-level protection multiplied by median cost of available land, from smallest to largest

BAU stands for "business as usual" and represents a strategy whereby observed acquisition and conversion rates remain the same as those observed between 1993 and 2009.

INTRODUCTION

The 2020 Strategic Plan for Biodiversity states that 17% of Earth's land area should be placed under protection and that protected areas (PAs) and other effective area-based conservation measures must represent the current diversity among habitats and species within their borders (Convention on Biological Diversity [CBD] Aichi Target 11).[1] Ecological representation is a central pillar of this target, recognizing that while it may not be possible to save everything on Earth, nations should strive to preserve a representative sample of all ecosystems and habitat types.[2] As a consequence, ecological representation is reported by most nations and global institutions.[3] At present, there are large gaps in the PA network such that many ecosystem types and species have little or no formal protection;[4] this pattern holds at national[5,6] and global[7] scales. Ecoregions are the preferred unit when mapping ecosystems globally.[1,3] Those that are not yet protected to the desired level (e.g., 17%) but could still meet the protection target (e.g., having <83% converted land) are faced with a race to establish new PAs before natural habitats are degraded.[8–10] This race makes the strategic allocation of limited conservation funds a priority for achieiving global biodiversity targets.

Summary of Approach

We developed a dynamic protection strategy that achieves maximum representation of ecoregions by 2030 while accounting for ongoing habitat conversion. We chose 2030 as a time frame because it is the current time horizon set for the Sustainable Development Goals (under which any future CBD PA target must be embedded). Given the uncertainty regarding the future of international protection targets, we used the current requirements of Aichi Target 11, i.e., to protect 17% of each global ecoregion up to 2020 and an aspirational 30% target by 2030, which is now being widely proposed by the conservation community.[11] We tested several simple but robust PA expansion strategies to determine which method best achieves these goals. In some ecoregions, additional protection is needed to meet the representation goals,[12] but unprotected land may already be too modified to be suitable for conservation because it is unlikely to be successfully restored.[13] Incorporating land-conversion processes into our analysis reduces the amount of land available for protection and ultimately implies that some ecoregions will not have enough unconverted land remaining to meet the area protection target by 2030.

We first established a "business as usual" (BAU) strategy for PA expansion within each ecoregion on the basis of the observed rates of land protection[12] and conversion between 1993 and 2009.[14] We then defined several realistic PA strategies where ecoregions are prioritized for protection according to characteristics such as the amount of land already protected and annual rates of conversion (see Table 1 for descriptions). These PA acquisition strategies used single-step myopic algorithms (i.e., with investment decisions made annually) and were tested for a wide range of budgets. We examined a "quick win" strategy whereby ecoregions that are the

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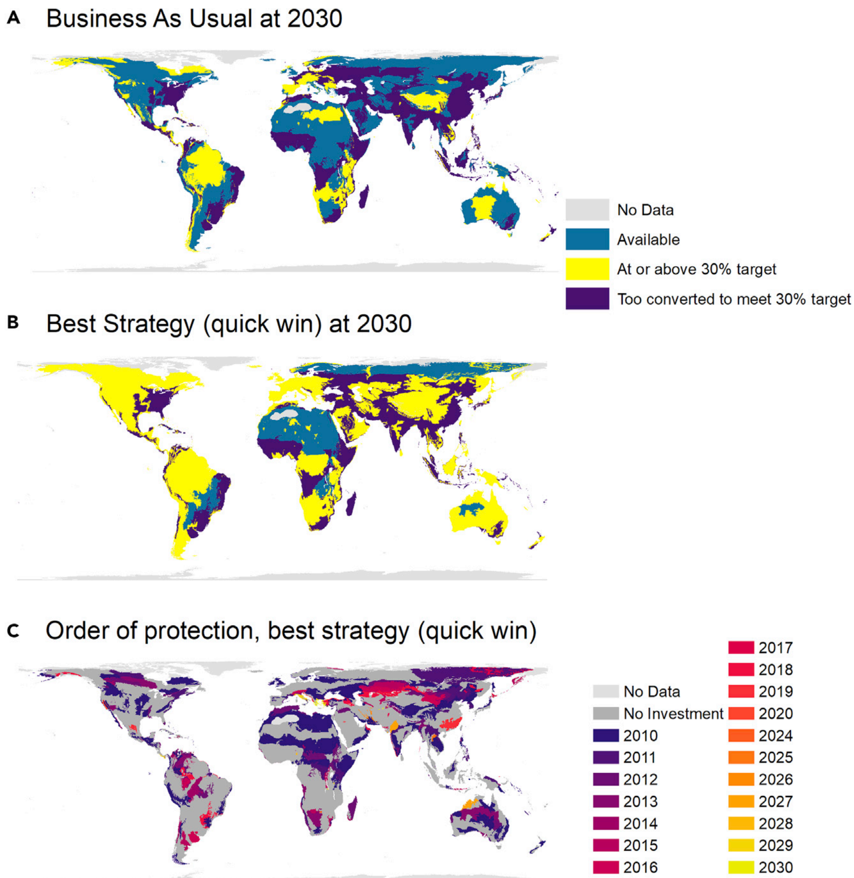

Figure 1. Predicted Fate of the World's Terrestrial Ecoregion in 2030

(A and B) The BAU strategy (A) and the overall best strategy (B) for the average observed annual budget for protection.

(C) Order of protection of ecoregions under the best strategy; darker colors represent where action is needed most urgently. No investment can signify that the ecoregion is already at target or that it was not possible to reach the protection target by 2030.

closest to the protection target (17% or 30% depending on the time step) are prioritized for further gazetting and an opposite "greatest need" strategy targeting ecoregions that are the furthest from the target and in need of the most investment. A realistic approach would be to focus on land that can be cheaply acquired,[15] which we implemented in the "cheap land" strategy by prioritizing ecoregions with the smallest agricultural opportunity cost,[16] or where we can afford the most land for the budget, as explored in the "quick and cheap" strategy. Because of the threat of rapid land conversion, decision makers might choose to focus on the ecoregions experiencing the highest rates of conversion ("most threatened" strategy), or they could focus on ecoregions that are closest to being too converted in terms of area ("last chance" strategy). These myopic strategies were also compared with a "random" strategy whereby ecoregions were selected randomly for land protection.

RESULTS AND DISCUSSION

Strategies for Reaching Area Targets

By comparing seven alternative strategies with BAU (Table 1), our goal was to identify which PA strategy would maximize the number of ecoregions with at least 30% of their area protected by 2030. As a proxy for including the cost of buying available land for protection, we calculated the median opportunity cost of a km^2 of available area in each ecoregion in 2009.[16] According to this measure, the median annual protection budget (i.e., the budget available for buying land) between 1993 and 2009 was more than US$114 million. In our future projections, we therefore tested a range of annual budgets varying between $1 million and $160 million annually.

Performance of BAU Strategy

After removing those with no cost or human footprint data, we were left with 748 ecoregions in our analysis. Between 1993 and 2009, 24.8% (n = 185) of these were not being converted and 15.5% (n = 116) were not being protected.

In 2009, just before the 2010–2020 Aichi Targets were established, 247 ecoregions had $\geq$17% of their area under protection (33.0%) and 226 were $\geq$83% converted (30.2%); in these latter ecoregions, the 17% target (or anything higher) is unattainable without restoration. In addition, 29 ecoregions (ca. 3.9%) were so heavily converted that they had no available land for protection. The BAU scenario performed well in predicting the number of ecoregions with 17% or more PA in year 2016 (293 ecoregions predicted versus 279 observed with an 85.1% match between the two sets).

When projecting the BAU to 2030, we predicted that 190 ecoregions would be at least 30% protected by 2030 but that 321 ecoregions would be too converted to meet this target. This would leave 237 ecoregions without 30% protection by 2030 but with sufficient land to hypothetically reach that target (Figure 1A).

Alternative Acquisition Strategies for Meeting the 30% Target in 2030

The strategy that led the most ecoregions to reach 30% protection by 2030 depended on the annual budget available for PAs. All PA expansion strategies performed better than BAU for the average observed annual budget (~$114 million) and yielded between 56 and 260 additional adequately protected ecoregions than BAU in 2030 (Figures S1 and S2). Moreover, there was always an acquisition strategy that performed better than BAU in 2030. For the smallest annual budget ($1 million), only the "cheapest" strategy outperformed BAU. However, for as low as $10 million annually (less than 10% of the current budget), the "cheap land," "quick win," and "last chance" strategies

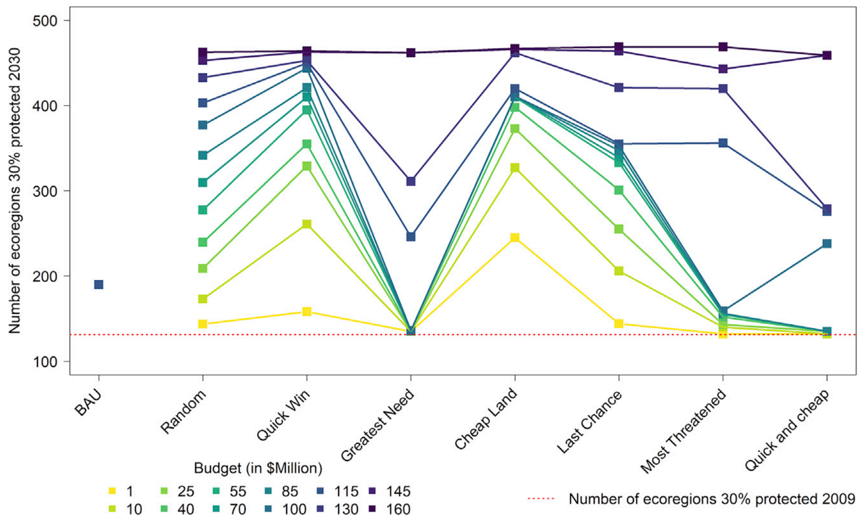

Figure 2. Number of Ecoregions with 30% Protection by 2030 as a Function of PA Strategies and Budgets

We compare the results of BAU in 2030 and seven strategies: random, quick win, greatest need, cheap land, last chance, most threatened, and quick and cheap. The maximum number of ecoregions achieving the target protection in 2030 was 469 for all budgets.

respectively yielded 137, 71, and 16 additional adequately protected ecoregions in 2030 (Figure 2). With smaller budgets, the "cheap land" strategy performed best for meeting the 2030 target, but with budgets between $85 and $130 million annually, the "quick win" strategy performed best. For the highest budgets, all acquisition strategies performed nearly as well as each other, yielding between 269 and 279 more ecoregions adequately protected than BAU. These results were unaffected by the assumptions made for the rate of conversion of ecoregions (Figure S3). Under the current observed budget, the "quick win" strategy achieved the protection of almost all available ecoregions at the desired level (Figures 1A and 1B). The timing of protection, however, varied between ecoregions (Figure 1C).

Performance of Acquisition Strategies over Time

The rate of accumulation of ecoregions reaching adequate protection over time also varied among strategies and budgets (Figures S1 and S2; Tables S1 and S2). As the target changed from 17% to 30% after 2020 in our simulations, there was a reduction in number of ecoregions meeting the target. For example, BAU yielded 309 ecoregions with a 17% target but yielded 190 in 2030 with a 30% target. However, even in 2020, at least one acquisition scenario always outperformed the BAU strategy regardless of the budget.

The "quick and cheap" strategy performed best up to 2020 for the smaller budgets and equally as well as the "quick win" strategy for budgets > $100 million (Table S1). However, when the target increased to 30%, the best acquisition strategy became either the "cheap land" or the "quick win" strategy. For larger budgets, most strategies performed very well. In contrast, the strategy of prioritizing ecoregions that are the furthest from the 17% target ("greatest need" strategy) performed the worst across most budgets up to 2020 (Table S2). Between 2021 and 2030, the worst-performing strategies were mainly "greatest need" and "quick and cheap." Focusing on ecoregions with the greatest need might seem like a more equitable strategy because those ecoregions that have historically received the least protection are prioritized and, under a different objective, e.g., maximizing the amount of land protected across all ecoregions or achieving equitable representation,[17] might perform better.

Other Measures of Success

In addition to maximizing the number of ecoregions that are 30% protected in 2030, we measured ecoregion representation by using two quantitative metrics designed to assess equity in representation, namely protection equality[18] and gaps in protection (protection gap),[19] over the entire PA network in 2030. The first metric looks at the overall evenness of protection across ecoregions, and the second looks at the average gap between how well an ecoregion is protected and the target (e.g., 17%). We found that all acquisition strategies contributed to improving ecoregion representation in the global PA network between 2009 and 2030 (Figure 3), although at different rates. Protection equality increased the most and protection gap decreased the most under the "cheap land" scenario up to a budget of $85 million, followed by "quick win" for larger budgets. These results support our findings that "cheap land" and "quick win" strategies perform the best and that the latter is best for the current protection budget.

Caveats and Future Research

One caveat to this analysis is that we did not investigate the spatial configuration of the land available for protection with regard to fragmentation (i.e., how big would the resulting PAs be?) or the biodiversity present within a PA (i.e., are endemic species protected when we meet the ecological representation target?). Our aim was not to identify specific areas for protection but rather to show that there are quick and cost-effective ways to meet the ecological representation components of the CBD Aichi Target 11 as well as future targets. Detailed spatial plans are required for priority regions in order to maximize the gains within these regions.

A second caveat was that we did not consider the amount of human pressure within individual PAs. Jones and colleagues found that up to one-third of the global PA estate is converted.[10] We followed a similar analysis that assessed PA coverage and habitat loss[13,20] and considered that it would be impossible to assess the state of the PA based on the degree of human modification. This is because some PAs could have been designated in poor condition but could be rapidly improving through on-ground management, and we would misclassify these areas. Given that even converted PAs are nationally designated as "protected," they are contributing the goals of a PA because they should (in theory at least) be stopping threats from increasing and ensuring that restoration occurs. It would be

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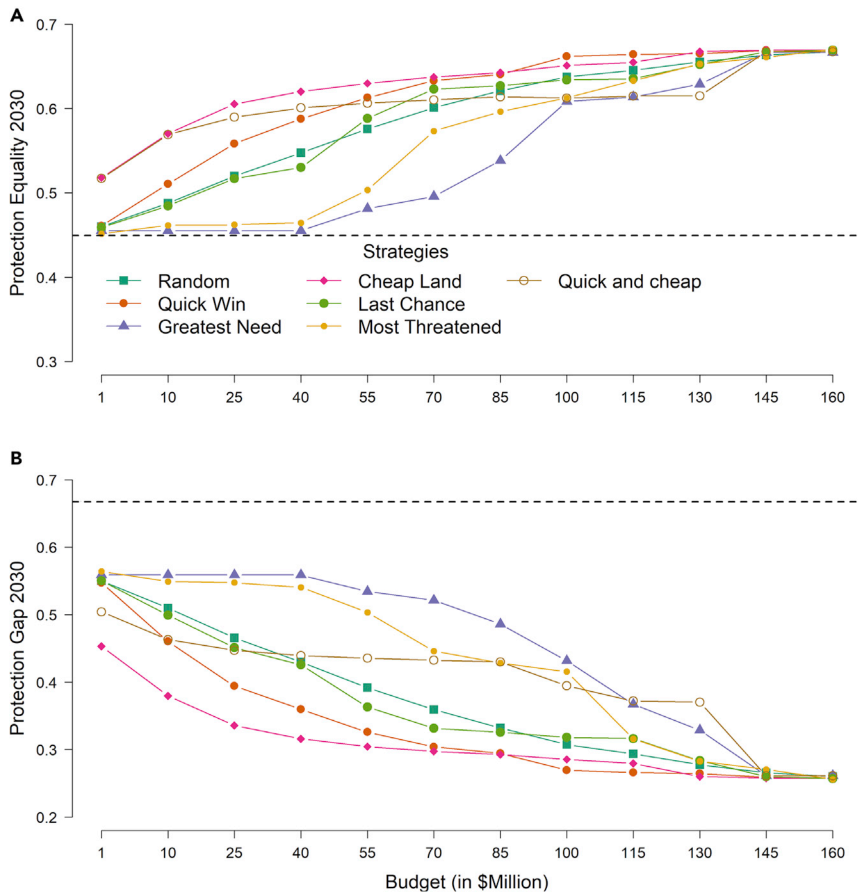

Figure 3. Ecoregion Representation as Measured by Two Metrics in 2030 for Each Protection Budget

Protection equality (A) and protection gap (B) in 2030 for various budgets and for seven strategies: random, quick win, greatest need, cheap land, last chance, most threatened, and quick and cheap (see Table 1 for descriptions). The dotted black line represents the protection equality (top) and protection gap (bottom) calculated in 2009. For improved ecological representation, we expect an increase in protection equality and a decrease in protection gap. Note that the total number of ecoregions is 748.

impossible to tease out which PAs are indeed actually protected and which are only "paper parks." In addition, because of data restrictions for the human footprint (only available to 2009), we chose to use only PA data to 2009 (instead of 2019) and base our comparison with BAU on modeled data rather than partially available data from 2009 onward. This could have introduced additional uncertainty into our predictions. However, the performance of protection models (r^2 ranging between 0.38 and 0.99 with an average of 0.79) and of the resulting BAU strategy in 2016 (85.1% match in ecoregions predicted and observed to be 17% protected) indicated that our model performed well.

Finally, the dataset used for calculating total area protected in each ecoregion and deriving the annual rate of protection does not take into account areas that might have been degazetted between 1993 and 2009 (PA downgrading, downsizing, and degazettement [PADDD]).[21] As a result, the rate of protection used in our analysis could have been inflated for some ecoregions. Because PADDD events are mostly rare and infrequent, we believe that the modeled rates of protection would not have been significantly affected by this omission.

Questions about co-benefits (e.g., species representation or carbon storage) and optimal spatial configuration could be investigated at the implementation stage at a national scale. For example, spatial conservation planning tools, such as Marxan[22] or Zonation,[23] can help identify suitable areas that meet multiple requirements including ecological representation and other biodiversity targets within priority ecoregions.

Conclusion

To achieve the goal of a globally ecologically representative PA estate as outlined in the 2020 CBD Aichi Targets and beyond, a global strategy is needed for the protection of broad ecosystem types. The prioritization presented here implies a "global" top-down approach to planning future protection most relevant to organizations that work across many countries. We acknowledge, however, the difficulty associated with this approach given that conservation funding and decision making are usually at the national scale[24] and ecoregions are often shared between countries and continents.[25,26] However, international policy is a powerful platform from which to guide all levels of decision making, and this analysis shows that signatory nations to the CBD would be more effective in achieving positive biodiversity outcomes by embracing a prioritization schedule. This type of cooperation between nations was core in the Rio Principles,[27] which laid the foundation for the CBD.

The resources required to meet global biodiversity targets are immense, and conservation funding is already inadequate.[28,29] This is perhaps the greatest impediment to implementing the prioritization proposed here. In an ideal world, a common pool of resources would be created by, and be available to, all CBD signatories so they could implement the prioritization schedule by a deadline. Although it might seem unlikely to happen for geopolitical reasons, and there remains the question of who would store and administer such a fund, a similar initiative, the Global Environment Facility (GEF), was created to help support countries meet future environmental challenges on the eve of the establishment of the CBD. The GEF is almost exclusively available to developing countries, acknowledging the mismatch of available resources between richer and poorer countries. Another way to address this resourcing gap could be a grant or loan system among signatory countries. If the objective is to maximize the number of ecoregions meeting the 17% (or 30%) target, countries with ecoregions that are closest to the target already should be expected to allocate their resources to protection immediately. In addition, countries with low conversion rates have a longer time until protection is required and therefore have more time available to raise the required funds.

Our work demonstrates that, with the appropriate political will, smart acquisition strategies and accepting the reality of future conversion rates will always outperform the current BAU strategies. Achieving a 30% ecoregion representation target in each country would be a great achievement for conservation compared with the current state of the PA network. However, this should not be where efforts stop. In conjunction with PAs, we also need to invest in retaining habitats and ecosystem diversity within ecosystems. In addition, the way forward is for the global PA agenda to move beyond achieving representation goals and fit within the wider outcome-based policy agenda:[30] prioritizing actions on the basis of achieving critical biodiversity goals.

EXPERIMENTAL PROCEDURES

Resource Availability

Lead Contact

Further information requests should be directed to and will be fulfilled by the Lead Contact, Alienor Chauvenet (a.chauvenet@griffith.edu.au).

Materials Availability

This study did not generate new unique reagents.

Data and Code Availability

The data and code to run the acquisition strategies are available on the Dryad repository: https://doi.org/10.5061/dryad.cfxpnvx2z.

Data

We based our analysis on the ecological subdivision of the world presented by Dinerstein and colleagues,[25] which contains 847 ecoregions that represent "distinct assemblages of natural communities sharing a majority of species, dynamics, and environmental conditions." From these we removed ecoregions for which there were no cost or human footprint data, leaving 748 ecoregions for this analysis. Following the rationale of Aichi Target 11, we simulated scenarios of PA expansion to ensure that each ecoregion was represented in the world's reserve network at a certain target level. We set the target to 17% up to 2020 to reflect the current requirements and then increased it to 30% between 2021 and 2030 to reflect an aspirational renegotiated target for the next Strategic Plan for Biodiversity.

We calculated the past and current protection of each ecoregion from the World Database on Protected Areas (WDPA, accessed December 2016)[12] and the rates of habitat conversion from the Human Footprint (HFP) dataset for 1993 and 2009.[14] The WDPA dataset was filtered down to include only terrestrial PAs and exclude PAs with a status recorded as "proposed."[31] Some PAs were missing an establishment year (in the "status_yr" column). For each of those (ca. 9.4% of all PAs), we assigned an establishment year by randomly sampling a value on a uniform distribution bounded by the first and last establishment dates of PAs in each country.[32]

Annual Rates of Conversion and Protection of Each Ecoregion

We calculated the annual rate of conversion and protection of each terrestrial ecoregion between 1993 and 2009. We divided the world's terrestrial surface into a 1-km raster grid and assigned cells to one of three categories: protected, converted, or available. Cells overlapping PAs were considered "protected" even if their HFP value was ≥ 4 (Jones and colleagues[10] found up to one-third of the global PA estate under some kind of conversion) because these cells still contribute, in theory at least, to stopping threats. Cells not overlapping PAs and characterized by HFP values $\geq$ 4 (on a 0–50 scale) were considered "converted,"[20,33] and all other cells were "available." For each ecoregion *i*, we counted the total number of "converted" cells in 1993 (C_{i93}) and 2009 (C_{i09}).

We posited that the amount of area of ecoregions lost (L) is a function of the total area available (A) and a rate of conversion (d) such that

$$L = d \times A \qquad \text{(Equation 1)}$$

It follows from Equation 1 that d = L/A.

We thus calculated the rate of conversion for each ecoregion *i* as

$$d_{i93\text{-}09} = L_{i93\text{-}09} / A_{i93}, \qquad \text{(Equation 2)}$$

where $L_{i93\text{-}09}$ is the difference between the number of cells converted in 2009 and 1993 in each ecoregion *i*, and A_{i93} is the total number of cells available (i.e., not "converted" or "protected") in 1993 in ecoregion *i*.

For comparison, we also assumed a linear rate of conversion of ecoregions, where d_i is independent of area available, such that

$$d_i = L_{i93\text{-}09}/(2009\text{–}1993). \qquad \text{(Equation 3)}$$

For the annual rate of protection (i.e., acquisition) of each ecoregion, we calculated the percentage of protected land each year between 1993 and 2009 and fit different models of acquisition to the data over time by using linear regression. We tested different forms of acquisition: constant (intercept only), linear, logarithmic, and second-degree polynomial; we then compared models by using the corrected Akaike information criterion (AICc).[34] For each ecoregion, we recorded the best-fitting model according to the AICc and its parameters (slope *b* and intercept *a*).

Predicting the Amount of Protected and Converted Land between 2009 and 2030 (BAU)

We predicted the amount of ecoregion *i* that is converted (C_{it+1}) between 2009 and 2030 under a nonlinear conversion rate by using Equation 1 such that

$$C_{it+1} = C_{it} + L_{it} \qquad \text{(Equation 4)}$$

with

$$L_{it} = d_i \times A_{it}. \qquad \text{(Equation 5)}$$

For the linear conversion rate, $L_{it} = d_i$.

We predicted the amount of ecoregion *i* that is protected (P_{it+1}) between 2009 and 2030 by using the best model according to the AICc such that

$$P_{it+1} = a + b \times f(t),$$

where f(t) represents the acquisition form (constant, linear, logarithmic, exponential, power of 2, or power of 3).

It is worth noting that the annual changes in converted and protected land could be either positive or negative. Moreover, these projections were constrained by the fact that the percentage of protected, converted, and available land in ecoregion *i* at all times *t* should sum to 100. This ensured that the amount of protected and converted land never surpassed the amount of total available land in each ecoregion.

Prioritizing Ecoregions for Protection

We tested several land-acquisition strategies for the protection of ecoregions, which represent plausible simple real-life policies (Table 1). All land-acquisition strategies used single-step myopic algorithms: at a given time step, all the area required to reach the target in the ecoregions selected for protection was protected (and thus became unavailable for protection or conversion at the next time steps). We tested a range of annual budgets from \$1 million to \$160 million. To decide whether a selected ecoregion was to be protected, we calculated the area needed for it to reach the set target and multiplied that by the average cost of 1 km^2 in this ecoregion (estimated as potential revenue in US dollars per year per hectare for the most profitable crop[16]). The ultimate aim of all strategies was to achieve 30% protection targets within as many ecoregions as possible each year by 2030.

We developed seven PA strategies to compare to the BAU strategy. For each simulation, at each time step, we took into account how much of each ecoregion was being converted, which affected the land available for protection in the next time step.

(1) In the "random" strategy, we randomly ordered ecoregions for acquisition and protected them at the target level (either 17% or 30%) until we ran out of budget each year; because of its stochasticity, we repeated the process 100 times and calculated the average number of ecoregions protected to 30% by 2030.
(2) In the "quick win" strategy, we calculated the amount of area remaining to protect for each ecoregion to reach the desired target (17% or 30%) each year and ranked ecoregions in increasing order according to that

number; each year, ecoregions were sequentially protected to the target until we ran out of budget.

(3) In the "greatest need" strategy, we ranked ecoregions by the amount remaining to be protected to reach the desired target in decreasing order, thus prioritizing ecoregions that have been neglected the most, and we acquired them sequentially until we ran out of budget.
(4) In the "cheap land" strategy, we calculated the cost of protecting ecoregions to the target level by multiplying the average cost per available cell by the number of cells needed to achieve target protection. Ecoregions were ranked in increasing order according to that cost; ecoregions were sequentially protected in the ranking order until we ran out of budget.
(5) For the "last chance" strategy, we ranked ecoregions according to the amount of land left before we reached >83% or 70%, and we acquired them sequentially until we ran out of budget.
(6) For the "most threatened" strategy, ecoregions were ranked by rate of conversion from largest to smallest, and ecoregions were acquired sequentially until we ran out of budget.
(7) Finally, for the "quick and cheap" strategy, we calculated the number of cells needed to reach the target and multiplied it by the cost to acquire those cells; ecoregions were then ranked according to this cost (from smallest to largest) and acquired sequentially until we ran out of budget.

Measuring Success

To determine how successful the BAU and acquisition strategies were, we calculated the number of ecoregions that reached 30% protection in 2030. We also looked at the accumulation rate of ecoregions adequately protected over time to discern whether the best strategy changed depending on the time frame. Finally, we calculated two ecological representation metrics, the protection equality[18] and the protection gap,[19] to assess the results of the seven strategies under the current average budget size. Both metrics provide assessments of how representative a reserve network is with values ranging from 0 to 1. Protection equality does not assume a protection target but looks at the uniformity of protection of all ecoregions, giving a higher score if all ecoregions are protected equally. The protection gap does take into account the 17% protection target and looks at how many ecoregions have not yet reached it (i.e., the gap), giving a lower score if the gap is small. Therefore, a more representative PA system achieves a higher protection equality score but a lower protection gap score.

SUPPLEMENTAL INFORMATION

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Conceptualization, A.L.M.C., J.E.M.W., V.M.A., K.J.D., B.M., C.J.K., and H.P.P.; Methodology, A.L.M.C., J.E.M.W., V.M.A., M.D.M., O.V., K.J.D., B.M., C.D.K., and H.P.P.; Software, A.L.M.C.; Visualization, A.L.M.C.; Data Curation, A.L.M.C.; Writing – Original Draft, A.L.M.C., J.E.M.W., V.M.A., K.J.D., and H.P.P.; Writing – Review & Editing, A.L.M.C., J.E.M.W., V.M.A., M.D.M., O.V., K.J.D., B.M., C.J.K., C.D.K., and H.P.P.; Funding Acquisition, H.P.P. and C.J.K.; Supervision, A.L.M.C., H.P.P., and J.E.M.W.

DECLARATION OF INTERESTS

The authors declare no competing interests.

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