Integrating economic costs into conservation planning

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Recent studies that incorporate the spatial distributions of biological benefits and economic costs in conservation planning have shown that limited budgets can achieve substantially larger biological gains than when planning ignores costs. Despite concern from donors about the effectiveness of conservation interventions, these increases in efficiency from incorporating costs into planning have not yet been widely recognized. Here, we focus on what these costs are, why they are important to consider, how they can be quantified and the benefits of their inclusion in priority setting. The most recent work in the field has examined the degree to which dynamics and threat affect the outcomes of conservation planning. We assess how costs fit into this new framework and consider prospects for integrating them into conservation planning.

Systematic conservation planning and economic costs

In trying to stem biodiversity losses, ecologists and conservation biologists have focused on how conservation plans affect biological targets. The focus of most articles on conservation planning is on the biological benefits of the plans. However, conservation plans cannot be implemented for free. By ignoring the cost side of conservation planning, ecologists and conservation biologists are missing great opportunities to achieve more efficiently conservation objectives in a world of limited conservation resources.

Systematic conservation planning [1] attempts to solve a cost-effectiveness problem: how to achieve a given conservation target (e.g. represent at least 10% of every species range) at least cost; that is, how to achieve the most conservation given limited resources. Although much attention has been devoted to the biological aspects of this problem (e.g. [2–5]), most conservation planning incorporates economic costs simplistically, using only aggregate measures, such as total area or total number of planning units, as constraints [6,7]. This biology-focused approach implicitly assumes that all areas are equally costly, which is incorrect; just as biodiversity is not distributed evenly over landscapes and regions, the spatial variability of costs can be enormous [8–10] and should be explicitly considered in planning [11,12].

A few studies have considered how the inclusion of spatially explicit information about economic costs can affect the outcomes of conservation planning [8,10,13–18]. These studies yield a consistent message: we can conserve biological targets at a fraction of the cost (or achieve higher targets for the same cost) if the spatial heterogeneity of conservation costs is formally considered at the outset of the planning process. In fact, data and anecdotal experience suggest that incorporating the spatial heterogeneity of costs into planning is just as or even more important than incorporating the spatial heterogeneity of environmental benefits [8,14].

Here, we review the costs associated with conservation, the conditions under which including them in conservation planning is important, how they can be estimated or modeled in a spatially explicit manner, and empirical examples of how plans differ when costs are formally considered. We also illustrate how costs can fit into a dynamic framework for conservation planning, and end by discussing impediments and ways forward to including conservation costs in planning. We do not review studies that estimate economic costs of conservation in an aspatial way [19,20], because conservation planning is inherently a spatial process. Our review necessarily focuses on the published literature, which might underestimate the use of costs in conservation planning because many plans are not published in peer-reviewed journals (Hugh Possingham, pers.commun.).

A review of the costs of conservation and their relevance to planning is timely for two reasons. First, although publications in this area are increasing, they appear in diverse journals in ecology, conservation biology and economics. To our knowledge, no review accessible to ecologists or conservation biologists exists (although some of this material has been reviewed for economists; e.g. [21]). Second, donors are increasingly concerned about the effectiveness of the conservation interventions that they fund [22], and consideration of costs can substantially increase the efficiency of their investments.

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What are conservation costs?

All conservation interventions have associated costs, which cover everything that must be given up to implement the intervention. Costs can include acquisition costs, management costs, or transaction costs (Box 1). A high cost of one type might not necessarily mean other cost types are high. For example, a parcel of forest close to a road might have low management costs, because it is easily accessible, but high acquisition costs, because its proximity to infrastructure means it is potentially valuable for other economic uses.

Most intervention costs must be paid by a conservation organization, as when land is purchased. In some cases, however, conservation actions do not carry financial burdens, at least not directly to the conservation organization. For example, government regulations might prohibit conversion of natural habitat (e.g. wetlands or forests), which might accomplish conservation objectives and require no payments. Such regulatory actions, although they do not require direct payments, might impose 'opportunity costs' on society because of foregone opportunities to use the land in economically valuable ways, such as agriculture or forestry.

The economic costs of conservation can be used in several ways in conservation planning. In a cost–benefit analysis [23], the costs and the benefits of conservation are estimated (in monetary terms) across a landscape or region for individual land parcels or units. This enables a direct comparison between costs and benefits, with the net benefits (benefits–costs) used to guide decisions on where conservation versus development should proceed.

However, given the difficulties in quantifying the economic benefits of conservation in monetary terms (particularly less tangible benefits, such as the existence value of biodiversity), most applications involving conservation planning and costs are based on cost-effectiveness analyses [23]. Such analyses express the costs of conservation in monetary terms, but the benefits remain in the original units (e.g. numbers of species or area of forest). The most efficient plan is the one that delivers a given conservation target for the least cost or, alternatively, maximizes the conservation target level for a given cost [10].

Non-monetary proxies

Another approach to including costs in conservation planning is to use non-monetary proxies. These can be easier and more intuitive for biologists to understand and develop than economic costs expressed in dollar terms, but they have some significant disadvantages. The simplest proxy for cost is total area, but as mentioned earlier, using area or the number of planning units as a measure of cost incorrectly assumes that costs are homogeneous across space. Another method involves developing a weighted combination of disparate factors such as distance to roads and human population density [24,25]. The weights, however, are often arbitrary and difficult to justify. Monetized costs, where weights are prices grounded in economic theory and data, should therefore be used whenever feasible.

Other non-monetary cost methods include distance function approaches [26], which enable planners to work with multi-input, multi-output interventions without the need to specify weights, and using vulnerability or threat to remaining habitat as a correlate of cost [27]. For example, the edge of a growing metropolitan area will have high land prices, which are directly tied to the high probability of using the land to build housing or other urban developments. As well as being a proxy for cost, vulnerability or threat measures also have direct relevance for conservation, indicating areas that might be lost if conservation is not undertaken. In a dynamic analysis, such threats should be incorporated along with, rather than as a substitute for, cost.

Box 1. Different types of conservation cost

Acquisition costs

Acquisition costs are costs of acquiring property rights to a parcel of land. Acquisition of property rights can be total (i.e. the land and title are sold to a conservation agent) or partial. Partial transfers of property rights include short-term land rental, conservation easements [53], and contracts between conservation agents and landowners that exchange money for land management that enhances conservation value [62].

Management costs

Management costs are those associated with management of a conservation program, such as those associated with establishing and maintaining a network of protected areas. Management costs can be fixed, and therefore independent of the amount of conservation activities pursued (e.g. regardless of how much land is protected in an area, an office will need to be opened and a minimal amount of staff hired); or variable, and therefore proportional to the amount and type of conservation intervention.

Transaction costs

Transaction costs are those associated with negotiating an economic exchange. In a terrestrial conservation context, the costs over and above the price of a transfer of property rights to a given parcel of land. These include the costs of searching for properties, negotiating with individual landholders and obtaining approval for title transfer. Transaction costs can be substantial; for example, carbon sequestration projects involving afforestation or reforestation can be beneficial for conservation, but high transaction costs often limit their viability [64,65].

Damage costs

Damage costs are those associated with damages to economic activities arising from conservation programs; for example, damages to crops and livestock from wild animals living in protected areas adjacent to human settlements can result in significant losses in income. In other cases, direct wildlife attacks might physically harm or kill humans, resulting in further economic losses [66].

Opportunity costs

Opportunity costs are costs of foregone opportunities; that is, they are a measure of what could have been gained via the next-best use of a resource had it not been put to the current use. In terrestrial protected areas where extractive uses are forbidden, the opportunity cost represents the highest-value extractive use for that land. When purchasing land or conservation easements from private land owners, payments will reflect the value of lost opportunities. With public land or with regulation, direct financial obligations might be divorced from the value of lost opportunities. From a social perspective, it is important to include opportunity costs to track the full set of consequences of conservation planning.

Efficiency gains from including conservation costs in planning

The gains in efficiency from including the spatial distribution of costs in planning have been demonstrated in a variety of contexts. One of the best-known examples involves endangered species in the USA. After a team of ecologists had shown that endangered species are clustered geographically and suggested conservation priorities based on this result [6], a team of economists pointed out that the acquisition costs of conservation also vary across space and that by including both costs and biodiversity in reserve design algorithms, biological targets could be achieved at 25–50% of the costs of plans that only considered the spatial heterogeneity of biodiversity [10].

Priority setting across nations, using protected area management costs and mammal species richness and endemism as conservation targets, revealed that strategies that incorporate the spatial distributions of costs and species can conserve roughly one–two times more species for the same expenditure as strategies that only consider species [15]. Continental-scale priority setting in Africa has also shown that including the variation in management costs in conservation planning results in conservation plans that conserve as much as 66% more vertebrate species compared with planning approaches that ignore costs [16].

At smaller scales, plans that include costs and species information are also more cost effective than are plans that ignore costs. A study in Oregon found that the costs of conserving species were just 10% of the costs of plans that ignored the spatial heterogeneity of opportunity costs of conservation [14]. In New York State, including both the benefits (reduction in pollutants and sediments to a watershed) and the costs (acquisition costs of land parcels) in conservation planning resulted in expenditures that were 16–67% of the total costs of plans that considered benefits only [8,28] (Figure 1).

Several studies have examined the use of costs in marine conservation planning. A study off the Welsh coast showed that the use of fine-resolution data on opportunity costs of marine reserve establishment (i.e. foregone net revenues from fisheries) resulted in much less costly reserve networks compared with approaches that used coarse-scale economic data, or that used area as a cost surrogate [17]. In South Australia, a planning approach that minimized a combination of the foregone value of lobster catch and spatial area reduced total reserve network costs by more than a third compared with approaches that ignored costs or that used only area as a cost constraint [13].

These studies show increased but variable levels of efficiency gains when costs are included in conservation planning as opposed to ignored. Under what conditions will the inclusion of costs improve the cost effectiveness of conservation planning? The importance of including costs depends on the spatial correlation between biological benefits and costs and, more importantly, the relative variability of costs compared with the variability of the biological targets (Box 2).

Tradeoff analysis: conservation targets and costs

Beyond showing efficiency gains, incorporating costs into conservation planning can be used to demonstrate

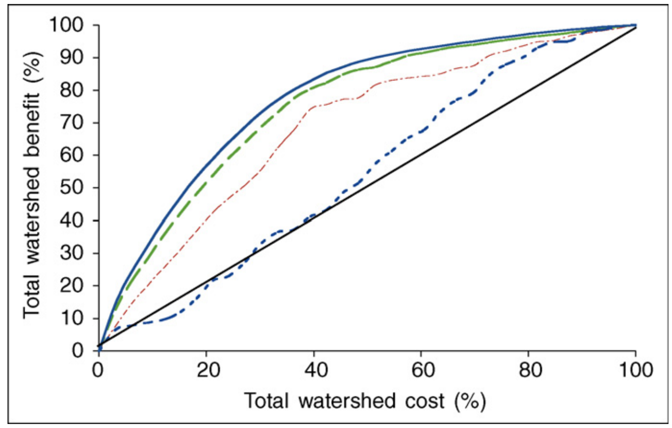

Figure 1. Accumulation of environmental benefits as the costs of conservation increase for various conservation planning approaches in the upper watershed of Lake Skaneateles, New York State [8]. The planning approach that integrates benefits and costs (blue solid line) is the most efficient at accumulating benefits. An approach that ignores benefits and focuses only on costs (green dashed line) performs better than an approach that targets only benefits and ignores costs (bluedotted line); the former is 92% as efficient as the optimal approach, the latter only 16% efficient. An approach that substitutes area for cost (red dot-dash line) also performs reasonably well, capturing 67% of the benefits that the benefit–cost approach does. The straight black line is the expectation for random selection. Reproduced, with permission, from [8].

the tradeoffs between obtaining higher levels of a conservation target and the increase in cost necessary to obtain it. A typical pattern shows that it is relatively inexpensive to achieve moderate levels of conservation but often quite expensive to achieve maximal levels [10,14,29,30]. For example, one study found that achieving ~75% of conservation objectives was possible while reducing economic returns by only 7%. Achieving the remaining 25% of the conservation objective, however, would reduce economic returns by ~70% [31].

Several papers have estimated the tradeoffs between the value of timber production, or timber and agricultural production, and species conservation objectives [29,31–34]. These studies show that increased flexibility in conservation strategies (e.g. conservation easements that allow some human uses while restricting those incompatible with conservation objectives) tends to reduce cost, especially at low–moderate levels of protection, thereby reducing the apparent tradeoffs between conservation objectives and economic activities [35].

How to estimate conservation costs

Several methods to estimate the spatial distribution of the costs of conservation have been developed. These vary with the type and geographical context of the cost being considered.

Acquisition costs

Acquisition costs are the costs of buying or otherwise placing land under protected status. In many developed countries, such acquisition costs can be directly estimated by land prices or assessed land values [10,14]. For example, the USA has a national database on agricultural land values at the county level. Assuming that protected private land would otherwise be used for agriculture, these land values are estimates of the acquisition costs of conservation. Similar databases exist for agricultural land values in Europe and have been used to assess the cost effectiveness

Box 2. When are conservation costs important for planning?

When costs, *C*, are ignored in conservation planning, priorities are determined only by the spatial distribution of benefits, *B*. Within a cost-effectiveness framework, however, it is the B:C ratio that determines conservation priority. The importance of including costs in conservation planning therefore depends on how different the spatial distributions of *B* and *B*:*C* are. This is a function of two characteristics: the spatial correlation of costs and benefits, and the relative variability of costs as compared to benefits [8].

If costs and benefits are negatively correlated in space (Figure Ia), then when *B* is large, *B*:*C* is also large (Figure Ib); therefore, including costs will have little effect on priorities determined by benefits alone. However, if costs and benefits are positively correlated (Figure Ic), when *B* is large, *B*:*C* is not necessarily large and might even be small (Figure Id), and so including costs in planning can change conservation priorities.

If costs are more variable than benefits, then the distribution of *B*:*C* will be primarily driven by *C*, and therefore focusing on *B* alone will lead to the inefficient use of conservation funds. In fact, when costs are much more variable than benefits, ignoring the biology and targeting costs alone would be better than ignoring costs and targeting biology alone (although incorporating both is of course best). For example, in an empirical analysis of a riparian buffer acquisition program [8], 92% of the benefits obtained by integrating costs and benefits into planning could be achieved by targeting costs alone, whereas only 16% could be achieved by targeting biophysical characteristics alone.

What do the empirical data imply about the spatial correlation and heterogeneity among biological and economic variables? At large scales, the spatial distributions of humans and biodiversity are positively correlated; where there are more people, there are more species [67–69]. Because land prices are usually correlated with human population density [70,71], we might reasonably expect that opportunity costs of conservation and biodiversity are also positively correlated, and the few studies published to date have found this correlation [8,16]. Although studies that have looked at the relative variabilities of conservation costs and benefits are sparse, land values at a site in New York were more variable than were scores for water conservation [8]. More generally, whereas conservation costs typically vary over two–four orders of magnitude, species richness or endemism scores rarely vary by more than one [9,10,16,42,43].

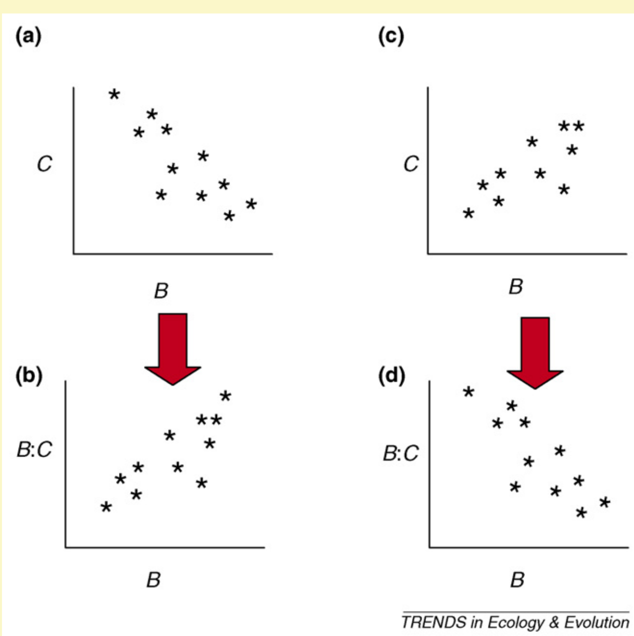

Figure I.

of reserve designs in Denmark [36]. For public lands in the USA, no such measures of market values exist. Applications that have incorporated acquisition costs of public land in conservation-planning exercises have estimated the net benefits from activities that occur on these lands (e.g. livestock and timber production) by considering market prices of commodities and the input costs of production [14].

Comprehensive databases on land prices usually do not exist in developing countries and, even in developed countries, these might not exist at appropriate scales for conservation planning. In such situations, modeling approaches have been used to develop cost maps for conservation planning applications. These are based within econometric frameworks such as land price modeling using farm characteristics [37] or net present value and/or asset value modeling of agricultural land values [38].

For example, to estimate acquisition costs in the Atlantic rainforest of Brazil, land prices were regressed on land characteristics such as soil type, climate, current land cover and proximity to roads [39]. The regression coefficients and GIS coverage of the relevant variables were used to create a predicted land price layer for the entire study region. This estimated acquisition cost layer was used to evaluate alternative conservation scenarios from top-down (optimal command-and-control designs) and bottom-up (voluntary participation) perspectives [40,41]. Similar approaches have been used in South Africa (P. Osano, MSc Thesis, University of Cape Town, 2005) and Australia [42] to map costs. In eastern Paraguay, land values were modeled by calculating the expected net economic benefits from various land-use systems and integrating these with spatially explicit conversion probabilities; the estimated land values were strongly correlated with observed land prices [43] (Figure 2).

In all four of these cases, the per-unit area costs of conservation were highly spatially heterogeneous, varying over two (Brazil and Australia), three (Paraguay), or four (South Africa) orders of magnitude. These approaches demonstrate that, even in the absence of comprehensive cost databases, one can still model the spatial distribution of acquisition costs in monetary terms for use in conservation planning.

Management costs

A significant part of the literature on conservation costs comprises studies that model the management costs of field-based conservation at different scales. At the global level, the per unit area management costs of terrestrial protected areas vary over seven orders of magnitude. These costs are positively correlated with the economic output and purchasing power of a country as well as with local human population density, and are negatively correlated with the geographical size of the protected area [9]. Similar results for marine protected areas have also been demonstrated [44]. These empirical relationships have been used to estimate the total management costs for several large-scale conservation strategies [16,45].

In South Africa, the management costs of protected areas have been estimated for the Cape Floristic Region [46]. This approach also involved the modeling of protected area management cost from park attributes such as size

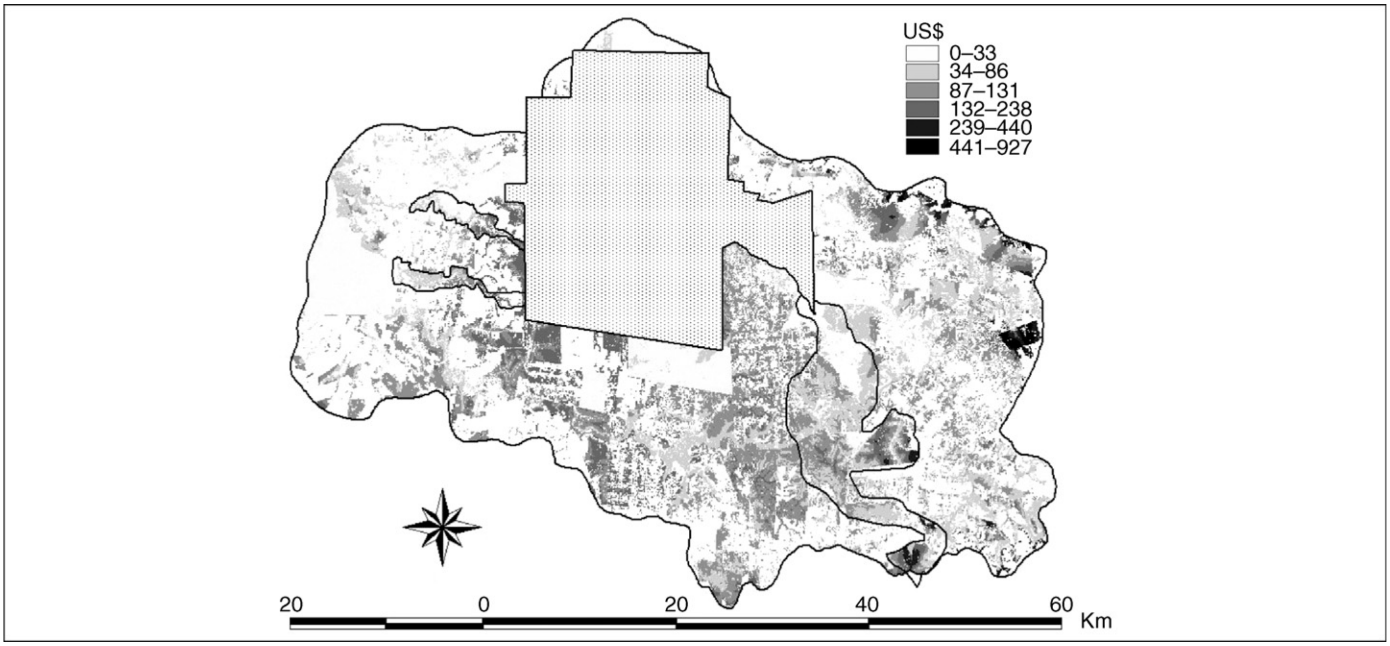

Figure 2. Opportunity costs of conservation (net present value, expressed as US\$ ha^{-1}), mapped at 1-ha resolution, for the Mbaracayu Forest Biosphere Reserve in eastern Paraguay [43]. Opportunity costs of land in the reserve varies from 0 to 927 U\$ ha^{-1}, with a mean of 60 US\$ ha^{-1}. Central stippled area is a core protected area; proposed corridors are outlined in black. Reproduced, with permission, from [43].

and habitat type. Per-area costs were again heterogeneous, varying over two orders of magnitude.

Costs and dynamics in conservation planning

The most recent advances in the conservation planning literature suggest that conservation priorities should be selected based on an approach that integrates benefits, costs and threat [12,47–51]. In a dynamic framework, there is a sequence of conservation investment decisions through time that better reflects a real-world decision-making process (theories addressing acquisition and uncertainty have a long history in economics). Conservation opportunities do not all occur simultaneously; neither can conservation organizations take on all challenges at once. A dynamic approach can address how to prioritize the sequence of conservation investments for targets facing different levels of threats. Results from these studies indicate that the timing of investment decisions can have significant impacts on the ultimate conservation portfolio and that, in some cases, heuristics can approximate optimal solutions derived from stochastic dynamic programming techniques [47].

In most of these studies, both costs and benefits were fixed in time; the dynamic aspect was based on changing levels of threat, expressed as differing annual probabilities of conversion of biological targets. This framework could be usefully extended to include dynamics in conservation costs, because costs can change quickly over timescales that are relevant to conservation planning. In fact, conservation interventions themselves can result in changes to future costs and threats. Setting aside land for conservation can increase the price of remaining lands, as well as the probability of habitat conversion in adjacent areas [52,53]. Depending on the geographical distribution of biodiversity, conservation land purchases that are not well targeted might even reduce overall biodiversity levels. These land market feedbacks have not yet been incorporated into a conservation planning process, but provide an additional (and sobering) reminder that it is important to consider dynamics of conservation costs.

Economic costs of conservation: prospects

If costs are so important to conservation planning, why have so few studies in the literature examined them? There are several reasons [54]. First, the field of systematic conservation planning was developed by biologists, and most biologists have neither been trained to consider economic concepts such as cost effectiveness nor to collect relevant economic data. Furthermore, spatially explicit economic information that would be appropriate for use in conservation planning is often not readily available. Fortunately, spatial economics is a newly developing area of research (witness the launch of the journal *Spatial Economics* in 2006) and, although studies incorporating costs in planning are relatively few, they are increasing. A growing importance and emphasis on the integration of economics and biology in the conservation sciences [55–58] means that economic ideas and techniques will become increasingly instilled in conservation planning methodologies.

Second, prescriptive conservation plans, which comprise the bulk of the papers in the field, might be optimal in theory but difficult or impossible to implement [59]. Indeed, the lack of implementation of most conservation plans suggests conservation planners have historically not been overly concerned with practical factors that will influence implementation, such as the costs of plans. Confronting the 'implementation crisis' of systematic conservation planning [60] means transcending the academic assessment phase of planning and moving towards models for implementing plans [60,61]. Although the implementation of conservation plans is a complex political and social process, one possible way forward is discussed in several recent papers that show how voluntary participation schemes that elicit landowners' conservation costs via auction mechanisms can lead to efficient conservation outcomes. Resulting plans can meet biological goals while encouraging the participation of landowners whose land will ultimately be enrolled in a conservation program [41,62,63].

Finally, ecologists might be reluctant to let factors other than biology dictate their conservation priorities. Nevertheless, as soon as priority setting leaves the ivory tower, a host of real-world concerns, including the costs of conservation actions, must be considered. We have indicated here that it is better to recognize and incorporate costs at the outset of the planning process, rather than belatedly incur the (higher) costs of a less efficient plan. If results continue to suggest that conservation costs are more variable than the biodiversity and environmental service benefits that conservation funds seek to obtain, they imply a need for a radical shift in conservation research. Balancing research on biodiversity features (i.e. the benefits side) with a greatly strengthened understanding of economic (and indeed other) aspects of the costs side will lead to novel and creative ways to obtain environmental benefits in the most efficient manner possible.

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