

Biodiversity conservation and management

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Abstract: This paper gives a brief overview of the research activities of the French Institute in the field of biodiversity conservation. First, biodiversity-related issues are set in the global context, while India's own biological profile is highlighted. Then, the importance of forest management and policies are expressed, as well as the necessity of a new strategy and action plans for sustainable conservation and management of biodiversity through an integrative approach by taking into account ecological, social, economic and institutional aspects. In the wide field of biodiversity, the French Institute's research programmes have been focusing for about four decades on species diversity and ecosystem diversity at the local (i.e. stand and community), landscape and regional levels. The Institute has been concentrating on plant ecology with a strong emphasis on trees and forests, from open woodland to dense moist evergreen forests, considering their present status as well as their long-term history. Geographically speaking, most of the studies are being carried out in the western ghats and some projects in the eastern ghats and mangroves. The biodiversity-related activities of the French Institute come under 'assessment of biodiversity' and 'monitoring the dynamics of biodiversity'. Assessment employs both ecosystem and species oriented approaches and makes comprehensive use of GIS to integrate them. The monitoring of biodiversity dynamics covers studies on land use and land cover changes, ecosystem uses and forest products, and forest dynamics itself. Although these long-term efforts have already been able to put together a sum of knowledge that can help to better define conservation strategies, more insight is now to be gained on landscape changes linked to social and economic aspects of forest use and management.

Resumen: Este artículo ofrece una breve revisión de las actuales actividades de investigación del Instituto Francés en el campo de la conservación de la biodiversidad. En primer lugar, los temas relacionados con la biodiversidad se ponen en un contexto global, a la vez que se destaca el perfil biológico propio de la India. A continuación se expresa la importancia del manejo y las políticas forestales, así como la necesidad de una nueva estrategia y planes de acción para la conservación y el manejo sostenibles de la biodiversidad por medio de un enfoque integrador que considere aspectos ecológicos, sociales, económicos e institucionales. En el amplio campo de la biodiversidad, los programas de investigación del Instituto Francés se han enfocado durante casi cuatro décadas en la diversidad de especies y de ecosistemas en los niveles local (i.e. del rodal y la comunidad), de paisaje y regional. El Instituto se ha venido concentrado en la ecología vegetal con un fuerte énfasis en los árboles y los bosques, desde los bosques abiertos hasta los densos bosques húmedos perennifolios, considerando su estatus actual así como su historia a largo plazo. Desde el punto de vista geográfico, la mayoría de estos estudios se han estado llevando a cabo en los Ghates Occidentales, con algunos proyectos en los Ghates Orientales y en manglares. Las actividades del Instituto Francés relacionadas con las biodiversidad se presentan como 'evaluación de la biodiversidad' y 'monitoreo de la dinámica de la biodiversidad'. Las evaluaciones utilizan enfoques tanto orientados al ecosistema como a las especies y utilizan ampliamente a los SIG para integrarlos. El monitoreo de la dinámica de la biodiversidad abarca estudios sobre el uso del suelo y los cambios en la cobertura de la tierra, los usos de los ecosistemas y los productos forestales, y la dinámica misma del bosque. Si bien estos es-

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fuerzos de largo plazo ya han logrado juntar un acopio de conocimiento que puede ayudar a definir de mejor manera las estrategias de conservación, ahora hace falta adquirir nuevas perspectivas sobre los cambios en el paisaje ligados a los aspectos sociales y económicos del uso y manejo del bosque.

Resumo: Este artigo uma revisão breve das actividades de investigação do Instituto Francês no campo da conservação da biodiversidade. Primeiro, as questões da biodiversidade são abordadas no contexto global, enquanto o perfil biológico próprio da Índia é evidenciado. A importância da gestão florestal e das políticas são expostas, bem como a da necessidade de uma nova estratégia e de planos de acção para a conservação sustentada e a gestão da biodiversidade através de uma abordagem integrativa que tem em consideração aspectos ecológicos, sociais, económicos e institucionais. No campo vasto da biodiversidade, durante cerca de quatro décadas, os programas de investigação do Instituto Francês têm focado a diversidade em espécies e a diversidade do ecossistema aos níveis locais (i.e. parcela e comunidade), paisagem e regional. O Instituto tem-se vindo a concentrar na ecologia vegetal, com uma ênfase forte nas árvores e florestas, das matas abertas às florestas densas húmidas sempreverdes, considerando não só o seu status actual como também a sua história a longo-prazo. Em termos geográficos a maior parte dos estudos são levados a cabo nos Gates ocidentais e alguns projectos nos Gates orientais e nos mangais. As actividades do Instituto Francês relacionadas com a biodiversidade cabem na designação “avaliação da biodiversidade” e “monitorização da dinâmica da biodiversidade”. A avaliação emprega abordagens igualmente orientadas para o ecossistema e espécies, fazendo uso generalizado de GIS para as integrar. A monitorização da dinâmica da biodiversidade cobre os estudos do uso e das mudanças na cobertura do solo, usos dos ecossistemas e produtos florestais bem como da dinâmica da floresta. Embora estes esforços de longo-prazo já tenham possibilitado pôr em conjunto uma soma de conhecimentos que podem ajudar a definir melhor as estratégias de investigação, são necesarios novos conhecimentos quanto às mudanças na paisagem ligadas aos aspectos sociais e económicos do uso da floresta e da gestão.

Key words: Biodiversity conservation, geographical information system.

Introduction

Biodiversity refers to the variety and variability among living organisms, the ecological complexes in which they occur, and the ways in which they interact with each other and their environment. At present, biodiversity is a result of a series of turnovers in the rate of evolution and extinction since the geological past.

Extinction is a natural process. The geological record indicates that hundreds of plant and animal species have disappeared over the aeons as they failed to adapt to changing conditions due to geological events like continental drift, massive volcanic eruptions or asteroid impacts. Currently, humans are the most powerful agents of environmental change driving the latest wave of extinction. Human activities have already caused the

destruction of over one third of the world's forest. The rapidly escalating human demand for natural resources is causing genes, species and habitat to disappear at an unprecedented rate. Conservative estimates indicate that human activity has increased the extinction rates of plants and vertebrates to between 10 and 100 times the normal “background” rate. The IUCN Red List of Threatened Species indicates that species extinction is on an increasing spiral.

Since the earliest date of recorded history, the fundamental social, ethical, cultural and economic values of humans have directly or indirectly revolved around biological resources. Diversity in genes, species and ecosystems has contributed immensely to the productivity of agriculture, forestry, fisheries and industry. Especially the tropical forests, which are rich in biological diversity,

contribute substantially to the local communities in terms of security in income, employment and livelihood and farming systems. In developing countries, issues related to poverty and gender revolve largely around forests and forest habitats. Even at the global level, these forests are important in terms of checking greenhouse gases, soil erosion and climate change. Over a period of time, due to use and abuse of these forests and with wrong or inappropriate property rights and institutional arrangements, they are subjected to severe degradation and depletion resulting in loss of biodiversity and access to people's needs.

One of the greatest challenges facing society today is the need to address the unsustainable use of natural resources. In an ideal world, all biodiversity conservation needs should be addressed without jeopardizing human aspirations for social and economic development. Thus, conservation is becoming the crisis discipline. Deciding what, where and for whom to conserve is an essential first step in managing the crisis.

India's biological profile and status

India has a rich and varied heritage of biodiversity, encompassing a wide spectrum of habitats, from tropical rainforests to alpine vegetation and from semi-arid vegetation to coastal wetlands. India figured with two hotspots - the western ghats and the eastern himalayas - out of 25 biodiversity hotspots identified by Myers (1988). In addition, India has 26 recognized endemic centres that are home to nearly one third of all the flowering plants identified and described to date.

Of the 1.7 million of the world's described biota, India contributes 7.3% of the global fauna. Among flowering plants, India accounts for 7% of the 250,000 flowering plants so far described in the world. India is one of the 12 centres of origin of cultivated plants. There are 167 cultivated species and 273 wild relatives of crop plants.

The endemism of Indian biodiversity is high. About 33% of the country's recorded flora (49,219 plant species) are endemic to the country and are concentrated mainly in north-east India, the western ghats, north-west himalayas and the Andaman and Nicobar islands. In animals, the endemism among mammals and birds is relatively low (6 to 9%). However, the amphibians and reptiles are, respectively, nearly 62 and 50% endemic to India,

and the majority of them are found in the western ghats.

In India, as in many tropical regions of the world, deforestation and forest degradation continue due to various factors such as extension of cultivation, grazing, extraction of forest products, hydroelectric projects and commercial plantations. Because of these activities, for example, in the western ghats, nearly 40% of the natural vegetation has disappeared during the last 8 decades (Menon & Bawa 1997). In north-east, central and eastern India, shifting cultivation is a major reason for forest degradation and loss. According to one estimate, about 6.4 million hectares are affected by shifting cultivation.

Deforestation leads to several changes in the landscape. The degradation and fragmentation of forests, which generally precede deforestation, considerably affect the biodiversity. Several species with narrow distribution patterns become extinct and several rare and endemic species become endangered or threatened. According to the IUCN, 2000 Red List Data, India contains nearly 3% of the world's total number of threatened species. These include 86 species of mammals, 70 birds, 25 reptiles and 3 amphibians. Among plants, 19 are extinct, 44 critically endangered, 113 endangered and 87 vulnerable.

Forest management and policies

The concept of the management of forests was introduced in India 150 years ago. Colonial legacy and princely states carved out Reserved Forests and State Forests under different forest laws for the "scientific" management of forests. While doing so, nearly an equal percent of forests were kept outside the purview of the Reserved Forest for community use, that is, for obtaining their bonafide requirements of small timber, fuel, fodder, green manure and a host of other non-timber products. At that time, the population was less and consequently the pressure on the forest was minimal. Most of the requirements of the local population were obtained from the Revenue Forests.

Currently, the State Forest Departments, which are the custodians of forests, control large areas of forest as state property. However, substantial areas of natural vegetation still remain either in private control or under the Revenue Department's authority. The management of the Re-

served Forests (RF) under the State Forest Departments has traditionally revolved around protection, silviculture and plantation. On the other hand, Revenue Forests are under the control of the Revenue Departments without any kind of management. Locals have had free access to revenue forests, and due to heavy pressures, vast areas of such lands are being converted into private croplands by granting title deeds to local communities under different schemes and programmes. With the disappearance of Revenue Forests, pressure is being brought on the Reserved Forests to provide the bonafide requirements of the local people. This has resulted in the degradation of Reserved Forests, too.

In north-east India, the forests are still worse from the management point of view. Only 5-10% of forests in the region is under the control of the forest department and the rest is vested with autonomous district forest councils. These councils do not follow any management guidelines and most of the decisions on forest utilization are made following other than scientific considerations. The result is a continuous onslaught on the forests.

Until recently, forest management policies have been largely a legacy of the colonial era with its industrial / commercial bias. Biodiversity, preservation of the environment and people's dependence on forests were given secondary importance. With the increasing range of stakeholders in forests - indigenous / local communities, public sectors, private sectors - the existing forest management system and policies are incapable of limiting the onslaught on forests. The rapid changes in the biological and socio-economic environments make it relevant to adopt management policies in tune with sustainable development, equitable access to forest resources by local communities and environmental conservation.

Moreover, the implementation of the management plans faces numerous constraints, both through poor correspondence with national policy and the lack of an effective integrative approach in the field. India is a signatory to the International Convention on Biological Diversity, which emphasizes the identification of biodiversity components and its conservation and sustainable use. In the spirit of this convention, the current Indian Forest Policy has given importance to Joint Forest Management (JFM) and the formation of Village Forest Committees (VFC) in order to use and manage for-

est resources without jeopardizing the biodiversity.

The change in the National Forest Policy has necessitated a new strategy and action plans for sustainable conservation and management of biodiversity through an integrative approach which takes into account ecological, social, economic and institutional aspects. There are several strategies and action plans being worked out at global and national levels. However, these strategies become irrelevant, unless they are site-specific and can be implemented through existing mechanisms like working and management plans, which are the operational tools of State Forest Departments. Moreover, developing strategies requires a good information system. Still, there are major gaps in information resources pertaining to forest biodiversity, causative factors of degradation and threats. The available data are often inadequate to provide lucid a picture of the current status and the ongoing losses in biodiversity.

Developing an information system to prioritize biodiversity conservation areas and management zones

Developing a good strategy requires a highly reliable and meaningful information system at different levels. In the wide field of biodiversity, the French Institute of Pondicherry (FIP) research programmes have been focusing for about four decades on species and ecosystem diversity at the local (i.e. stand and community), landscape and regional levels. The Institute has been concentrating on plant ecology with a strong emphasis on trees and forests, from open woodland to dense moist evergreen forests, considering their present status as well as their long-term history. Geographically speaking, most of the studies are being carried out in the western ghats and some projects in the eastern ghats and mangroves.

The biodiversity-related programmes of the FIP could be listed under two main headings: 'assessment of biodiversity' and 'monitoring the dynamics of biodiversity'. These programmes are being carried out in collaboration with Forest Departments in Karnataka, Kerala, Tamil Nadu and Andhra Pradesh, the School of Environmental Sciences (JNU), the Kerala Forest Research Institute, the Centre for Ecological Sciences (IISc), the Salim Ali School of Ecology (Pondicherry University) and the National Remote Sensing Agency (Department of Space).

Assessment of biodiversity

A key feature of biodiversity assessment is the very duality of its nature. If we consider the species and ecosystems in a given region, a first viewpoint is to examine the geographical distribution and the ecological niche of each species; a second is to study the various ecosystems and characterize their floristic composition and structure. In order to address this duality, the following approaches are carried out at the FIP and are being integrated under Geographic Information Systems (GIS).

The habitat/ecosystem oriented approach

This approach is derived from biogeography and phytocology and was the cornerstone of the ecological mapping programme initiated in the late 50s by the FIP. It consists in studying and classifying vegetation in relation to ecological conditions (climate and soil), in characterizing the species composition, structure and physiognomy of the vegetation units, in analyzing their dynamics and succession under 'natural' and 'disturbed' regimes. The ultimate outputs of this approach are the following vegetation and land use maps, along with floristic lists attached to each vegetation type.

Regional level (Scale: 1/250,000)

Forest map of South India (published by the French Institute, and the Karnataka, Kerala and Tamil Nadu Forest Departments – 1982, 1984, 1997)

Area covered: From Kanyakumari to Goa

Main theme: Vegetation types (based on phenology, physiognomy, floristic associations and ecology)

154 unique habitats are identified and classified according to their ecology and degradation stages

Other layers: plantations (forest and commercial) hydrography, transport, settlements, forest administrative units and PA network)

Landscape level

Nilgiri Biosphere Reserve Area (Scale: 1/100,000) – vegetation and land use maps (published by the French Institute and the Centre for Ecological Sciences - 1996)

Wildlife Sanctuaries (Scale: 1/50,000):

- Kalakad-Mundanthurai Tiger Reserve, Tamil Nadu (prepared by the French Institute, the TNFD and the WII)

- Biligirangaswami Wildlife Sanctuary, Karnataka (FIP and ATREE)
- Sharavathi Wildlife Sanctuary (part), Karnataka (FIP)
- Chinar Wildlife sanctuary, Kerala (FIP and KFRI)

Besides vegetation mapping, the FIP worked on sampling strategies to optimize the estimation of richness and diversity indices. One of the classical problems in biodiversity assessment is indeed to characterize it in a compact manner through synthetic indices, the values of which can be compared in a consistent way across ecosystems, along ecological and disturbance gradients and over time.

The species oriented approach

This approach is in direct lineage of taxonomic and botanical studies. It is best illustrated by the "Atlas of Endemic Plants of the Western Ghats" published by the FIP (Ramesh & Pascal 1997).

The species oriented approach consists in collecting information on the location of the species from various sources: herbaria, literature and field surveys. This information may be extended to include the ecological conditions (bioclimate, soil, altitude, topography) and the type of ecosystems in which the plant is encountered, the role it plays in these ecosystems, as well as its biological traits (morphology, architecture, growth and reproductive strategy). The ultimate goal is to have a sort of 'identity card' for each species. This information is most crucial for rare and endangered species in the perspective of their *in situ* conservation.

GIS to integrate both approaches

Both of the above approaches end with large sets of spatial information and especially with maps. A major issue is to ensure the consistency of this information and to recombine it according to various viewpoints. In order to perform this, different 'layers' of GIS data have been created using Arc/Info to generate the following information:

- Vegetation physiognomy and human pressures (deduced from density of population or road network) to assess disturbance levels
- The spatial distribution of several species to determine biodiversity 'hotspots'
- Past and present maps for monitoring land cover and land use changes

- Conservation value maps using biodiversity indicators (richness, diversity, endemism, uniqueness etc.) to prioritize the area for conservation and management.

Monitoring the dynamics of biodiversity

Biodiversity assessment has the following outputs: lists of species, sets of values for several diversity indices and land use and vegetation maps. More often these statistics bear no meaning by themselves. Their significance depends more on their absolute and relative variations over space and time. Thus, it is crucial not only to study the biological diversity but also *i)* to monitor it in relation to factors (ecological, human and social), which influence its dynamics, and *ii)* to study the processes (biological, ecological, human and social) that govern its evolution.

Land use and land cover changes

The first step in monitoring changes in biodiversity consists in comparing successive observations. At the local level, this can be done by observing the appearance and disappearance of species: it requires that the same sites be sampled on several occasions. In order to observe this, two permanent plots have been set up in the Biligirirangan hills (3.5 ha) and the Kadamakal RF (28 ha), both in Karnataka. In addition to these, initial data have also been collected from one hundred 1-ha permanent plots, established by the Karnataka Forest Department in the Karnataka, part of the western ghats.

At the regional and landscape levels, this can be done using past and present land cover and land use maps. The joint development of satellite imagery, image analysis techniques and GIS has opened avenues for such studies.

At the regional level, such studies are being carried out for the entire western ghats of Karnataka and at landscape level it was done for the Agastyamalai area, which is one of the 'super hot-spots' in the southern western ghats.

Ecosystem uses and forest products

Understanding changes in biodiversity requires the analysis of the processes that are at play. A first major set of processes is constituted

by those related to human activities, especially the direct exploitation of the ecosystems and species. This is where the social sciences play a key role: the land tenure system, the representation of ecosystem and species and the sacred and economic values of the resources are important factors to explain the changes.

In order to understand the processes and to assess the impact of anthropogenic activities on biodiversity, the following work is being carried out in the Kodagu district of Karnataka:

- Impact of extension of coffee and cardamom plantations
- Assessment of biodiversity and disturbance gradient
- Modelling of the sacred grove system using the Multi-Agent System

Forest dynamics

Biological processes and ecological factors temporally govern plant demography and constitute a major set of processes, which have a strong influence on changes in biodiversity. It is thus important to analyze, in 'natural' and 'disturbed' conditions, how the plants regenerate, grow and die when they interact with each other. Such studies are best carried out at the local level in large permanent plots where the environmental conditions can be described.

Since the mid-80s, the FIP has been monitoring such plots in the low-elevation wet evergreen forests of the Kadamakal Reserved Forests in Karnataka, comparing an unlogged compartment to a once-selectively-logged compartment, analyzing the spatial variation of diversity according to topographical heterogeneity, studying silvigenesis, tree regeneration and growth strategy in relation to environmental factors and monitoring phenology.

Perspectives

These long-term efforts have already been able to put together a sum of knowledge that can help to better define conservation strategies. Further, using these data, it may be possible to construct models that simulate disturbance regimes and their impacts on the forest physiognomy and species composition. Modelling the effect of various types of activity, particularly on sensitive areas, would allow an informed assessment of the poten-

tial environmental impact and a comparison of costs and benefits, which also takes into account the losses of biological diversity.

There is a need to carry out or incorporate data from studies on a finer scale of forest and landscape change linked to social and economic studies of forest use and management. These would shed light on some of the proximate and underlying causes of deforestation and loss of biodiversity.

New approaches that are holistic, integrative and involve multiple agents would require a degree of coordination and cooperation between institutions. It would be useful for the State Forest Department to assume a leading role in this and to invite participating institutions to share their findings and to propose resource management alternatives based on empirical studies. There also needs to be better coordination among government agencies and research institutions, for example, between the State Forest Departments and the Revenue Department, which between them administer vast tracts of land in India.

The links between research and development and extension services need to be better defined and better implemented. The Joint Forest Planning and Management (JFPM) experiment represents a good overall attempt by the Forest Department to enter into a participatory mode. These projects will need to be continued, extended to cover a broader geographical area and closely monitored for their impact on forests and on the livelihood security of the participants.

Most critically perhaps, we reiterate here that biodiversity conservation must be integrated with national planning and economic/infrastructural priorities. Article 6 of the Convention on Biological Diversity calls upon signatory countries to approach biodiversity planning in a comprehensive manner (Johnson 1995). Biological diversity must be assigned a high priority based upon long-term planning and studies of human-ecosystem relationships.

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