Biodiversity conservation planning for sustainability: linking local, regional and global conservation efforts

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Abstract

Limited resources and competing demands of society mean trade-offs are required in biodiversity planning. Areas selected for biodiversity protection should have a high enough "complementarity" value (marginal gain in biodiversity protection) to compensate for any corresponding opportunity cost of conservation. This promotes "regional sustainability" – the degree to which the region has achieved its capacity for finding a balance among competing needs of society. Trade-offs may be achieved more effectively when production lands are credited in the allocation process to at least partial protection of biodiversity, using probabilistic strategies for expressing local biodiversity persistence. Trade-offs scenarios help in understanding the implications of change – for example, whether a land use allocation implies that the best trade-offs curve for the region is now much worse. In recent scenarios analysis for Papua New Guinea (PNG), achieving a biodiversity protection target with minimum opportunity cost was important, given that biodiversity values overlap with forestry production values, and high forgone forestry opportunities mean significant losses to land owners and the government. The PNG study demonstrates that biodiversity complementarity is not just about selecting a set of priority protected areas, but about a new "biodiversity economics" relating to offsets, levies, subsidies, and incentives. Ongoing scenarios development in PNG concerns biodiversity targets, land use constraints, timber plans, population issues, and the scope for applying new economic instruments. Similar trade-offs scenarios are relevant to two new international initiatives, the Millennium Assessment and the Critical Ecosystems or "hotspots" program. In these contexts, trade-offs can provide a natural linkage between local, regional and global planning levels.
1 Introduction

In preparing this paper, we noted the primary aim of ECOSUD 2001 as encouraging interdisciplinary approaches to studies of ecological systems and sustainable development, particularly in developing countries. The research that we report here has broad interdisciplinary links, and easily could be discussed in several of the conference’s theme areas, including Development Economics, Conservation, and Modelling of Natural and Human Ecosystems. The reason is simple; any attempts to link biodiversity planning to sustainability means that information that is often thought to be the preserve of other disciplines must be integrated into such biodiversity studies.

That necessity has been apparent in our exploration of such approaches in developing countries, including Papua New Guinea, Brazil, and Indonesia. Evaluating sustainability at such a regional scale requires some assessment of the degree to which conservation and socio-economic criteria are integrated so as to provide high present and future net benefits to society. This kind of assessment cannot be achieved simply by using the usual indices based on the individual criteria, because such indices may not capture the potential trade-offs among the criteria. Reflecting this requirement, Faith [1] has defined “regional sustainability” as the degree to which a given region’s particular capacity for trade-offs has been (or is potentially) realized. That term partly overlaps with, and partly contrasts with, the various definitions of “sustainable development” that have appeared since that term was popularized in the World Conservation Strategy [2] (“WCS”) and later in the “Brundtland report” [3]. The WCS argued for the integration of conservation and development, promoting the idea that “conservation and sustainable development are mutually dependent”. The World Commission on Environment and Development [3] defined sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. In Caring for the Earth [4], the successor to the WCS, the definition of sustainable development was restated as “improving the quality of human life while living within the carrying capacity of supporting ecosystems”. Within the discipline of ecological economics, sustainable development has been linked to constraints on the conventional mechanisms for assessing economic development, as in Pearce and Turner’s [5] assertion that: “it involves maximising the net benefits of economic development, subject to maintaining the services and quality of natural resources over time”.

A notion of regional sustainability based on finding a balance among society’s needs requires that trade-offs be recognized in making decisions about land management and land-use allocation – for example, determining which areas in a region are priorities for protection of their components of biodiversity. Those tradeoffs must reflect the realities of limited resources and the competing demands of society, and may rely on cost-benefit analysis, or multi-criteria analyses that escape the need for monetary valuations of biodiversity.

Biodiversity conservation planning presents a special challenge for trade-offs at the regional level. The biodiversity value of a given area needs to be
expressed, not as the area’s total diversity, but rather as a list of the components (e.g. species) of biodiversity that it has that are additional to the components already protected elsewhere. That contribution or “marginal gain” is called the complementarity value of the area (e.g. [6]). Based on complementarity, the criterion of regional biodiversity protection can be incorporated into a trade-offs or multi-criteria framework [1, 7, 8]. Areas selected for biodiversity protection will have a high enough complementarity value to compensate for any corresponding “opportunity costs” of conservation. Of course, that comparison of complementarity and costs depends on the weighting given to the costs. Different weights lead to different optimal land allocations that fall along a trade-offs curve (Fig. 1). Based on such curves, any given level of biodiversity representation/protection may be linked to some allocation providing minimum opportunity costs [1]. Such a trade-offs space also can be used to explore scenarios – for example, whether a fixed allocation of some areas to one land use means that the best trade-offs curve for the region is now much worse (Fig. 1).

Figure 1: A trade-offs space, showing two trade-offs curves, in which greater net benefits are found towards the lower left hand corner. The upper trade-offs curve reflects land-use constraints, such as previous land use outcomes/decisions that restrict the capacity to achieve the degree of balance previously possible. The line segments are examples of equal net-benefits contours for a weighting of 5.0 on opportunity costs. The point of intersection of the trade-offs curve with the lowest possible line segment defines the greatest net benefits solution for that weight. Numbers along the trade-offs curves are the weights that would lead to selecting corresponding points along the trade-offs curve.
Allocation of different areas to different land uses so as to maximize net benefits is only one approach to achieving a balance among society’s needs. The search for net benefits also recognizes cases where two or more values or “services” can be met in the same area. We use the term “partial protection” [9] to refer to any land-use that contributes both to biodiversity protection and to one or more of society’s other needs. For example, partial protection of biodiversity in forestry production areas provides benefits of both kinds, resulting in a trade-offs curve providing greater net benefits. Higher curves (lower net benefits; Fig. 1) in trade-offs space will exist when there are fewer opportunities for such partial protection. Net benefits to society - a better balance between potentially conflicting goals - are best achieved on occasions when it is found that the different land uses are not so much in conflict. Partial protection may be credited to production land uses (e.g. eco-forestry) and taken into account in calculating consequent complementarity values for regional planning [9]. When we take into account those contributions, clearly there is then reduced pressure on other areas to contribute to biodiversity goals, and so there is greater opportunity for other land use opportunities. Further, we can identify those areas where most would be gained through partial protection and apply economic incentives for the nominated land use specifically to those areas [10].

2 Case studies

Our first case study in New South Wales, Australia [7, 11] demonstrated advantages of trading-off biodiversity and other sectoral needs of society at the regional level. While not having any “correct” weighting for various opportunity costs, sensitivity analysis revealed which areas were selected for protection no matter what the weight assigned to costs – and which areas were never selected [7]. That study also highlighted another important aspect of such trade-offs. The optimal solution had low overlap with another that would have achieved the same biodiversity target while ignoring costs, suggesting that consideration of costs cannot simply be an add-on consideration to refine land allocations.

Our more recent trade-offs work [12, 13, 14] identified “priority” areas for biodiversity protection in Papua New Guinea (PNG). This project produced an ongoing evaluation framework for moving towards a country-wide conservation goal, while at the same time providing opportunities to alter the priority area set in light of new knowledge, changes in land use, and/or changes in economic and social conditions. Trade-offs also provided the basis for a new approach to percentage-based conservation targets. This approach takes into account the way that trade-offs curves vary depending upon constraints. First, the maximum diversity that could be protected by an unconstrained 10% (say) of total area was identified as the working biodiversity target (akin to using the lower curve in Fig. 1). Reaching that same biodiversity target in the actual planning exercise then required more than 10% of the area, because of trade-offs integrating constraints (e.g. existing reserves) and opportunity costs (akin to now having to use the upper curve rather than lower curve in Fig. 1). Satisfaction of the “10%-based” target in a low-cost proposed protected set required 16.8% of PNG [13].
proposed land allocation corresponded to relatively high net benefits. Estimated consequent forgone forestry production was only 14.3 percent of PNG's total estimated forestry production potential. That low value would not be achieved using planning methods that ignore costs [13].

The PNG study also demonstrated that complementarity is important not just for selecting a set of priority protected areas, but also for a new 'biodiversity economics' relating to credits, levies, subsidies, incentives and other economic instruments (Fig. 2). An area having high complementarity, in the context

![Figure 2: A proposed protected set of areas for biodiversity protection in PNG satisfies a 10%-based biodiversity representation target, while minimizing conflict with forestry production, agricultural potential, population centres, and high land use intensity areas. For this map, complementarity values for all other areas were then calculated, based on a higher 15%-based biodiversity target which requires protection of more attributes. The calculation of these values assumes a regional 0.999 probability of persistence goal for all biodiversity attributes, with 0.10 "baseline" probability of persistence (in the absence of any land-use change), and assumes a 0.90 probability of persistence for areas (and their attributes) within the proposed protected set. An area will have high complementarity if changing its persistence probability from 0.10 to 0.90 would make a large step towards a 0.999 probability of persistence for all attributes. Low to high complementarity values are indicated by off-white, grey, dark-grey, black. The proposed protected set is also coloured off-white. Such complementarity values may determine degree of carbon or biodiversity credits, attractiveness for eco-forestry programs, or the size of environmental levies to be charged for production use of the area (see also [14, 15]).}
Of current regional land uses may attract investment under a biodiversity or carbon credits scheme, or may be assigned a high environmental levy as a disincentive to non-conservation land uses. Because complementarity values reflect marginal gains in biodiversity, they are always changing with changes in land-use and other factors. Scenario development therefore concerns possible biodiversity targets, land use constraints, timber plans, population issues, scope for levies, or offsets markets or subsidies, and other factors [14].

Regional sustainability was addressed at two interacting levels in the PNG study. First, the planning approach minimized forgone timber opportunities while achieving a nominated biodiversity protection target. Second, the analysis framework addressed the potential for eco-forestry as potentially replacing intensive logging, so that areas producing logging income could contribute to biodiversity protection. The process of biodiversity planning in PNG, however, does not yet fully credit allocations of "partial protection" of biodiversity towards achieving targets. Future trade-offs may be achieved very effectively when production lands are credited in the allocation process to at least partial protection of biodiversity, for example using the probabilistic strategies for expressing biodiversity persistence in a planning framework [1, 9, 13]. Regional sustainability implies a clear link between balanced land use allocations among areas and balanced use within areas. A unified calculus takes both the "regional" and "local" into account in assessing overall regional sustainability—the degree to which the region has achieved its capacity for trading-off society’s needs.

We note that implementation of "partial protection" requires models for estimating the associated probabilities of persistence [14]. Future work will explore how the probability of persistence of the (known and unknown) biodiversity components in an area varies according to models based on factors such as the shape and size of the geographic area. Such a "biodiversity viability analysis" (BVA) [14] extends methods used in population viability analysis (PVA: see e.g., [16]), which only treat viability of "known" components of biodiversity. Faith et al. [14] discuss models that generate "hypothetical" species making up the biodiversity of an area. Based on predictive models linking these species to environmental variables, each hypothetical species forms geographic fragments of predicted species-presence that can then be associated with different probabilities of persistence. For example, Faith and Carter (unpublished data) explore the use of species-area curves, applied to such fragments, to assess persistence probabilities. These form estimates of "partial protection" that can feed into complementarity assessments, as in the PNG study.

3 The Millennium Assessment and Critical Ecosystems Program

The potential role of trade-offs is an important issue in two new international conservation initiatives: the Millennium Assessment [17, 18] (MA; see also http://www.ma-secretariat.org) and the Critical Ecosystems (CE) or “hotspots” program [19, 20, 21] (see also http://www.cepf.net/). In both programs, there is scope for a stronger role for complementarity-based trade-offs, similar to those
of our case studies. The need to move beyond single sector assessments already is established as a central rationale for the MA, which is concerned with trade-offs among "ecosystem services" that include such things as water quality, food production, and conservation of biodiversity option values. However, while trade-offs already form a program rationale, species richness is the primary biodiversity focus, suggesting that biodiversity complementarity can play a greater role. Similarly, the CE has a focus on conserving the key biodiversity hotspot areas of the world, with a prioritization strategy that takes into account the need to minimize opportunity costs. However, while complementarity (as estimated by endemism) of different regions is central to priority setting for conservation, trade-offs within regions could play a strong role. Both the MA and CE so far appear to have no explicit framework that incorporates the sorts of trade-offs used in our case studies, where balance is achieved by balanced allocation among areas and the crediting of partial protection within areas.

3.1 Trade-offs and the Millennium Assessment

The MA is a new international program of ecosystem assessments, organized and supported by UNEP, IUCN, World Bank, WRI, and others [17, 18]. It has the "goal of improving management of ecosystems (at all scales) by providing information to decision-makers about the condition or "health" of ecosystems, consequences of ecosystem change, and options for response" (see http://www.ma-secretariat.org). The web pages for the MA also indicate that trade-offs among services are a key issue: "the challenge of meeting the human needs for ecosystem goods and services is so great that trade-offs have become the rule" and "it remains to be seen whether the capacity of the system to provide the combination of the services is optimized".

One ecosystem service, among the wide range of different services considered, is conservation of biodiversity [22]. However, the process of trading-off services in an market-based economic framework, as favoured by the MA, may lead to neglect of biodiversity and corresponding "option values" – those values reflecting options for the future that are difficult to put in monetary terms. Because the ecosystem services approach primarily looks for economic values, the option values of biodiversity may be ignored as part of such assessments. We see the use of complementarity-based trade-offs in a multi-criteria framework as a way to ensure that the trade-offs of interest in the MA are compatible with the non-economic valuations that are central to biodiversity assessment and planning. Trade-offs spaces such as those used in our case studies therefore might play an important role in the MA. Complementarity values of areas can provide a basis for both quantification of option values for land-use allocation/assessment, and feed into the new complementarity-based economic instruments. As the PNG study illustrates, there can be a mix of "markets" – as in carbon and biodiversity credits schemes – together with "top-down" imposed trade-offs achieving biodiversity targets that are based on quantification of biodiversity option values [14].

Complementarity plays a role in developing biodiversity-related scenarios for PNG; complementarity value changes under different scenarios affected
expectations about carbon offsets, levies and other services. The focus in the MA on exploring scenarios of impacts on services due to human-induced change on ecosystems, similarly will call for the associated assessment of changes in biodiversity complementarity values.

That key role of biodiversity complementarity in trade-offs among services and scenarios development contrasts with the MA’s primary perspective on biodiversity; the MA planning documents (http://www.ma-secretariat.org) describe biodiversity information largely as species-richness or total diversity. On the other hand, Daily’s [22, 23] proposed framework for trading-off ecosystem services, which is linked to the MA, does acknowledge the importance of considering marginal gains: “the evaluation of the tradeoffs currently facing society, however, requires estimating the marginal value of ecosystem services (the value yielded by an additional unit of service, all else held constant) to determine the costs of losing - or benefits of preserving - a given amount or quality of service” [23]. We endorse this perspective as compatible with the role of complementarity in trade-offs, but with one caveat. In our biodiversity trade-offs framework, the quantities potentially being traded-offs are even more general than “ecosystem services”. Often the opportunity costs are not a good or service. For example, in PNG a cost of protection is the “transaction” cost equal to costs of administration.

We conclude that the MA, which has a strong focus already on finding a balance among “ecosystem services” within areas, will benefit from trade-offs among areas (and scenarios development) that consider complementarity.

3.2 Trade-offs and critical ecosystems

The critical ecosystems (CE) program [19, 20, 21] is based in part on Conservation International’s programs identifying 25 global “hotspots” having high estimated levels of endemicity. The CE hotspots approach excludes trading-off biodiversity with opportunity costs as a strategy for prioritizing among regions: “We believe that it is dangerous and misleading to mix threat and biological criteria in the first step of analysis, and even more confusing when social, economic, and even political feasibility criteria are mixed into this first level.” [20]. Nevertheless, this perspective allows for the possibility that the CE program can make use of trade-offs to determine which areas within the region are to be protected for biodiversity conservation. The CE program, in spite of the biology-only criteria quoted above, acknowledges such a consideration: “The three major wilderness areas of the Congo, the Amazon, and New Guinea and associated forests in insular Southeast Asia not only contain a very large fraction of the world’s species….. Their protection has to be a major priority. These areas suffer from a variety of threats that include logging, mining, the extraction of oil and gas, and the conversion to monoculture agriculture, such as soybeans.” [24]. Thus, the CE program appears compatible with trade-offs (such as those applied in the PNG study) within a region, possibly with priority given to regions within which trade-offs are most needed.

Given that PNG is part of the CE priority tropical wilderness areas for conservation, it is interesting that PNG is regarded as having relatively low costs,
as one of the "good news areas" (http://www.conservation.org/hotspots/). Low population density and large areas "intact" are seen as implying low opportunity costs of conservation. However, while PNG has large intact forest areas, it is not yet a "good news" area. In truth, PNG can imply low realized opportunity costs or quite high realized opportunity costs, depending on whether a balance is found through biodiversity planning (and implementation) based on trade-offs [13,14]. Thinking in terms of global priorities, PNG is a good example of a worthy priority region for conservation attention, because potential net benefits for society otherwise may be needlessly foreclosed through poor planning that does not address conflict among various needs of society. The risk of losing those potential net benefits is the strong argument for planning investment in PNG that achieves regional sustainability through regional and local trade-offs. Other CE global priority regions may benefit in the same way. We conclude that, for the CE, as for the MA, a biodiversity trade-offs framework can provide a natural linkage between local, regional and global planning levels.

References


