Biodiversity and Conservation **10**: 353–365, 2001.

Incorporating landscape transformation into local conservation prioritization: a case study in the Western Ghats, India

HARINI NAGENDRA
Centre for Ecological Sciences, Indian Institute of Science, Bangalore – 560012, India (e-mail: harini@ces.iisc.ernet.in; fax: +91-80-3601453); Present address: Center for Study of Institutions, Population, and Environmental Change, Indiana University, 408 N. Indiana Avenue, Bloomington, IN 47408, USA (e-mail: nagendra@indiana.edu; fax: +1-812-855-2634)

Received 14 July 1999; accepted in revised form 12 April 2000

Abstract. In fast-changing tropical landscapes, effective strategies for conservation must incorporate information on ecosystems and species distribution with that on landscape change. A possible methodology for conservation prioritization is developed and illustrated using a 27.5 km^2 tropical landscape in the Western Ghats hill chain of southern India. Vegetation types or ecosystems within the landscape are ranked based on the ecosystem services they might provide: number of endemic species harbored, species richness, contribution to carbon uptake, economic value of produce per ha and contribution to soil renewal. For a vegetation type, the weighted average of these ranks indicates its net conservation value. Weights thus provide a means of ascribing differential importance to an ecosystem service. Information on landscape change is also summarized by a matrix depicting the likelihood of transformations between vegetation types present in the landscape, projected 5 years into the future. For each transformation between two vegetation types, information on ecosystem service and dynamics is then integrated. Implications from the perspective of conservation are assessed as the product of transformation probability and the resultant gain/loss in conservation value. Strongly positive transformations are likely to result in positive impacts on conservation value, and occur without any additional conservation effort. Strongly negative transformations are likely to occur and have a strong negative impact on conservation value. Maximum conservation effort may be directed at halting or reversing these. This study thus describes a method for conservation prioritization, which integrates information on ecosystem function and services with ecosystem dynamics.

Key words: biodiversity, conservation priorities, ecosystem management, ecosystem services, India, landscape change, tropics, Western Ghats

Introduction

An objective method of determining conservation priorities is essential for effective utilization of scarce resources. Although many approaches have been suggested, no single methodology is as yet widely accepted. Previous approaches have been placed into three categories by McNeely (1996) – those concentrating on individual species or populations (such as Ceballos et al. 1998; Diamond et al. 1997), those focusing on ecosystems (such as Goodall and Naude 1998; Wright and Tanimoto 1998) and those that approach the problem from a socio-economic perspective (for example Biodiversity Support Programme 1995, unpublished).

Species-centered or population-centered approaches are essential to save certain highly endangered species, but cannot by definition include all species (Noss 1996). Ecosystem-based approaches to conservation may be preferable in cases where detailed species information is missing, as they can be more efficient at saving a wide variety of species (Franklin 1993). Information on species or ecosystems cannot however be used as surrogates for each other, and ecosystem approaches need to be combined with species-based criteria such as species composition and richness, to develop more complete conservation strategies (Eisner et al. 1995; Daily 1997).

Habitat conservation plans have been intended to provide comprehensive coverage of multiple species within habitats (Noss et al. 1998). However, in practice, they often focus on one species and at the most a few specific areas (Smallwood et al. 1998). Other means of combining habitat and species conservation approaches have also been developed (Ramesh et al. 1997; Yeo et al. 1998). These approaches however tend to focus on ecosystems as harbors for species, and do not consider the range of possible ecosystem services, from emergent ecosystem properties such as carbon sequestration or soil generation, to properties specific to the species they harbor such as medicinal value, or genetic uniqueness (Ayensu et al. 1999).

An approach based only on assessment of ecosystem services does not take into account the dynamics of landscape transformation. Such dynamics are driven largely by socio-economic constraints, and need to be incorporated into conservation strategies for maximum effectiveness (Warren et al. 1997; Ayensu et al. 1999). An effective method of ecosystem evaluation therefore requires the consideration and integration of two separate themes: ecosystem function or service, and ecosystem dynamics or change (Walker and Steffen 1997).

Species-related and ecosystem-related ‘services’ may be combined to effectively evaluate conservation priorities (Ayensu et al. 1999; Daily 1999). However, different axes valuing ecosystem services may result in conflicting or even contradictory assessments of net ecosystem value. It is not easy to visualize how an assessment of properties so widely different as, for instance, carbon sequestration and bio-diversity might be combined to evaluate the net services provided by an ecosystem. Ecological economics provides a possible framework for this purpose (Edwards and Cyrus 1998; Costanza 1999). However, not all ecosystem services can be identified and compared using economic terms.

A framework is thus required for evaluating conservation priorities, that integrates assessment of ecosystem services, with that of ongoing ecosystem transformations. In resource-rich and heterogeneous tropical areas such as cover large parts of India, patterns of ecosystem and landscape change are often locality-specific. Conservation strategies for such regions are best formulated at local scales. Consideration of species-based and ecosystem-based approaches along with an understanding of local landscape dynamics enables the design of more comprehensive strategies for assessing conservation priorities. This paper presents a possible methodology for assessing local conservation priorities, which takes into consideration dynamics of landscape transformation, within an ecosystem services framework. The methodology is illustrated through a case study of a tropical, species-rich landscape in the Western Ghats of India that is undergoing fairly rapid transformation.

Methods

Study site

The case study focuses on a landscape of 5×5.5 km at an altitude of 400–600 m near the town of Siddapur in the Uttara Kannada district of the southern Indian state of Karnataka (14°16′–14°19′ N latitude, 74°52′–74°54′ E longitude). This landscape falls within the Western Ghats hill range of peninsular India, in a region where relatively low-lying hills merge gradually with the Deccan plateau (Daniels et al. 1991). The natural vegetation is characterized as West Coast tropical evergreen forest by Champion and Seth (1968) and as a *Dipterocarpus indicus – Diospyros candolleana–Diospyros oocarpa* wet evergreen forest type by Pascal (1988). As in large parts of Asia, this bio-region is under pressure for conversion to agricultural land (Walker and Steffen 1997).

The study landscape is therefore typical of many species-rich, rapidly transforming regions that today occupy large areas in this part of the world. There have been severe losses in forest cover in the region due to human influences, especially in the last century (Chandran and Gadgil 1993). There is clearly a need for effective conservation strategies to combat these losses.

Extensive modification of the natural vegetation has lead to a series of degradation stages identified as secondary evergreen, secondary moist deciduous, savanna-woodland and grassland by Pascal (1982), along with the creation of essentially single species plantations of *Casuarina equisetifolia* L., *Acacia auriculiformis* Forst., *Areca catechu* L. (areca), *Cocos nucifera* L. (coconut), *Saccharum officinarum* L. (sugarcane) and paddy fields. Initial field visits from 3 to 7 November 1994, enabled the characterization of the 27.5 km^2 landscape as being composed of the following vegetation types (Nagendra and Gadgil 1999):

(1) Secondary evergreen forest: These are fairly open semi-evergreen formations with bushy undergrowth, described as a *Hopea ponga* (Dennst.) Mabb. – *Dimocarpus longan* Lour. – *Mimusops elengi* L. secondary evergreen forest series (Pascal 1988). The most common species include *Aporosa lindleyana* Blume., *Tabernaemontana heyneana* (Wall) Cooke and *Ixora brachiata* Roxb.

(2) Secondary moist deciduous forest: These forests have been derived from the degradation of an initial evergreen forest, either by shifting cultivation during the last century or excessive felling in more recent times (Pascal 1988). Common species include *Terminalia paniculata* (Roxb.) Rath., *Terminalia crenulata* (Roxb.) Rath. and *Xylia xylocarpa* (Roxb.) Taub.

(3) Savanna or tree-savanna: This type most often surrounds forested areas, and may be subjected to regular fire as well as biomass extraction for fuelwood and fodder. Thus, trees are mostly fire-resistant, deciduous species, although a few evergreen species may also be found (Pascal 1988). Common species include *Careya arborea* Roxb., *Syzygium cumini* (L.) Skeels and *Terminalia paniculata*.

(4) Grassland: The grasslands found in this landscape are not natural in origin and are mostly without tree cover. They have arisen through degradation of the natural evergreen forest, initially by clearfelling and later by biomass extraction for fuelwood and grazing. Many grassland patches are now maintained in this condition by regular setting of fires, for the specific purpose of maintaining areas for grazing. Common species include members of Acanthaceae, *Tridax procumbens* L., and *Crotolaria* spp.

The study landscape also contains paddy fields and separate plantations of *Acacia auriculiformis, Casuarina equisetifolia*, *Areca catechu*, *Saccharum officinarum* and *Cocos nucifera* – as the latter three vegetation types occupy only a small fraction of the landscape, they are omitted from further discussion.

This area was mapped using Indian Remote Sensing Satellite (IRS) 1B LISS 2 imagery of 4 March 1993 into the seven major vegetation types present in the landscape– secondary evergreen, secondary moist deciduous, savanna, *Acacia auriculiformis* plantations, *Casuarina equisetifolia* plantations, grassland and paddy fields (hereafter referred to as evergreen, moist deciduous, savanna, *Acacia*, *Casuarina*, grassland and paddy respectively) (Nagendra and Gadgil 1999).

Sampling and data analysis

Utilizing the vegetation map, during the months of January and February 1995, a total of 246 10×10 m^2 quadrats were distributed across the landscape such that they covered all major patches of all vegetation types, sampling patch edges as well as interior. Although the satellite imagery-based landscape map was used to position quadrats, these were finally assigned to vegetation types based on visual observation of physiognomy and commonly found angiosperm species. A total of 37 quadrats were placed within paddy, 46 in grasslands, 43 in *Acacia*, 27 in *Casuarina*, 36 in savanna, 22 in moist deciduous and 35 in evergreen.

Within a quadrat all trees (plants $>$10 cm in girth at breast height) were identified to the species level. Each quadrat also contained a nested subquadrat of 5×5 m^2 for sampling the shrub layer (all non-tree plants taller than 1.5 m). This further contained two nested subquadrats of 1×1 m^2 to sample the herb layer (all non-tree plants shorter than 1.5 m). For each quadrat/subquadrat, the number of individuals belonging to all angiosperm species, excluding grasses was recorded. Since sampling in all vegetation types was carried out during the dry season, it is likely that some herbaceous species, other than grasses, may not have been observed. Narrow bunds that surround paddy fields, and which may contain certain additional herb species, were not sampled.

A total of 168 species were recorded during sampling. In addition to the data analysis described here, an exercise was carried out to determine whether vegetation types distinguished using satellite imagery were distinctive in terms of their species composition (Nagendra and Gadgil 1999).

The seven major vegetation types were ranked along various axes of ecosystem services they might provide. Services considered were of five kinds:

(1) Average number of endemic species harbored per $10 \times 10\,m^2$ quadrat – estimated from field data. The list of endemic plants was taken from Saldanha (1995).
(2) Average species richness per $10 \times 10\,m^2$ quadrat – also estimated from field data.
(3) Contribution to carbon sequestration, in terms of relative photosynthetic activity per ha. This was assessed using the mean Normalized Difference Vegetation Index per pixel for each vegetation type. This index is believed to correlate with photosynthetic activity and vigor (Gutman 1991), and was computed from the IRS LISS 2 satellite data.
(4) Economic value per ha in terms of marketable produce – timber, rice, grass and non-timber forest produce collected from each vegetation type. This attribute was qualitatively ranked based on information provided by farmers, plantation owners and other local inhabitants.
(5) Contribution to renewal of soil fertility – these may be positive due to addition of decomposable plant biomass, or negative, resulting from fertilizer and pesticide input. This attribute was also qualitatively assessed, based on knowledge of local practices of cultivation (pesticide/fertilizer input) and of periodic setting of fires, as well as the perception of local inhabitants.

For each attribute, the vegetation types were thus ranked in order of increasing importance. For each vegetation type 'i', its net 'value' in terms of ecosystem services provided, V_i, was then computed as a weighted average of these ranks. Weights provide a means of assigning different levels of importance to different ecosystem services, based on the requirements of the local situation. For instance, the economic value of produce per ha for a given ecosystem might be a central question affecting development of this landscape, and this particular attribute may consequently be given a high weight. In the Siddapur landscape, no single attribute assumed overriding importance. All attributes were therefore treated as equally significant, and weights assigned equally.

The attributes used in this study, and weights assigned to them, may be treated as illustrative. Depending on local requirements, additional or completely different axes of value for an ecosystem may be considered, for instance cultural significance, or disservices such as the provision of sinks for disease vectors.

In addition to ranking vegetation types in terms of ecosystem services, an analysis of landscape transformations was also carried out. Towards this, old maps of the area (Survey of India topographic sheets and revenue maps) and satellite imagery of previous years were initially used to assess earlier changes in vegetation type distribution in the landscape. Ten knowledgeable local inhabitants, located in different regions of the landscape, were then interviewed about their perceptions of landscape changes that had taken place in the past and those that would occur in the future, specifically over the next 5 years. Comparing their knowledge about previous transformations in the landscape, with information based on older maps and imagery, was used to confirm the reliability of information provided by each informant. Using an average of answers provided by the ten local informants, a Landscape Transformation Matrix (LTM) was prepared for the landscape. This describes $\mathbf{X}_{ij}$, the projected probability of transformation from vegetation type 'i' to type 'j' in the next 5 years. For illustrative purposes, this matrix provides an adequate representation of future changes in the landscape, although a more systematic way of assessing future changes in the landscape, perhaps through a model projecting developmental changes into the future, may be preferred.

For each pair of vegetation types, the implication of transformation (for conservation value) from type 'i' to type 'j', D_{ij}, was then calculated as $\mathbf{X}_{ij}(V_j - V_i)$. A highly positive value of D_{ij} indicates a transformation with strong positive influence on the landscape's conservation value. Highly negative D_{ij}s conversely, have strong negative implications for the landscape. These D values are ranked in ascending order, with the lowest rank having the most negative and the highest rank the most positive implications for conservation.

Results and discussion

Table 1 assigns the vegetation types ranks in conservation value based on the ecosystem services they might provide (endemicity, species richness, economic value, contribution to carbon sequestration and contribution to renewal of soil fertility). The first five columns represent the rank in conservation value for an attribute of type specified by column headings, for the vegetation type specified by row headings.

Based on field data evaluating endemicity, paddy, grassland, *Acacia* and *Casuarina* have no endemic species, and were given the lowest rank of 1, while savanna, moist deciduous and evergreen were ranked 5, 6 and 7 respectively. Paddy, grassland, *Acacia*, *Casuarina*, savanna, moist deciduous and evergreen were similarly ranked 1–7 respectively, using field information on average species richness per quadrat. The contribution to carbon sequestration for a vegetation type is related to photosynthetic rate, and was ranked by the mean Normalized Difference Vegetation Index per pixel of vegetation type, from the IRS LISS 2 satellite image. Paddy, grassland, savanna, moist deciduous, evergreen, *Casuarina* and *Acacia* were ranked 1–7 respectively.

Economic value rankings were derived based on a qualitative appraisal of differences in value. Relatively low levels of timber extraction from moist deciduous and savanna fetch them the lowest ranks of 1 and 2 respectively. Evergreen comes

Table 1. Vegetation types are ranked based on the ecosystem services they might provide. The methodology used for assessment of ranks is elaborated in the Methods section. Values in the first five columns represent the conservation rank in order of increasing services provided, for an attribute of type specified by column headings, and vegetation type specified by row headings. Values in the last column indicate the weighted average conservation rank V_i for each vegetation type 'i' – in this case study, all axes of value are considered equally significant, and all weights equal – the weighted average is thus a simple arithmetic average of ranks.

	Endemicity	Species richness	Contribution to carbon sequestration	Economic value	Contribution to soil fertility	Average conservation rank
Paddy	1	1	1	5	1	1.8
Grassland	1	2	2	4	5	2.8
Acacia	1	3	7	7	2	4.0
Casuarina	1	4	6	6	3	4.0
Savanna	5	5	3	2	4	3.8
Moist deciduous	6	6	4	1	6	4.6
Evergreen	7	7	5	3	7	5.4

next with rank 3, since non-timber forest produce (such as honey) collected from this vegetation type fetch a relatively low price in the market when compared to the monetary yield per ha from grass, paddy and timber. The next rank of 4 was assigned to grassland, producing grass that is cut and sold as cattle fodder, followed by paddy with a rank of 5, which fetches a high price in the grain market. *Casuarina* and *Acacia* are timber plantations, and timber fetches a high price in the local market. These were given ranks of 6 and 7 respectively, as *Casuarina* plantations have typically lower levels of biomass per hectare compared to *Acacia*.

Ranking of vegetation types based on their contribution to the renewal of soil fertility was somewhat more qualitative. Paddy, with no leaf litter and large negative contribution in terms of pesticide input, was given the lowest rank of 1. *Acacia* and *Casuarina* have relatively high levels of leaf litter, but these are exotic trees relatively immune to leaf predation, and are known to decompose fairly slowly. The perception of local inhabitants was that *Acacia* litter decomposes relatively slowly, and it therefore received rank 2, followed by *Casuarina* with rank 3. This was followed by savanna with an intermediate level of leaf litter, and rank of 4. Grassland carried the next rank of 5, as it is maintained by the setting of periodic fires, during which nutrient recycling is fairly high. Moist deciduous and evergreen were ranked 6 and 7 respectively. Both have relatively high levels of leaf litter that decomposes relatively rapidly, but moist deciduous has relatively higher levels of leaf extraction as compared to evergreen. Assessment of ecosystem services can thus be quite different depending on the nature of service considered. For instance, endemicity provides a ranking quite different from that based on economic value.

The last column of Table 1 provides an assessment of ecosystem value, that takes into consideration various assessments of ecosystem services. Each cell in this column displays the overall value V_i for a particular vegetation type, calculated as a weighted average of its rank along each axis of ecosystem service. In this analysis, the most trivial form of the weighted average has been utilized, where all axes of service are treated as equally significant and the weighted average is identical to the arithmetic average.

Based on this, the vegetation types ranked in order of increasing 'value' are paddy, grass, savanna, *Acacia* and *Casuarina*, moist deciduous and evergreen. An unforeseen outcome is that a more 'natural' ecosystem, savanna, takes a lower net rank compared to *Acacia* and *Casuarina*. This is a consequence of combining human-accounted services such as economic value and carbon sequestration with 'natural' services such as harboring endemic species, and contributing to overall species diversity. Though *Acacia* and *Casuarina* fall below savanna in terms of endemicity, species richness and contribution to soil renewal, they provide greater economic value and contribute more to carbon sequestration. Hence these have a greater net value.

Table 2 describes projected landscape transformation. Each value in this matrix, $\mathbf{X}_{ij}$, represents the probability of transformation from vegetation type 'i' specified by the column headings, to vegetation type 'j' specified by row headings, over the next 5 years. The transformation that appears most frequent is that from grassland to paddy. It is estimated that over the next 5 years, as much as 30% of the land presently under grassland may be brought under rice cultivation. Savanna and moist deciduous are the vegetation types most likely to be transformed into other vegetation types. This is due to high pressure on these categories, created by a demand for fuel-wood extraction, and for land conversion to a more economically productive category such as *Acacia* or *Casuarina*.

Table 3 depicts the outcome of the exercise of assessing conservation priorities. Cells in Table 3 depict, for each transformation from one vegetation type to another: above, D_{ij} values or implications of transformation from type 'i' specified by column headings to type 'j' specified by row headings and below, rank in ascending order of D_{ij} values. For each D_{ij}, the associated sign is positive or negative depending on whether conservation value increases or decreases. Transformations that either have zero probability of occurrence or do not cause a change in conservation

Table 2. The landscape transformation matrix. Each value in this matrix, $\mathbf{X}_{ij}$, represents the probability of transformation from vegetation type 'i' specified by column headings, to vegetation type 'j' specified by row headings, over the next five years.

From / To	Paddy	Grassland	*Acacia*	*Casuarina*	Savanna	Moist deciduous	Evergreen
Paddy	1.00	0.30	0.00	0.00	0.10	0.00	0.00
Grassland	0.00	0.60	0.00	0.00	0.20	0.05	0.00
Acacia	0.00	0.05	0.95	0.00	0.10	0.10	0.10
Casuarina	0.00	0.05	0.05	0.95	0.10	0.10	0.10
Savanna	0.00	0.00	0.00	0.00	0.45	0.20	0.05
Moist deciduous	0.00	0.00	0.00	0.00	0.05	0.45	0.20
Evergreen	0.00	0.00	0.00	0.05	0.00	0.10	0.55

Table 3. For each pair of vegetation types, the implication of transformation from type 'i' to type 'j', D_{ij}, is calculated as $\mathbf{X}_{ij}(V_j - V_i)$. If D_{ij} is highly positive, it is then a transformation that should be encouraged strongly – if highly negative, it is to be strongly discouraged. Values in a cell indicate above, D_{ij}s for transformations from vegetation type 'i' specified by column headings to vegetation type 'j' specified by row headings, and below, their rank in ascending order.

From / To	Paddy	Grassland	*Acacia*	*Casuarina*	Savanna	Moist deciduous	Evergreen
Paddy	0.00	−0.03	0.00	0.00	−0.20	0.00	0.00
	–	11	–	–	1	–	–
Grassland	0.00	0.00	0.00	0.00	−0.20	−0.09	0.00
	–	–	–	–	1	7	–
Acacia	0.00	0.06	0.00	0.00	0.02	−0.06	−0.14
	–	15	–	–	12	9	5
Casuarina	0.00	0.06	0.00	0.00	0.02	−0.06	−0.14
	–	15	–	–	12	9	5
Savanna	0.00	0.00	0.00	0.00	0.00	−0.16	−0.08
	–	–	–	–	–	3	8
Moist deciduous	0.00	0.00	0.00	0.00	0.04	0.00	−0.16
	–	–	–	–	14	–	3
Evergreen	0.00	0.00	0.00	0.07	0.00	0.08	0.00
	–	–	–	17	–	18	–

value, have a D_{ij} of 0, and may be ignored – these have therefore not been ranked. Strongly positive values indicate 'good' transformations, which will increase conservation value. They are also reasonably likely to occur in the landscape under the present socio-economic conditions. Additional conservation effort need not therefore be concentrated in further supporting this transformation. Strongly negative values, on the other hand, are cause for serious concern. These transformations will lead to serious decline in conservation value and will almost inevitably occur unless definite preventive measures are taken.

Transformations between these extremes should be given priority depending on their sign and value. Positive values require relatively more attention if low in magnitude, especially if likelihood of transformation is low (Table 2) but concomitant increase in conservation value is high (Table 1). Negative values, on the other hand, require less attention if low, either in likelihood of transformation or in loss in value. They need to be given priority only if likelihood of transformation, or loss in value, or both are high.

If one looks at the specific prioritization suggestions that are an outcome of this study from Table 3, the transformation with the highest rank, 18, is from moist deciduous to evergreen. The next highest rank, 17, is associated with the transformation from *Casuarina* to evergreen. These transformations have been initiated by a locally influential group of farmers belonging to the predominantly agricultural Havyak community. These farmers, alarmed at the depletion of the water table which they believe to be caused by the growth of *Acacia* and *Casuarina* plantations, have persuaded the

Forest Department officials to allow certain patches of *Casuarina* to regenerate into forest, through a serial conversion from *Casuarina* to moist deciduous, and moist deciduous to evergreen. This transformation has a high probability of providing a favorable impact on the landscape. However, since local conditions are already in favor of this transformation, little needs to be done to encourage this further. Conservation effort need not therefore be concentrated in this area.

To take an example from the other extreme, the transformations to be most strongly discouraged are from savanna to grassland and savanna to paddy, both with a rank of 1. These particular transformations form part of a serial conversion from moist deciduous to paddy fields which often takes place. Trees in forested areas belonging to the Forest Department of the Indian Government are first encroached on for fuelwood, following which they get converted to savannas. These savanna lands may be directly cleared for planting paddy, especially if on private land. Alternatively, if they form part of Government property that has been encroached, the process of conversion is carried out gradually so as not to draw attention to the process of encroachment. Grazing cattle and further tree extraction first converts the area from savanna to grassland. These grasslands are cleared and ploughed after a year or two, and paddy planted, thus completing the process of encroachment. The entire process of conversion from moist deciduous forest to paddy fields can take from 3–4 years and upwards, depending on the size and location of the forest patch to be cleared.

The highest loss in conservation value during this serial conversion takes place during the transformation from savanna to paddy and savanna to grassland. The transformation from savanna to paddy leads to twice as great a loss in conservation value as from savanna to grassland, but is only half as likely to take place. These transformations have an equally strong potentially negative impact on the ecosystem services provided by the study landscape, and demand equal priority for conservation. These transformations are driven by local socio-economic conditions of development, and will not be easy to halt or reverse. They must therefore be given maximum attention while developing conservation measures.

This approach can be used to identify the crucial stages in ecosystem conversion, at which positive initiatives need to be taken. It can be easily adapted to suit local conditions and requirements, and offers a high degree of flexibility. Time scales used to analyze future landscape transformation may be varied depending on local scenarios. Addition or completely different axes of value for an ecosystem service may also be taken into account, depending on local requirements. Different axes of value may be weighted differently depending on a balance between local needs and larger, regional or global needs for particular services. A more systematic way of assessing future changes in the landscape, possibly through a model projecting developmental changes into the future, may perhaps be used to assess transformation probabilities.

The proposed methodology thus provides a locality-specific means of prioritizing ecosystem management that explicitly combines landscape transformation dynamics with information on ecosystem services, which can be adapted to local conditions.

Conclusions

Ecosystem goods and services provide a potentially useful framework for devising priorities for ecosystem management, by promoting the evaluation of ecosystems in terms of the varied services they provide (Ayensu et al. 1999). Although there is a general consensus on the broad nature of the services provided by ecosystems, there is very little information on the actual services provided by specific, local ecosystems (Daily 1999). It is not also clear as to how these services of diverse kinds, from the harboring of specific important species to carbon sequestration, active at different scales, and important to various degrees depending on local, regional and global priorities, might be combined to evaluate 'net' ecosystem value (Daily 1997). Although ecological economics provides one possible method, not all services can be valued within an economic framework (Gren et al. 1995; Edwards and Cyrus 1998; Costanza 1999).

This paper outlines one possible framework for this purpose that can be flexibly adapted to incorporate different axes of ecosystem services, and ascribe them varying levels of significance. This method, illustrated at the scale of a 27.5 km^2 landscape in southern India, employs ecosystem rankings based on the services these ecosystems provide. Although resulting in a loss of information on relative differences between ecosystems, ranks provide a means of integrating different aspects of ecosystem value. Such rank-based evaluation can be carried out relatively rapidly, even without the availability of precise information.

In addition to evaluating ecosystem function and services, ecosystem evaluation must include components of ecosystem dynamics for maximum effectiveness (Walker and Steffen 1997). To assist the formulation of an effective management strategy, this methodology also incorporates projections of landscape transformation under the prevailing socio-economic environment. Such a method is both comprehensive and flexible. It may be especially useful for species and ecosystem rich regions as in the tropics, where conditions for conservation vary at highly local scales, and conservation strategies require to be concomitantly locality specific.

Acknowledgements

The ideas presented here evolved through several discussions with Madhav Gadgil. I thank two anonymous referees, for providing critical input. M. B. Naik and S. G. Patgar assisted with field data collection, and U. Ghate, M. D. S. Chandran and S. N. S. Singh with species identification. This study was financially supported by the Ministry of Environment and Forests and the Department of Space, Government of India.

References

Ayensu E, Claasen DVR, Collins M, Dearing A, Fresco L, Gadgil M, Gitay H, Glaser G, Juma C, Krebs J, Lenton R, Lubchenco J, McNeely JA, Mooney HA, Pinstrup-Andersen P, Ramos M, Raven P, Reid WV, Samper C, Sarukhan J, Schei P, Tundisi JG, Watson RT, Guanhua X and Zakri AH (1999) International ecosystem assessment. Science 286: 685–686

Ceballos G, Rodriguez P and Medellin RA (1998) Assessing conservation priorities in megadiverse Mexico: Mammalian diversity, endemicity and endangerment. Ecological Applications 8: 8–17

Champion HG and Seth SK (1968) A Revised Survey of the Forest Types of India. Government of India, New Delhi, India

Chandran MDS and Gadgil M (1993) State forestry and the decline in food resources in the tropical forests of Uttara Kannada, Southern India. In: Hladik CM, Hladik A, Linares OF, Pagezy H, Semple A and Hadley M (eds) Tropical Forests, People and Food: Biocultural Interactions and Applications to Development. Vol 15, Man and the Biosphere Series, pp 733–744. UNESCO and Parthenon Publishing Group, Paris

Costanza R (1999) The ecological, economic, and social importance of the oceans. Ecological Economics 31: 199–213

Daily GC (ed) (1997) Nature's Services: Societal Dependence on Natural Ecosystems. Island Press, Washington, DC

Daily GC (1999) Developing a scientific basis for managing Earth's life support systems. Conservation Ecology (Online) 3(2): 14. Available from the Internet. URL: http://www.consecol.org/vol3/iss2/art14

Daniels RJR, Hegde M, Joshi NV and Gadgil M (1991) Assigning conservation value – a case study from India. Conservation Biology 5: 464–475

Diamond DD, True CD and He K (1997) Regional priorities for conservation of rare species in Texas. Southwestern Naturalist 42: 400–408

Edwards PJ, Cyrus A (1998) The value of biodiversity: where ecology and economics blend. Biological Conservation 83: 239–246

Eisner T, Lubchenco J, Wilson EO, Wilcove DS and Bean MJ (1995) Building a scientifically sound policy for protecting endangered species. Science 269: 1231–1232

Franklin JF (1993) Preserving biodiversity: species, ecosystems or landscapes? Ecological Applications 3: 202–205

Goodall JM and Naude DC (1998) An ecosystem approach for planning sustainable management of environmental weeds in South Africa. Agriculture Ecosystems and Environment 68: 109–123

Gren IM, Groth KH and Sylven M (1995) Economic values of Danube floodplains. Journal of Environmental Management 45: 333–345

Gutman G (1991) Vegetation indices from AVHRR: An update and future prospects. Remote Sensing of Environment 35: 121–136

McNeely JA (1996) Assessing methods for setting conservation priorities. Paper presented to OECD conference on biodiversity. Cairns, Australia

Nagendra H and Gadgil M (1999) Satellite imagery as a tool for monitoring species diversity: An assessment. Journal of Applied Ecology 36: 388–397

Noss RF (1996) Ecosystems as conservation targets. Trends in Ecology and Evolution 11: 251

Noss RF, O'Connell MA and Murphy DD (1998) The Science of Conservation Planning: Habitat Conservation under the Endangered Species Act. Island Press, Washington, DC

Pascal J-P (1982) Forest Map of South India. Karnataka Forest Department and French Institute, Pondicherry, India

Pascal J-P (1988) Wet Evergreen Forests of the Western Ghats of India: Ecology, Structure, Floristic Composition and Succession. French Institute, Pondicherry, India

Ramesh BR, Menon S and Bawa KS (1997) A vegetation based approach to biodiversity gap analysis in the Agastyamalai region, Western Ghats, India. Ambio 26: 529–536

Saldanha JC (1995) Endemic plants of Western Ghats: Report of Pitamber Plant Fellowship of Environment. Department of Environment, New Delhi

Smallwood KS, Wilcox B, Leidy R and Yarris K (1998) Indicators assessment for habitat conservation plan of Yolo County, California, USA. Environmental Management 22: 947–958

Walker B and Steffen W (1997) An overview of the implications of global change for natural and managed terrestrial ecosystems. Conservation Ecology (online) 1(2): 2. Available from the Internet. URL: http://www.consecol.org/vol1/iss2/art2

Warren MS, Barnett LK, Gibbons DW and Avery MI (1997) Assessing conservation priorities: an improved red list of British butterflies. Biological Conservation 82: 317–328

Wright RG and Tanimoto PD (1998) Using GIS to prioritize land conservation actions: integrating factors of habitat diversity, land ownership and development risk. Natural Areas Journal 18: 38–44

Yeo MJM, Blackstock TH and Stevens DP (1998) The use of phytosociological data in conservation assessment: a case study of lowland grasslands in mid Wales. Biological Conservation 86: 125–138