Mapping ecologically sensitive, significant and salient areas of Western Ghats: proposed protocols and methodology

Madhav Gadgil, R. J. Ranjit Daniels, K. N. Ganeshaiah, S. Narendra Prasad, M. S. R. Murthy, C. S. Jha, B. R. Ramesh and K. A. Subramanian*

The Western Ghats Ecology Expert Panel (WGEEP) of the Ministry of Environment and Forests, Government of India (GOI) has been asked to identify ecologically sensitive areas (ESAs) along the Western Ghats, and to suggest how to manage them. The concept of ESAs has been extensively discussed in the literature. Several ESAs have been set up in India over the last 22 years under the Environment Protection Act, 1986, and a GOI committee under the chairmanship of Pranob Sen has proposed certain criteria for identification of ESAs. However, WGEEP noted that we still lack a global consensus either on the criteria to define ESAs or on a workable methodology to identify them. Furthermore, there are no clear guidelines on the management regime that should prevail in ESAs, and the Pranob Sen Committee has not addressed this issue at all. Hence, WGEEP decided to undertake an exercise of defining ESAs and developing a workable methodology to assign levels of ecological significance/sensitivity as a first step towards putting ESAs on the map of the Western Ghats. This article provides a report on the outcome of a series of discussions and consultations held by WGEEP to build a consensus on defining and mapping ESAs. It hopes to provoke discussion and feedback from a wider section of experts, with the aim of finalizing a generic methodology for mapping ESAs in other ecologically significant, biodiversity-rich areas within and outside the country. We hope to shortly prepare a companion paper that will address the equally vital management issues.

Keywords: Ecologically sensitive areas, mapping, methodology, protocols.

THE concept of an ecologically sensitive area (ESA) is appealing but difficult. Consequently, ESA is among the most widely used terms with no unequivocally accepted definition. In fact, ESA is often considered synonymous to: environmentally sensitive areas[1–5], environmentally sensitive zones[6], ecologically sensitive ecosystem[7], ecologically sensitive sites (http://cfs.nrcan.gc.ca/subsite/guidelines/introduction), etc., depending upon the context and the area or location of conservation interest. In most of these situations, the terms used are without any specific definition or with variable meanings (Table 1). For this reason, while it is possible only to list a set of criteria that characterise ESAs, all of them will not be applicable in all situations. One such criterion is that ESAs are expected to have low levels of resilience, and hence are difficult to be recovered or restored if perturbed by external influences.

The Western Ghats Ecology Expert Panel (WGEEP), set up by the Ministry of Environment and Forests, Government of India (GOI), has been assigned the task of identifying such sensitive areas. However, WGEEP noted that, world over a number of features are being used for identifying ESAs in different contexts. In fact, several of these criteria refer more to the significance, either ecological or economic, than to the resilience of the locality (Table 1). Given that the ultimate purpose of identifying ESAs is to promote environment-friendly management regimes and conservation of the ecological wealth of the sites, it is evidently necessary to consider features that

Madhav Gadgil is in the Agharkar Research Institute, G. G. Agarkar Road, Pune 411 004, India; R. J. Ranjit Daniels is in the Care Earth Trust, No. 5, 21st Street, Thillaiganganagar, Chennai 600 061, India; K. N. Ganeshaiah is in the School of Ecology and Conservation, and Department of Forestry and Environment Sciences, University of Agricultural Sciences, GKVK Campus, Bangalore 560 065, India; S. Narendra Prasad is in the Salim Ali Centre for Ornithology and Natural History, Deccan Regional Station, Tarnaka, Hyderabad 500 017, India; M. S. R. Murthy and C. S. Jha are in the National Remote Sensing Centre (ISRO), Balanagar, Hyderabad 560 625, India; B. R. Ramesh is in the Institute Francais de Pondicherry, 11 St Louis Street, PB 33, Puducherry 605 002, India, and K. A. Subramanian is in the Zoological Survey of India, Pune 411 044, India.
*For correspondence. (e-mail: madhav.gadgil@gmail.com)

Table 1. Terminologies used and the attributes suggested to be used while assigning 'ecological salience' scores

Term used	Intrinsic biological value	Intrinsic ecological service value	Intrinsic economic value	Intrinsic socio-cultural value	Intrinsic sensitivity
Environmentally sensitive area[3–5] or Ecologically sensitive ecosystems[7,29]	Habitats, plant types Fishes, reptiles birds, mammals	Linkage corridors Seismic areas	Community needs Economics	Human history, land use, unique farmlands, prime farmlands Recreation areas Community organization, demographics	Soils, hydrology, physiography (slope elevation), geology, climate
Ecologically sensitive zone[8]	Biological diversity, endangered species, forests	Groundwater recharge, public water supply areas, habitats	Agricultural land, major settlements	Tourist and religious places	Flood-prone, earthquake
Desertification sensitivity[30]	Vegetation quality (vegetation cover)				Soil quality (texture, depth, slope), climatic quality index (erosion, rainfall, aridity), etc.
Ecologically sensitive areas[1,10,31]	Endemism Rarity Endangered species Centres of evolution of domesticated species, special breeding site/area	Specialized ecosystems, wildlife corridors, origins of rivers Wetlands Grasslands	Areas or centres of less known food plants	Sacred groves	Areas with intrinsically low resilience, steep slopes

define ecological and economic values, along with the resilience of the locality while identifying ESAs. Therefore, following a country-wide consultation among experts and interested stakeholders, WGEEP has attempted to re-evaluate the concept of ESAs, redefine it for the purpose at hand and develop a consensus protocol for scoring levels of ecological significance and sensitivity over the entire Western Ghats, leading eventually to a mapping of ESAs along the Western Ghats. In this article, we outline the conceptual basis and details of protocols thus arrived at. We hope that a generalized form of these protocols could be used for other bio-rich areas as well, within and outside the country.

A working definition of ESA

Focusing on resilience, the Macmillan Dictionary (http://www.macmillandictionary.com/dictionary/british/environmentally-sensitive-area) defines an environmentally sensitive area as 'an area where the natural environment can easily be harmed'. We may therefore employ as a starting point the definition of ecologically sensitive areas as those 'ecological units that may be easily affected or harmed'. However, for operational purposes, we need to also consider the significance, and not just sensitivity, and therefore would like to define ESAs as those areas 'that are ecologically and economically important, but vulnerable even to mild disturbances, and hence demand careful management'. We consider 'ecologically and economically important' areas as those areas that are biologically and ecologically 'rich', 'valuable' and or 'unique', and are largely irreplaceable if destroyed. Further, by virtue of their biological richness, they could be potentially of high value to human societies, help in maintaining the ecological stability of the area, and be significant in conserving biological diversity. Similarly, their 'uniqueness' may be recognized either by the rarity of the living systems they harbour, that are difficult to replace if lost, or by the uniqueness of the services they offer to human society. Their 'vulnerability' could be determined by physiographic features that are prone to erosion or degradation under human and other influences such as erratic climate, and on the basis of historical experience. The Pronab Sen Committee[8] report as well as several other earlier attempts to define ESAs have also suggested these components as directly or indirectly important (Table 1).

Do we need different terminology?

As noted above, world over, ESAs are being proposed not merely as sensitive areas, but also as 'ecologically significant areas'. Their significance may lie in their biological value, ecological value, economic value, cultural and historical values (for instance, as sacred groves or forts), and also in being sensitive to external natural and anthropogenic pressures. Therefore, they need to be conserved taking the local context into account, on the basis of graduated or layered regulations as well as positive incentives depending upon their intrinsic value and extent of resilience. Indeed we believe that there is a consensus, that ESAs shall not only be ecologically sensitive areas, but also ecologically, economically and culturally significant areas. Since 'sensitive' and 'significant' each has its specific connotation, it would be useful to employ another word for the broader concept. Such a word is salient, whose meaning includes: 'relative importance based on context'. Therefore, we propose to use the term 'ecologically salient areas' in lieu of 'ecologically sensitive areas' to capture both aspects, while retaining the abbreviation as ESA. Thus in the ensuing pages we use ESAs in this sense and not to refer merely to ecologically sensitive areas.

Why ESAs?

India has a rich history of nature conservation, going back to prehistorical times. These traditions follow many criteria that are being proposed today as the bases for ESAs, such as sacred forests protecting origins of rivers (e.g. Bhimashankar in Pune District, Maharashtra, at the origin of the Bhima River), or important breeding habitats (e.g. Kokkre–Bellur Pelicanry in Mandya District, Karnataka)[9]. In modern times, we have established a substantial set of conservation sites such as biosphere reserves, national parks and wildlife sanctuaries that constitute a fairly effective network of protected areas (PAS) for conserving biological diversity and natural habitats[10,11]. Most of these tend to be large forested areas identified for conservation because they harbour high levels of biological diversity, flagship species, or unique landscape elements. However, except in certain cases, such as a few biosphere reserves, demarcation of the areas for these conservation programmes was not based on any scientific data or on large-scale consultation involving diverse stakeholders. Rather, more often they have been identified either on the basis of the understanding of the forest managers or on the basis of historical contingencies (e.g. royal hunting grounds, historically known places for certain species such as lions, buffers of reservoirs, etc.). Nevertheless, the demarcated areas have been quite effective in attaining the goals of the conservation programmes in the post-independence period, notwithstanding the repeated conflicts emerging between local communities and managers in several areas, and distinct limitations in some areas for effective conservation of the focal species, such as lack of the most essential corridors between certain PAs for large animals such as elephants[12], etc. We therefore need ESAs to complement the PA network to correct the biases and bring in flexible, people-oriented management systems.

Asymmetry in conservation efforts

Although national parks, wildlife sanctuaries and biosphere reserves are important in conservation, their establishment has led to a complacency in our attitude towards other unrecognized but equally important areas. A host of unique habitats and other areas outside the formal PA network[13–15] (such as *Myristica* swamps, floral plateaus of north Western Ghats, sholas of high altitude), lesser charismatic species (such as the endangered plants, lesser visible but threatened insects, etc.) and newly emerging hotter spots (e.g. 'hot-specks' such as certain water bodies with unusually high concentration of diversity, water seepages that teem with insect, plant and other animal life, but are vulnerable to desiccation; P. T. Cherian, pers. commun.) lack the required attention from existing conservation programmes. Identification of such unique habitats and micro-niches of species requires special efforts and the ESA approach would at least partly address this problem.

The neglect of small and beautiful

There are a number of smaller units of the wilderness that are significant for their historical, cultural and social relevance, and hence deserve to be conserved (for example, limestone outcrops at Yana, Karnataka). Unfortunately, they cannot be conserved via the existing network of conservation sites because they are smaller in size or biologically poor or lack charismatic wildlife, etc. There are, of course, new conservation approaches emerging such as the identification of biodiversity heritage sites, community conservation reserves, etc. For instance, according to the provision of Wildlife (Protection) Act 1972, even small areas such as sacred groves, traditionally venerated by local human communities can be conserved; there are also instances of such efforts as, for example, of the kind established by the Tamil Nadu Forest Department along the banks of the Tambaraparani river close to Kalakad–Mundanthurai Tiger Reserve (KMTR) in Tirunelveli. However, the ESA approach proposed here attempts to encompass all these along with a host of areas of conservation interest that are otherwise neglected.

Non-valuation of invisible services

There are several areas that do not fall under the existing network of conservation, but offer a range of tangible and often invisible services to the communities. These services that have generally gone unnoticed require immediate consideration. For instance, vast areas of grasslands, not so rich in biodiversity could be serving as catchment areas for important rivers that provide agricultural and food stability to people far-off downstream. A small patch of land in the form of a sacred grove could be offering the most important medicinal plants used regularly by the communities depending on it. Areas that provide such invisible services may be important for local communities dependent on them and hence could be considered as important components of ecologically salient areas.

Need for flexible and people-oriented management strategies

PA networks are governed by exceedingly rigid management regimes with local communities having little role in utilizing, managing and conserving them. This approach has led to many difficulties, as recently assessed comprehensively by the Tiger Task Force[13]. The nature conservation regime must also now take into account new legislation such as the Scheduled Tribes and Other Traditional Forest Dwellers (Rights over the Forests) Act, 2006 (refs 16, 17). Furthermore, modern ecological theory strongly favours an adaptive co-management approach[18]. Clearly, we need a network of conservation sites that have locality and time-specific, flexible management strategies. As discussed below, ESAs can be identified with such a flexible system of management. In fact, there could be ESAs with PAs embedded within them, with an adaptive regime of regulation.

Thus, there is a need to expand the scope of the existing process of identifying areas for conservation. ESAs as proposed here aim at attaining this much more comprehensively than focusing merely on biodiversity richness, or on ecological fragility. We thus propose a broader complementary (rather than competing) approach for identifying conservation sites.

Demarcating ESAs

Criteria for demarcating ESAs

As discussed above, there are three important categories of attributes that need to be considered in defining the ecological salience/significance/sensitivity of an area: physico-climatic features (geo-climatic features), biological features and social relevance (including cultural, economic and historical importance) of the area. All these may be grouped as (a) abiotic attributes, (b) biotic attributes and (c) anthropological or socio-cultural attributes. Such attributes have been suggested and used by other workers also[4]. But we are not aware of any structured protocol for using these attributes to arrive at ESAs. We propose below a set of these attributes with the criteria to be used for each of them, and then provide a methodology to combine and use them in demarcating ESAs, especially for a large region such as the Western Ghats.

Biological attributes: We propose that demarcation of an ESA shall consider the following components of biological and cultural uniqueness and richness.

Biodiversity richness: Richness in diversity for all taxonomic groups and hierarchies.

Species rarity: Rarity in terms of population size, extent of geographical distribution, and also rarity in taxonomic representation in terms of paucity of closely related taxa.

Habitat richness: Spatial heterogeneity of landscape elements.

Productivity: Total biomass productivity.

Estimate of ecological resilience: Level of persistence of original climax vegetation.

Cultural and historical significance: Evolutionary–historical value and cultural–historical value of the area.

Geo-climatic layers attributes: These include layers that permit assessment of the innate or natural vulnerability of the area. Obviously features such as slope, aspect, altitude, precipitation, etc. shall be used under the following component attributes:

Topographic features: Slope, altitude, aspect, etc.

Climatic features: Precipitation, number of wet days, etc.

Hazard vulnerability: Natural hazards such as landslides and fires.

Stakeholders valuation: It is important to take on board perceptions of the civil society and local bodies, especially the zilla, taluk and gram panchayats, to decide on areas that they consider to be ecologically and environmentally sensitive. Of course, these perceptions will depend on the proposed management regime.

Methodology to demarcate ESAs

Grid the study area: Most often, ESAs are discussed and debated with a focus on individual landscape elements, specific sites, localities and habitats. This has obviously brought a lot of ad hocism into the process of recognizing ESAs. In its place, we propose that the exercise proceed in two steps: (i) to assign levels of ecological salience to an entire region such as the Western Ghats using a common set of criteria and by adopting a uniform, replicable methodology, and (ii) to identify ESAs along with locality-specific management prescriptions. With this in view, we outline below such a protocol for mapping ESAs of the Western Ghats (Figure 1). This methodology can be generalized for other similar bio-rich regions.

Since the ESAs may be of variable sizes, we propose that the region in question could be divided into grids of suitable size, depending upon the datasets available and vastness of the area. In case of the Western Ghats, we propose $5' \times 5'$ grids because most of the datasets available complement well at this scale.

Assign a value to grids for their ecological sensitivity: Data and information could be obtained for the entire

Western Ghats on each of the criterion listed and maps developed depicting the three attributes as below.

1. *Biological and cultural layer*

Species biological richness

Areas that harbour high levels of biological diversity shall be assigned a higher score than those that are less diverse. Since taxa inventories are incomplete in the Western Ghats, rarity value may be initially calculated based on well-studied taxa such as flowering plants, mammals, birds, freshwater fishes, butterflies and dragonflies. The diversity will be captured using the avalanche index[19,20] that integrates diversity at all levels of taxonomic hierarchy. Further in this particular situation, these values could to be normalized from the lowest (1) to the highest (10) value of biological diversity and each grid cell shall then be assigned the normalized value corresponding to its level of biodiversity.

Rarity of species

Distributional rarity: Areas that contain the 'rarest' of the species are to be considered more important because the loss of these species is irreversible. For this, the rarity of each species needs to be defined quantitatively as the proportion of the total grids occupied by it (Pi) and for each grid these rarity values are summed over all the species in that grid. Accordingly, the rarity of species can range from $1/N$ for those that occur in only one of the total N grids, to 1.00 for those that occur in all the grids. These rarity values of the species are then summed over all the species (S) for each grid to arrive at a rarity value for each grid. It is important to consider only the naturalized species to avoid the recently introduced invaders. The rarity value of a grid (RVg) is given by:

$$RVg = \sum_{i=1}^{S} (Pi).$$

Further, these RVg values shall be normalized again from 1 (lowest) to 10 (highest) and assigned to the grids. Such quantification is fortunately possible now owing to the datasets accumulated on the distribution of species for several bio-rich areas.

Taxonomic rarity: Using the taxonomic hierarchy from the datasets available[21] taxonomically (and hence probably evolutionarily), rare species shall be identified as belonging to families that contain only one monotypic genus. Such families are counted for each grid and normalized between 1 and 10.

Habitat richness: Habitat heterogeneity is well known to be correlated to the diversity of a range of organisms, especially of animals including fishes[22,23]. Therefore, in the absence of data on a wide range of animals, we propose that grids that contain high levels of habitat heterogeneity or landscape heterogeneity shall be regarded as biologically rich and hence assigned a higher score. Habitat heterogeneity can be quantified for large areas such as the Western Ghats as fine-resolution remote sensing datasets are now available. The habitat richness of a grid (HRg) can be computed using an information theoretic measure such as Simpson index, where the species are replaced by the landscape element types and the frequency of the species by the proportion of the area occupied by the landscape element types as given below:

$$HRg = \sum_{i=1}^{L} (Pi)^2,$$

where Pi is the proportion of the area of the ith landscape element and L the number of elements in the grid.

These values are then normalized from 1 to 10 and assigned to the grids.

Productivity

It has been demonstrated that productivity of an area, as represented by the cumulative greenness or Normalized Differential Vegetation Index (NDVI) over the year is a good surrogate for the vegetation diversity[24,25]. Since this index captures the extant primary productivity that sustains life, it can also be used as a surrogate for diversity of a host of organisms for which datasets are not available. Here again, the cumulative NDVI over the year is attached for each grid and normalized to range from 1 to 10. We appreciate that this parameter may underestimate the importance of certain habitats such as grasslands, and

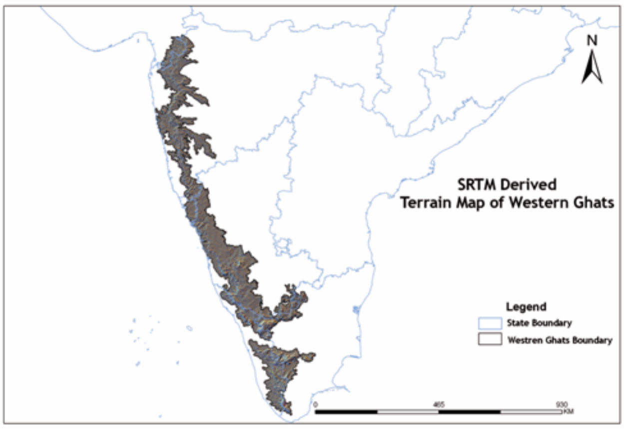

Figure 1. Terrain map of Western Ghats. The boundary map has been prepared following a series of discussions[23] by Narayani Barve, K.N.G. and R. Uma Shaanker. The terrain on the boundary has been overlaid by S.N.P. For details, see www.westernghatsindia.org.

overestimate that for others such as evergreen forests. We also realize that there are a number of possible ways of using NDVI to correct these biases. But given that we have other attributes that capture the importance of such habitats, we wish to restrict to the cumulative values of NDVI since it does represent basic biological productivity.

Estimate of biological/ecological resilience

The extent of deviations in the biological composition (plant composition) of an area from its original plesio-climax composition would reflect the resilience of the system over large timescale; those that have deviated more from the original composition can be considered to be least resilient and hence are ecologically highly sensitive. For this, we propose to estimate the proportion of the existing vegetation that reflects the plesio-climax as an index of resilience[26,27]. These proportions are assigned to all the grids and then normalized to range from 1 (highest deviations) to 10 (least deviations).

Cultural significance

Areas that harbour historical relics and cultural diversity also shall be assigned a higher score. While there is no easy way to value the cultural significance, we suggest that the oldest of the relics shall get the highest value (10) and the most recent a low value (1); if there are no relics, the grid gets zero value.

2. *Geo-climatic layers*

Topographic features

Areas with steep slopes and high altitudes are likely to be eroded more easily, and are hence vulnerable to natural degradation. Obviously such areas need to be considered as least resilient and hence assigned a higher score. We suggest that the slopes, and altitudes can be normalized within each grid from 1 (least average slope or lowest average altitude) to 10 (high slope and high altitude) and assigned to the grids (see Figures 2 and 3 as examples).

Climatic features

Areas with high rainfall, and with a narrow window of wet or rainy seasons (actual length of dry season or number of rainy days in conjunction with total annual precipitation; rainfall in excess of 3000 mm and dry season that exceeds 6 months have made landscapes the most vulnerable/least resilient[28]) are most vulnerable to erosion and hence need to be considered environmentally sensitive. Accordingly, these are normalized within each from 1 (low rainfall or highest number of rainy days) to 10 (highest rainfall or least number of rainy days) and assigned to grids.

Hazard vulnerability

Available data on natural hazards such as landslides and fires shall be obtained wherever possible and attached to the grids, and normalized from 1 to 10.

3. *Stakeholders valuation*

WGEEP has undertaken local consultations, and is also getting responses from a wide section of civil society (through the website www.westernghstsindia.org) for their inputs on ESAs. Similar opinions are also being invited from the public and local bodies. We would work out a methodology of referring these to grids, and assigning normalized values ranging from 1 to 10.

Grading ESAs

There is no available consensus on how to weigh each of these attributes. Hence a starting point would be to weigh the three criteria (abiotic, biotic and socio-cultural) equally. We will undertake such a process with the hope that once the results are out in the public domain, there could be further discussions, revaluation and revision of the scores, and identification of ESAs and their management regimes. However, for the time being, we propose that all the three attributes, viz. biological, geo-climatic and public perception are developed and graded as given in Table 1. Each of them is divided into three categories based on the importance of the biological component, environmental sensitivity and valuation by the public, and are ranked accordingly. These attributes will be later overlaid. The biological and geo-climatic layers are proposed to be first combined and the public perception

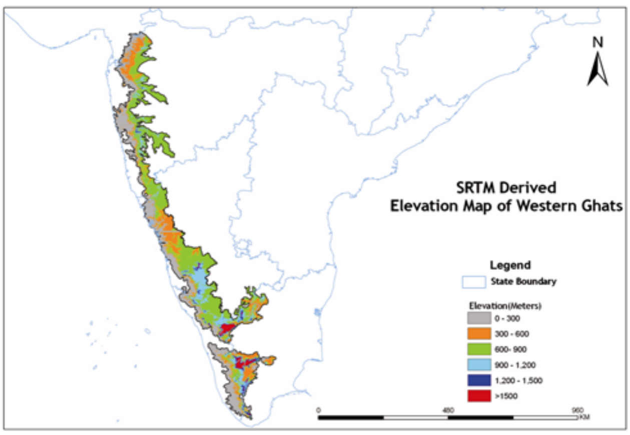

Figure 2. Elevation map of the Western Ghats (prepared by S.N.P.).

Table 2. Suggested scores for attribute and category layers

Attributes	Category	Value
Biological	BHV (biologically highly valued)	10
	BMV (biologically moderately valued)	5
	BLV (biologically less valued)	0
Geo-climatic	EHS (environmentally geo-climatically highly sensitive)	10
	EMS (environmentally geo-climatically moderately sensitive)	5
	ELS (environmentally geo-climatically less sensitive)	0
Public perception	VIPP (very important in public perception)	10
	MIPP (moderately important in public perception)	5
	LIPP (less important in public perception)	0

Table 3. Suggested methodology to combine the valuation and assign 'ecological salience' scores

Combined value from layers 1 and 2	Value from public perception	ESA grade	Extent of proposed protection
10–20	5–10	Grade 1	High
	0–5	Grade 2	Moderate
0–10	5–10	Grade 3	Low
	0–5	Grade 4	To be kept under watch

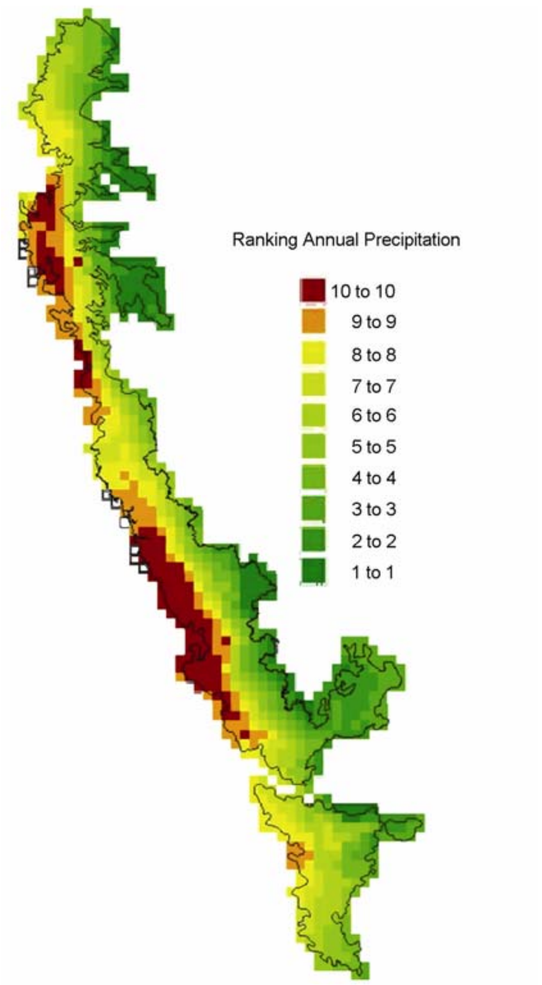

Figure 3. Grids (0.125° × 0.125°) of the Western Ghats ranked based on annual precipitation. Data were obtained from the DIVA GIS program, which offers average for 100 years. Map was prepared by Asha and K.N.G.

layer will be overlaid on this to assign 'ecological salience' scores (Tables 2 and 3).

Once the grids are assigned these 'ecological salience' grades/ranks, areas for demarcating ESAs may be identified as one or more adjacent grids with scores exceeding a threshold to be decided upon. The finer-scale borders of the ESAs can be developed with local inputs from the stakeholders and managers before they are being declared as ESAs under the provisions of the Environment Protection Act.

Conclusions

We have attempted to propose an objective and workable protocol and methodology for arriving at a set of ESAs. This is meant to be a starting point for a wider discussion. It is our hope that such feedback would permit us to develop a more generic methodology on which there could eventually be a consensus. In the meanwhile, WGEEP has been compiling the datasets required for the purpose of assigning 'ecological salience' scores for the Western Ghats employing these steps. We welcome all constructive suggestions to take this process further.

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ACKNOWLEDGEMENTS. We thank all the members of the Western Ghats Ecology Expert Panel, especially R. Sukumar, Ligia Naronha and Renee Borges for their inputs and suggestions at different stages of the development of this manuscript, and Renee Borges for suggesting the term 'ecological salience'. We also thank the Ministry of Environment and Forests, GOI, for funding this work. In particular we thank Dr G. V. Subramanyam for help and cooperation in organizing the discussions, and the staff of ATREE, FERAL and French Institute for their suggestions and inputs. Asha (UAS, Bengaluru) and Narayani Barve (Kansas State University) have helped in preparing the maps. S.N.P. acknowledges the assistance of the SACON team from Hyderabad, in particular Siva Krishna and N. Ravikumar.

Received 17 October 2010; accepted 26 October 2010