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ECOLOGICAL METHODS FOR BIODIVERSITY ASSESSMENT IN EIA

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ABSTRACT

Natural Resources are being harvested at a rapid rate for various developmental activities. The development projects are required to take mitigative measures for Environmental management and restoration of degraded ecosystems. The projects are appraised on the basis of Environmental Impact Assessment Report (EIA) by the regulatory authorities in the Country. One of the major components of EIA is inventorising the biodiversity and exploring the impact of the development activities on the biodiversity resources. Decline in biodiversity resources all over the world is being observed due to development pressure. By applying proper ecological methods and applications, we could substantially improve the investigation parameters related to existence of the natural resources and likely impact by the development activities. The present paper highlights the problems being faced today with respect to biodiversity loss and recommends various ecological methods for carrying out ecological assessment during EIA study.

Keywords : Biodiversity, Development, Ecosystem response, Environmental Impact Assessment, Importance value index.

INTRODUCTION

Developmental activities around the world have been affecting the earth's biota and its extraordinary diversity of about 10 million different species. Rapid decline of diversity in several ecosystems is advancing the rates of species extinction. The degradation of habitats has also been causing losses in genetic and functional diversity across population, community, ecosystem, landscape, and global scales. The habitat modifications and destruction, increased rates of invasions by non-native introduced species, over-exploitation and other human-caused impacts are major factors for biodiversity loss and extinction. About half of all species could be extinct within 100 years. Such an event would be similar in magnitude to the five mass extinction events in the 3.5 billion year history of life on earth. Conversion of natural ecosystems into agriculture, plantations, aquaculture and other urban settlements also cause Biodiversity declines. The diversity in man made ecosystems is often low compared with those of the natural systems. The EIA study has become a tool to address the impacts of developmental activities on ecosystem structure, function and changes in biodiversity.

LEGISLATIVE TOOLS IN INDIA CONCERNING BIODIVERSITY

The Convention on Biological Diversity (CBD) aims at conservation of Earth's biodiversity and sustainable use of biological resources. Its provisions are to be implemented within overall goals and policies of states and international agreements like Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) etc. The main focus of the Convention is on Conservation of biological diversity; Sustainable use of the components of biodiversity; and Fair and equitable sharing of benefits arising out of the utilisation of genetic resources. The convention also provides for equitable sharing of benefits arising from the utilisation of traditional knowledge and practices, with holders of such knowledge. India is a Party to the Convention on Biological Diversity (1992).

The Convention balances conservation with sustainable utilisation and access to and use of biological resources and associated knowledge with equitable sharing of benefits arising out of such use. The CBD offers opportunities to India to realize8 benefits from its rich biological resources and associated traditional knowledge. The CBD stipulates that the parties with sovereign rights over their biological resources can facilitate access to the genetic resources by other parties subject to national legislation and on mutually agreed terms. The Biodiversity Act 2002 lays down the framework for providing access, for determining the terms of such access and for ensuring the equitable sharing of benefits.

India is a mega biodiversity country with 2.4% of the world's land area, and having 7-8% of the recorded species of the world. Over 46,000 species of plants and 81,000 species of animals have been recorded. India has also been recognised as a centre of crop diversity with many wild relatives and breeds of domesticated animals. India has a number of Acts relating to environment, agriculture, forestry, wildlife and various policy documents and action plans and strategies. Following enactments deal with the issues of biodiversity conservation and management:

- Indian Forest Act, 1927
- Wildlife (Protection) Act, 1972
- Forest (Conservation) Act, 1980
- Environment (Protection) Act, 1986
- National conservation strategy
- National wildlife policy
- National forest policy

These acts and policy tools are regulations for protecting, propagating or developing forest and wildlife in the forests of the country including protected areas like national parks, sanctuaries etc. However, for conservation and use of biological resource, these enactments

are not very explicit. For example, the wild flora and fauna outside of the notified protected or regulated areas i.e. in other forest areas including deserts, coastal and marine systems, grasslands, riverine systems, and wetlands are not fully covered in respect to their use and conservation. These acts also do not cover large number of invertebrates and micro organisms. The issues of access to biological resources and benefit sharing and protection of traditional knowledge and equitable sharing of benefits arising out of the use of such knowledge have not been accommodated in these enactments.

Thus, the Biodiversity Act 2002 addresses the issues of access to genetic resources and associated knowledge by foreign individuals, institutions or companies, to ensure equitable sharing of benefits arising out of the use of these resources and knowledge to the country and the people. The following two documents further comprehensively deal with Biodiversity:

National biodiversity conservation strategy and action plan
National environment policy 2006

Importance of ecosystem services to human welfare requires that we adopt the prudent strategy of preserving biodiversity in order to safeguard ecosystem processes vital to society. There has been tremendous effort to compensate the loss of forest and biological diversity through various legislative mechanisms. The Forest (Conservation) Act, 1980 stipulates for compensatory land in lieu of forest land diverted to projects. Similarly, the stipulations for carrying out Catchment treatment, avenue plantation, developing green belt around industrial establishment and reclamation and restoration of mined out areas and waste lands by using the delegated powers under Environment(P) Act and Forest (C) Act make it mandatory for projects and other State agencies to develop plantation. However, there is not much emphasis on developing ecological guidelines for managed plantations to ensure that ecosystem services are improved by such activities and various attributes of ecosystem character are regenerated to achieve ecosystem stability and allow ecosystem to develop resilience of required magnitude to disturbance. Application of scientific ecological principles and monitoring of the progress in building up of ecosystem services are needed to be made an inbuilt mechanism in such programme. To ensure that ecosystem services are available to human society, we should define strategy for preserving biodiversity enhancing ecosystem services.

There is dramatic decline in the biodiversity of organisms due to various kinds of pollution, application of pesticides, destruction of habitat, modern agricultural practices, grazing and invasive species and increased emphasis on monoculture practices. Due to above influences, decline in biodiversity in all ecosystem is prominently highlighted across the countries and continents. The lack of systematic study on all biotic species and especially lower forms of organisms has made it difficult to map the diversity. There is clear need of inventorying all diversity including lower group of flora and fauna which play a crucial role in reproduction of

flowering plants and in the production of most fruits and vegetables. We need to ensure that developmental impacts should be fully studied, thoroughly investigated for alternatives and methodology for carrying out impact studies should be scientifically proven. In India, various kinds of developmental projects are subjected to environmental clearance process, which requires the developers to carry out EIA study to address the impacts associated with the project. The Environment Impact Assessment exercise for developmental projects enables the developers to know the possible adverse impacts to find out the mitigation measures. EIA exercise comprehensively deals with management of flora and fauna, conservation of biodiversity and environmental pollution control and management.

ECOSYSTEM IMPACT OF DEVELOPMENT

Critical processes at the ecosystem level influence plant productivity and other environmental conditions like soil fertility, water quality, atmospheric chemistry, and many that ultimately affect human welfare. The diversity and identity of the plant, animal, and microbial species living within a community along with abiotic components largely influence the ecosystem processes. Human alterations in an ecosystem can also influence ecological functions and life support services that are vital to the human being. Substantial changes in local and global losses of biodiversity are due to widespread human transformation of highly diverse natural ecosystems into relatively species-poor managed ecosystems. Following points are of significance to address the issues of biodiversity loss and magnitude and the stability of ecosystem processes.

Human impacts on global biodiversity have been dramatic, resulting in unprecedented losses in global biodiversity at all levels, from genes and species to entire ecosystems;

Local declines in biodiversity are even more dramatic than global declines, and the beneficial effects of many organisms on local processes are lost long before the species become globally extinct;

Many ecosystem processes are sensitive to declines in biodiversity;

Changes in the identity and abundance of species in an ecosystem can be as important as changes in biodiversity in influencing ecosystem processes.

Anthropogenic pressure on ecosystem functioning and consequent loss of biodiversity may lead to changes in various attributes of Ecosystem processes such as soil nitrogen levels, water use, plant productivity, and pest and disease cycles along with decline in biodiversity; thus over all productivity and ecosystem resistance to environmental perturbations will be reduced.

ECOSYSTEM RESPONSES TO CHANGES IN BIODIVERSITY

Researchers have established that loss of biodiversity and resulting degradation of ecosystem services are due to weakening of interactions between biodiversity and ecosystem functioning. The species richness and diversity vary from one ecosystem to other and so their functional attributes. The impact of development on a similar ecosystem at different locations could have different impacts on species richness and on ecosystem processes. Similarly, a tropical forest or a coastal wetland may vary in species number and composition, soil type, slope, rainfall, or nutrient levels. Developmental impacts on different ecosystems will create different response to variations in biodiversity due to variations in environmental and other factors. The EIA studies may provide useful information to the ecologists and other researchers to study the link between biodiversity and ecosystem functioning. The EIA should address the following issues;

1. How ecosystem functioning is affected by changes in biodiversity/species richness?
2. How dynamics of ecosystem functioning (the resilience and stability of processes) is affected by changes in biodiversity.

While carrying out EIA studies, there is only emphasis on collection of biodiversity related data from secondary sources like forest department and other research and academic institutions and published reports. The date is collected mainly on forest tree and sometimes shrubs species from secondary sources which may not be representing the area where development is proposed. What is needed is that EIA team must have team of ecological experts who can scientifically survey and study the area by applying scientific methods. Only taxonomic inventorisation will not help in finding out the ecological status of each species. All parameters like frequency, abundance, density and IVI, population structure, regeneration status of each species should be studied. On the basis of the above exercise, we may be able to develop rehabilitation plan for those species which are under threat or very sensitive to proposed development. The study should also cover the status of micro faunal and microbial diversity so that these species are also restored along with higher species. A reference ecosystem must be designated to monitor the development of biodiversity in the area.

Various studies have shown that ecosystem productivity increases with species richness. The degradation of habitat due to conversion or other developmental needs affect the species diversity. In addition to the impact on biodiversity of higher life forms, the anthropogenic activities also create impact on diversity of soil microorganisms, plant products and predators, and herbivores in communities. Several studies have indicated that ecosystem functioning is decreased as the number of species in a community decreases. Declines in functioning is more pronounced when number of species is low like in most managed

ecosystems i.e. croplands and plantations. The loss of functional groups from a food web, or reductions in the number of species per trophic group (producers, consumers, decomposers) can also cause declines in ecosystem functioning. There are only a few species of plants which may show no response at all to changes in the diversity of their communities. This indicates that natural species of ecosystem are closely interlinked.

MEASURING THE ECOLOGICAL FUNCTIONS OF ECOSYSTEM

The species available in Ecosystems have different structural and functional attributes. Before deciding for removal of any species, one should know about the functional place of the species within the ecosystem. There are various methods by which several parameters relating to structural and functional character of species could be found out. The importance of biodiversity can only be understood if the ecological position of the species is fully investigated. The development projects and the management authorities will have to take note of following parameters before deciding for species removal from any ecosystem:

ECOLOGICAL_METHODS

Methods provided by Cintron- Novelli (1984), Kershaw (1973), Misra (1968), Philips (1959), Curtis (1959) can be used for calculating the population characteristics.

Frequency: For comparison of different vegetation units frequency is expressed in terms of various species in a community.

$$\% \textit{ Frequency} = \frac{\textit{Number of quadrats in which the species occur}}{\textit{Total number of quadrats studied}} \; X \; 100$$

$$\textit{Relative Frequency (RF)} = \frac{\textit{Number of occurrences of a species}}{\textit{Number of occurrences of all species}} \; X \; 100$$

Raunkiaer's Law of Frequency

The frequency values are grouped in frequency classes to study the homogenous/ heterogeneous nature of vegetation (Raunkiaer, 1934). The Law of Frequency states that the number of species of a community in the 5 percentage frequency classes are distributed as-

$$A > B > C \geq D < E \leq$$

Where, A = frequency class- 0 to 20; B = frequency class- 21 to 40; C = frequency class-41 to 60; D = frequency class-61 to 80; and E = frequency class- 81 to 100.

Density

It is an expression of numerical strength of a species in a community. The formula used for calculation of density is,

$$\textit{Density} = \frac{\textit{Total no of individuals of a species}}{\textit{Total number of quadrats studied}}$$

Relative Density

This provides for numerical strength of a particular species in relation to total number of individuals of all species.

$$\textit{Relative density} = \frac{\textit{Number of individuals of the species}}{\textit{Number of individuals of all species}} \times 100$$

Abundance (A)

This is a measure of the number of individuals of a species in a community per quadrat in which it occurred.

$$\textit{Abundance} = \frac{\textit{Total number of individuals of the species}}{\textit{Total number of quadrats of occurrence}}$$

Basal Area/ Dominance

This is regarded as an index of dominance of a species. Higher the basal area, greater the dominance. The average basal area and the relative basal area are calculated from the average diameter of the stem at breast height (diameter at Breast Height- DBH).

Basal area= P r^2 where P = 3.142 or 22 / 7

$$\textit{Relative basal area} = \frac{\textit{Total basal area of a species}}{\textit{Total basal area of all species}}$$

Importance Value Index (IVI)

A total picture of the ecological status of a species with respect to a community structure can be obtained by summing up relative frequency, relative density and relative basal area or dominance as Importance Value Index (IVI).

Distribution pattern (A/F Ratio)

The Abundance to percentage frequency ratio (A/F) provides information about the nature of distribution of species. The ratio value being less than 0.025 indicates regular, 0.025 to 0.05 random and above 0.05 is contagious distribution (Cottam and Curtis, 1956). The A/F value is calculated from the data of abundance and frequency of individual species.

Species Diversity

Species diversity of trees, and seedlings is determined with the Shannon-Wiener diversity index (Shannon & Wiener, 1963). A high index value is suggestive of more diverse community.

Formula for calculating the index is, $H' = \sum_{i=1}^{s} ni/N \ln ni/N$

Where H' = Shannon Wiener Index of species diversity
ni = Number of individuals of the species
N = Number of individuals of all species

Concentration of Dominance

This is calculated to evaluate the level of dominance of a species within a community. This is expressed by Simpson's Index (1949). The index value is inversely proportional to Shannon-Wiener index and which means a higher value is indicative of a less diverse community.

$$C = \sum_{i=1}^{s} (ni/N)^2$$

Where, C = Concentration of dominance
ni = Number of individuals of all species
S = Total number of species at the site

Species Evenness Index (EI)

This is calculated as per Pielou (1975).

$$EI = \frac{H'}{\ln S}$$

Where, H' is the Shannon-Wiener diversity index and S is the total number of species in the community.

Species Richness Index (RI)

This is calculated as per Margalef (1958).

$$RI = \frac{S-1}{\ln N}$$

Where, S is the total number of species in the community and N is the total number of individuals of all species of a community.

Beta Diversity (β- diversity)

This is estimated following Whittaker (1972) and is calculated as follows.

β- diversity = $(S/\alpha) - 1$, where, S is the total number of species and α is the mean species richness.

Niche Width

This is calculated to ascertain the adaptability of different species to tolerate conditions at the interface between different habitat types. (Levins, 1968)

Niche Width or $\beta i = (\Sigma Nij)^2 / \Sigma Nij^2$

Where Nij is the density value for species i on stand j and βi is the niche width of the species i.

Similarity Index/ Community Co-efficient

The concept of similarity index was put forth by Jaccard (1912) to compare two plant communities to find out resemblance between each other in appearance. It is based on the presence/absence relationship between the number of species common to two sites and total number of species. This, it expresses the ratio of the common species to all species found in the particular vegetation.

Sorensen's (1948) formula for similarity index was used for the present study, which is

$$S = \frac{2C}{A + B} X\ 100$$

Where, C is the number of species common to both the stands, A is the total number of species found in stand I and B is the total number of species found in stand II.

Complexity Index

The Complexity Index (Ic) is calculated as a product of the following formula (Holdridge, 1967; Pool et al , 1977)

$$Ic = No.\ of\ species\ X\ Total\ Stand\ Density\ X\ Basal\ Area\ X\ Stand\ Mean\ Height\ X\ 10^{-3}$$

Population Structure

This is interpreted based on diameter class measurements of the tree species encountered through the quadrat survey with different diameter classes/ categories from lower diameter to the highest diameter. Number of individuals belonging to each of the girth classes is estimated and percent density of individuals of each diameter class was calculated as follows.

$$Percent\ Density = \frac{Number\ of\ individuals\ in\ each\ diameter\ class}{Total\ No.\ of\ individuals\ in\ all\ diameter\ classes} X\ 100$$

CONCLUSION

The decline in species richness can lead to decline in overall level of ecosystem functioning. Biodiversity assessment by following established ecological methods during Environmental Impact Assessment will help to know the level of removal of species and further action required to address the impact of loss of biodiversity. By developing an environmental management plan we could restore the natural germ plasm by taking afforestation/plantation. The monoculture or plantation programme with only a few species may not be able to stabilize the habitats as the ecosystem will always be at risk of losing the ecosystem character. More than one species per functional group may help improving the levels of ecosystem functioning and ensure against loss of functioning during disturbance. Strict enforcement of legislation and development of research and conservation programmes with periodical review on effectiveness of such programmes will help achieving sustainable development in the country. EIA studies must address biodiversity impacts in detail both macro and micro levels and suggest measures how to bring back the natural germplasms in the areas where degradation has occurred due to developmental pressures.

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