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Full Length Research Paper

Bioindicators in sustainable management of tropical forests in India

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Nature follows its own pattern to regulate the dynamic ecosystem. If the process is closely monitored it provides indication for the cause and effect of the changes occurring owing to natural factors and anthropogenic activities. The bioindicators are potentially useful tool for the scientists, researchers and foresters to assess the sustainable forest management (SFM) in countries like India, which is rich in biodiversity at ecosystem, species and genetic levels. Although the concept of bioindicators is well known to indicate the change in the forest ecosystems but its application in monitoring the health of forest ecosystems and its documentation is limited in India. Despite of heavy anthropogenic and developmental pressures (2.1% of the land mass, about 1% forest area, 16% human population and 18% livestock population of the world); India is committed to SFM. In this study, an attempt has been made to classify and identify the range of bioindicators (plants and animals both) in reference to SFM in two Forest Management Units (FMUs) in Central India.

Key words: Bioindicators, Biodiversity, Indicators, Sustainable forest Management, Criteria and Indicator, Forest Management Unit.

INTRODUCTION

Biological diversity is an important component that governs ecosystem resilience, its dynamic equilibrium and productivity. It is also important for securing and maintaining livelihood of human beings, particularly for the community living in and around forests. In India there are nearly 0.6 million villages, out of which nearly 1/3rd are in the vicinity of forests. Thus, quite a large population is traditionally dependent on forests. India is also among 12 mega biodiversity countries of the world and has 25 hotspots of the richest and highly endangered eco-regions of the world (Mayer et al., 2000). The policies, legal and institutional framework supports maintenance, enhancement and conservation of biodiversity globally. India is also signatory of various conventions, treaties and is committed for conservation of biodiversity and sustainable management of forests. The Earth Summit in Rio de Janeiro (1992) was the landmark where the world leaders came to a consensus that sustainable development can be achieved through sustainable management of forests, but assessing sustainable forest management (SFM) is a complex task (Aplet et al., 1993).

Various International organizations such as the International Tropical Timber Organization (ITTO), Food and Agriculture Organization (FAO), Center for International Forestry Research (CIFOR) and International Union for Conservation of Nature and Natural Resources (IUCN) have developed initiatives for conservation and monitoring of natural resources. In this context, the Indian Institute of Forest Management (IIFM) has developed 8 criteria and 43 indicators for SFM in India known as Bhopal-India Process, that has been modified to 8 criteria and 37 indicators (GoI, 2008).

India is a low forest cover country where the forest cover is 20.6% (FSI, 2005), which is quite less than the country's Forest Policy (1988) target that is, 1/3rd of total geographical area. Besides there are several issues such as frequent forest fires during summer (about 55% forest area), livestock grazing (nearly 270 million livestock graze in 78% forest area), extensive firewood collection

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by the communities (more than 300 million cubic meters), poor productivity (forest biomass 93 tonnes/ha and wood growing stock 47 cubic meter/ha) and natural regeneration (70% forest area has poor regeneration) (NFAP, 1999).

In order to indicate the impact of such human interventions and practices (beside natural factors), nat-ure has its own way to indicate the health of natural forest ecosystem through the indicator species of plants and animals, generally termed as bioindicators. Most of ecological and environmental bioindicators have strong relationship with some characteristic of their habitat (Kitching et al., 2000; Davis, 2001; McGeoch, 1998). Any deviation from the normal habitat conditions is reflected in alteration of their health, population, distribution etc. There are very few studies precisely identifying and quantifying the cause and effects of using the bioindicators. The indicator species of plants and animals vary with different types of forest ecosystems. In India, there are variations in altitude from few meters above mean sea level to 6000 m, terrain (plain to steep), soil types (highly fertile to barren), temperature (sub zero to 44^{o}C) and concomitant natural forests (16 types and 221 subtypes) (Champion and Seth, 1968). There is no standardized process for identifying bioindicators in different situations. It is difficult to find one common bioindicator for all the agro- climatic conditions of the entire country. In the Himalayan region some indicators may be found suitable but the same indicators may not be suitable for tropical and central region of India. Therefore, it is imperative to identify the species of bioindicators relevant to different biogeographic zones of India. The goal is to identify the best set of indicator species with representtation of ecosystems and biodiversity while avoiding the selection of so many indicator species that the monitoring becomes cumbersome.

Identification of suitable indicator species for different forest types would be helpful for assessment of health of the forests. The human population and resource use is increasing affecting the sustainable availability of forest resources. It is also affected by natural factors such as excessive rains, drought, etc. In this paper attempt has been made to identify some species of plants and animals that indicate the health and vitality of the forests.

Study sites

The present study is the outcome of field trips and observations in two different Forest Management Units (FMU) by the authors in Madhya Pradesh (India) that is, Harda and Sheopur Kalan during 2006-2007.

Harda: Harda forest division is situated between 21^{o}54'17" to 22^{o}34'45" North latitudes and 76^{o}46'52" to 77^{o}30'39" East longitudes. The geographical area of the division is 3293.98 sq. km. The division is known for its diverse forest resources. The minimum and maximum temperature ranges in the division is 19.5 and 42.6^{o}C respectively. The average annual rainfall is 1209.8 mm, more than 90% of total rainfall occurs during June-September. The rivers Majal, Moran, Ajnal, Bhaji, Mac-hak, and Siyani flow through the area and drain into river Narmada. Apart from these major rivers, several small rivers retain water up to month of February. According to forest classification by Champion and Seth (1968), following forest types are found in Harda forest division.

- South Indian Moist Deciduous Slightly Moist Teak (*Tectona grandis* L.) forest.
- Southern Tropical Dry Deciduous Teak (*Tectona grandis* L.*)* Forest.
- Southern Tropical Dry Deciduous Mixed Forest.

Sheopur Kalan: Sheopur Kalan division is located between 25^{o} 20' to 26^{o} 15' North latitudes, 76^{o} 30' to 77^{o} 30' East longitudes. The total geographical area of the district is 6666.603 sq. km, out of which the forest area is 2680.68 sq. km that comprises 40.21% of the geographical area. Sheopur Kalan forest division is located on Central Highlands between 213 to 498 m above sea level. The temperature ranges from 5 to 46^{o}C. May is the hottest month followed by monsoons in June. The recorded average annual rainfall in the division is 744 mm. According to forest classification of forest types by Champion and Seth, (1968) the following types of forests are found in Sheopur Kalan forest division:

- Southern Tropical Dry Deciduous Teak (*Tectona grandis* L.) Forests
- Northern Tropical Dry Deciduous Mixed Forests
  - (i) Dry Deciduous Scrub Type
  - (ii) *Anogeisus pendula* Edgew. Forest.
  - (iii) *Boswellia serrata* Roxb Forest
  - (iv) *Butea monosperma* Lam. Forest
- Northern Tropical Thorn Forest
- Ravine Thorn Forest.

METHODS

Criteria and Indicators (C&I) have been identified as a tool to assess and monitor the SFM globally. Data/information collected on identified indicators from the FMU, is aggregated at province or national level. The values of each indicator can be compared with the norms (standard values) to know the deviations. Periodic collection of such information/data for a period 5-10 years and analysis of such information over a period would indicate the trends towards or away from sustainability. This provides basis for resurrection of the forest system. Many researchers conducted studies on different aspects of C&I for SFM (Kotwal et al., 2008; Guynn et al., 2004; Hagan and Adrews, 2006; Failing and Gregory, 2003; Whitman and Hagon, 2003 and Franc et al., 2001). While working on C&I approach for SFM in Harda and Sheopur Kalan FMUs of

Table 1. List of bioindicators identified from Sheopur Kalan and Harda FMUs of Madhya Pradesh, India.

S/No.	Causes	Bioindicators
1	High grazing pressure of livestock.	Abundance of *Cassia tora* L., and *Lantana camara* Linn, unpalatable species, observed in patches indicating high grazing pressure of livestock.
2	Soil moisture and water table	Abundance of trees of T*erminalia arjuna* Roxb. indicates good soil moisture in the forest. They usually grow along the banks of streams where ground water table is not very deep.
3	Humidity	Abundance of orchids indicates existence/availability of high humidity throughout the year, which is usually due to high rainfall and dense forest (more than 40% canopy cover). Lichens are also good indicators of humidity.
4	Diversity of flowering plants	Abundance of honeycombs indicates availability of bee fodder (pollen and nectar) throughout the year and this in turn indicates diversity of flowering plants (including crop plants) in the area.
5.	Forest fires	The occurrence of fresh as well as semi-decomposed leaf litter of preceding years on the forest floor indicates that there was no fire incidence in the last few fire seasons. Simultaneously the malformed tree growth and burnt symptoms indicates that occurrence of forest fire in a given area.
6.	Soil erosion	Abundance of pebbles/stones, exposed rocks indicate status of soil erosion and intense run-off.

Madhya Pradesh located in central India for observations/data collection on the identified indicators involving communities to monitor the sustainability of forest management, observations were also made on the indicator species of plants and animals in the area. Local community during discussions in the field shared information and traditional knowledge about the species of plants and animals indicating the health of forest.

RESULTS AND DISCUSSION

India has a long history of management of forests by the local communities; the forests in and around the villages were traditionally managed as common property resources prior to introduction of the scientific management of forests in the year 1864. The communities living in and around the forests have their own perceptions on bioindicators, which they have learned through expe-riences. The study sites Harda and Sheopur Kalan are dominated by indigenous communities. The bioindicators coupled with the cause affecting the bioindicators were identified involving local communities of these areas based on the experience and field observations (Table 1).

As per the communities' wisdom and scientific studies, the plants and animals both indicate the health and vitality of forest and can be suitably adopted for monitoring the forest conditions. Hence, the bioindicators can be categorized as plants and animals.

Plants as indicators: Plants are very sensitive and to atmospheric changes if closely monitored. Gaikwad et al., 2006, conducted study on plant bioindicators, and observed that they are very sensitive and affected by increased atmospheric pollution. Out of these plants, Tulsi (*Ocimum sanctum* Linn) is most sensitive to pollution level and a minor change in pollution level adversely affects the growth of this plant.

Certain species of animals and plants can be used as bioindicators to judge the quality of fresh water habitat. Frogs are known to be sensitive to a range of environmental pollutants (Tyler and Capoo, 1983) including agricultural pesticides (Osborn et al., 1981; Cooke, 1972; Brooks, 1981). Frogs and tadpoles are bioindicators of aquatic environment because they are sensitive to a range of water borne substances. If there are plenty of frogs present at a fresh static water site, the water quality is likely to be good; if frogs are absent or scarce, the water quality may not be good (White, 1999). The moisture condition of any habitat may be adequate, low or high. In low moisture conditions, the vegetation is xerophytes, adapted to conserve water and live in low moisture conditions. Some of the adaptations include low height, small in size, thick leaves and thorns, that is, *Acacia catechu* Var. (Khair), *Opuntia dillenii* Haw. (Nagphani). Preponderance of such species in the area indicates low rainfall and poor moisture conditions. The vegetation growing in specific area such as in moderate or high moisture conditions can be judged by considering its morphological characters such as thin large leaves e.g. in *Salix* spp. In abundance of water and broad leaves *e.g.* in *Tectona grandis* L. which requires moderate water for its growth.

Animals as indicators: The animal species are adapted to certain habitat conditions and are sensitive to changes in the amicable conditions. An increase or decrease in population of certain animal species may indicate sign ificant changes in the ecosystem. Pollution may cause

Table 2. Flowering and foliage of tree species as indicators of monsoon.

Sr. No	Botanical name	Family	Vernacular name	Flower/foliage condition	Expected monsoon
1	*Aegle marmelos* Corr.	Rutaceae	Bel	Good foliage	Subnormal monsoon
2	*Azadirachta indica* A. Juss	Meliaceae	Neem	Heavy flush	Drought
3	*Dendrocalamus strictus.* Nees	Poaceae	Bans	Good foliage	Drought, rat attack
4	*Eragrostis cynosuroides.* Beauv	Poaceae	Darbha ghas	Good foliage	Good monsoon
5	*Ficus religiosa* Linn	Moraceae	Pipal	Good foliage	Adequate rains
6	*Limonia acidissima* L.	Rutaceae	Kothi	Good growth	Stormy rains
7	*Madhuca latifolia* Macb.	Sapotaceae	Mahua	Good foliage	Good monsoon
8	*Prosopis cineraria* (L) Druce.	Leguminosae	Khejri	Heavy foliage	Drought
9	*Zizyphus mauritiana* Lam.	Rhamnaceae	Ber	Heavy flush of fruit	Average monsoon

Data Source: Kanani et al., 1995

depletion of important food plant species on which herbivores thrives. Animal species dependent upon these food sources may also decline. In addition to monitoring the size of individuals and number of certain species, other mechanisms of monitoring animal indicators includes the concentration of toxins in animal tissues, or monitoring the rate at which deformities arises in animal populations.

Birds can be excellent bioindicator of the environmental health and sustainability. They are found in range of habitats in considerable numbers, indicate changes in biodiversity (food and shelter) and are sensitive to environmental changes (Gregory et al., 2003). Preponderance of houseflies and mosquitoes are indicative of unhygienic environmental conditions. The close monitoring of the abundance or limited insects will indicate the changes in the environmental conditions. Butterflies are considered good ecological indicators and respond to topographic/moisture effects. The presence of Butterflies indicates good environmental conditions (Weiss et al., 1988). Some of the insects are also identified as biocontrol and helps in maintaining the hygienic conditions. The abundance of cob-webs (spiders- the insect predators) in the forest would regulate the population of other harmful insects and can be used as bioindicators.

The undesirable/less useful species of plants and animals flourish at the cost of more desirable and useful species (Kotwal, 1987) . The spread of perennial and seasonal weeds, pests, diseases become common and thus indicate degraded habitat conditions. Various tree species serve as indicators of monsoon conditions, (Table 2) as believed by the local communities (Kanani et al., 1995).

Lichens are also indicators of humidity in forest environment and are among the most significant indicators of air pollutant and ecosystem health (Richardson, 1992; Wolseley et al., 1994; Upreti, 1995; Sloof, 1995; Mistry, 1998). Lichens respond to environmental changes in the forest including changes in forest canopy, air quality, and climate. They make ideal monitors and can be useful indicators for species diversity and habitat conditions throughout the year. Lichens differ subs-tantially from higher plants because of their poikilo-hydrous nature and combined with other physiological process makes lichens growth particularly susceptible to climatic variations, pollutions and other environmental factors and liable to changes at individuals, populations and community levels (Eva, 2003). Mushrooms can serve as bioindicators of Radio-cesium in forest ecosystems (Epik and Yaprak, 2003).

Use of certain plant and animal species as bioindicators in monitoring the health of forest ecosystems is relatively new (McGeoch et al., 2002). Attempt has been made to classify and identify the range of bioindicators relevant to forest ecosystems in India. India has 2.1% of the landmass, about 1% forest area, 16% human population and 18% livestock population of the world. A significant proportion of forest is subjected to accidental fires leading to forest degradation and loss. Despite these factors, the country is bestowed with a rich diversity of plant (49,000) and animal (83,000) species. A critical issue is that practically economically feasible, socially acceptable and environmentally sound feasible methods of management and monitoring of forest resources are difficult to develop. Despite these difficulties and pressures, India is ethically and legally committed to environmental, social and economic concerns. Identification of site-specific bioindicators and standardization of monitoring mechanisms would be very useful in managing forests sustainably. Considering this Government of India (Ministry of Environment and Forest) has identified 8 Criteria and 37 Indicators for SFM in the country.

Attempt has been made to identify suitable bioindicators for different forestry conditions. This study would help to restore the confidence of the local communities about their traditional knowledge on bioindicators.

The indicators of environmental health are not only useful in monitoring degradation but also play an important role in rehabilitation, restoration and ecosystem resilience and thus truly contribute to sustainable management, rather than simply indicating ecosystem changes. They also facilitate in the assessment of the acceptable degree of habitat modification (Azevedo-Ramos et al., 2006). Animals have a long history in the assessment of response to environmental perturbation (Rosenberg and Resh, 1993; Williams, 1993; Spellerberg, 1991 and McKenzie et al., 1995), but concern about their general utility has been the focus of debate (Landres et al., 1998; Landres, 1992; Pearman et al., 1995; Simberloff, 1998). Juutinen and Monkkonen (2004) suggested that birds and vascular plants are better indicators than other taxa. Pisharoty, 1993, reported that the *Cassia fistula* Linn. a tree species is a unique indicator of rain, it bears bunches of golden yellow flowers in abundance about 45 days before the onset of monsoon. The long-term impact is the survival of the vegetation that is adapted to fire with poor growth indicating poor productivity. Due to accidental fires in the forest during summer, the growth and regeneration of seedlings is hampered. Bioindicators are potentially useful for the scientists, researchers and fore-sters to evaluate SFM particularly in the countries like India, which is rich in biodiversity at ecosystem, species and genetic levels and has involved indigenous communities for the protection and management of forest jointly with state forest department. Despite of heavy anthropogenic/development pressures it is committed for SFM and conservation of biodiversity.

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