BIODIVERSITY IN COMMERCE:
AN ASSESSMENT OF CURRENT KNOWLEDGE ON THE BIOLOGICAL SUSTAINABILITY OF FOREST PRODUCT EXTRACTION IN WEST BENGAL AND PROPOSED RESEARCH STRATEGIES

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TABLE OF CONTENTS

SUMMARY

Under the Joint Forest Management (JFM) programme in south-western West Bengal, sal-dominated deciduous forests are being managed for the extraction of numerous plant products, both for commercial benefits and subsistence-level use, on a large scale. However, there has been little serious evaluation of the long-term biological sustainability of forest produce extraction or the accompanying ecological impacts. Lack of knowledge in the area of biological sustainability is likely to become a bottleneck in the long-term success of JFM initiatives in the region. The present report brings together all the available scientific information on the ecological sustainability of the forest management practices currently prevalent in south-western West Bengal in an attempt to delineate the lacunae in our knowledge regarding the issue and draw up realistic research and monitoring strategies that can be used to design sustainable management plans for the forests of the region.

It was found that currently there is little or no scientific data on the ecological impacts of forest produce extraction either at the species- or at the ecosystem-level. For example, not even one of the 150-200 species under use has been studied for ecology, distribution, productivity or sustainable yield. In the scientific literature that is available, there are problems associated with inadequate sample size, pseudo-replication, incorrect statistical analysis, experimental design and inadequate interpretation of collected data. In the absence of statistically viable or systematically collected data, few concrete strategies can be derived for long-term forest management.

In view of the status of current knowledge on the ecological sustainability of JFM in the study area, (1) critical areas of research, (2) ways to expand the ongoing initiatives in participatory vegetation monitoring, and (3) generalized research strategies for long-term forest monitoring, are delineated for this region, based on similar research work carried out in other parts of India and rest of the world. The emphasis is on realistic, inexpensive and time-efficient means of research that can be undertaken by scientists in collaboration with local communities and forest department officials.

GLOSSARY

a. Abbreviations used in the Report

CNS…Centre of Natural Studies, Midnapore

cu.m.…cubic metres

dbh…diameter at breast height

EERN…Ecological and Economics Research Network

FPC…Forest Protection Committee

FPP…Forest Preservation Plot

ha…hectare

IBRAD…Institute of Bio-Social Research and Development

JFM…Joint Forest Management

NGO…Non-governmental Organization

NTFP…Non-Timber Forest Products

RMLP…Ramakrishna Mission Loksiksha Parishad

sq.m.…square metre
yr…year

b. Latin Names of Plant Species Referred to in the Text

Akashneem…*Acacia auriculiformes*

Bahera…*Terminalia bellerica*

Bijasal…*Pterocarpus marsupium*

Chironji...*Buchanania lanzan*

Kurchi…*Holarrhena antidysenterica*

Dhok…*Anogeissus latifolia*

Eucalyptus...*Eucalyptus tereticornis*

Haritaki…*Terminalia chebula*

Kalmegh…*Andrographis paniculata*

Kendu…*Diospyros melanoxylon*

Mahua…*Madhuca indica*

Palash…*Butea monosperma*

Parashi…*Cleistanthus collinus*

Sal…*Shorea robusta*

*S*idha…*Lagerstroemia parviflora*

Teak…Tectona grandis

INTRODUCTION

Background to the Study

Indian forests have historically been a rich reservoir of products for people providing innumerable items for household and commercial use. Seeds, fruits, bark, sap, leaves and roots of a wide variety of plants are collected both for commercial purposes and domestic use. The collection of such plant products (collectively referred to as non-timber forest products or NTFPs) is extremely important for the rural economy (e.g., Hegde et al, 1996; Malhotra et al, 1991b). An estimated 400 million people living in and around forests in India depend on NTFPs for their sustenance and supplemental income (Government of India, 1999). The average contribution of NTFPs to annual forest-based revenues exceeds 50%, and in the 1990's, NTFPs brought in a revenue of Rs. 300 crores for the Indian government (M.P. Shiva, 1998). The importance of NTFP to the Indian economy in certain areas can also be seen by the fact that in Madhya Pradesh, forest-based revenues actually bring in more than 15% of the total revenue earned by the state (Saigal et al., 1997).

Despite the fact that most of India's forests are being exploited for plant products, there has been little serious evaluation of the biological sustainability of forest extraction or accompanying ecological impacts. It has generally been assumed that extraction of plant products from forests is sustainable in the long term and that it can have little or no adverse impact upon their biodiversity conservation values. However, it is likely that forest use may have become ecologically unsustainable in many places in India due to recent intensification of extraction pressure and unsuitable extraction practices (Ballabh et al 1998; Ganeshaiah et al, 1998; Koliyal, 1997; Murali et al 1996; Murali and Hegde, 1996; Prasad 2001; Roy, undated a; Shah, 1999; Shankar et al, 1998a; Singh et al, 1997).

There is an urgent need for evaluation of the ecological impacts and biological sustainability of plant product extraction from forest areas on the large scales as are currently being carried out. Such evaluation is of importance for the design of sustainable extraction strategies so that the continued supply of products can be ensured in the long term and irreversible ecological changes can be avoided. Also knowledge on the biological sustainability of plant products will provide invaluable input into the planning and implementation of community-based forest management programmes that have been initiated in various parts of India.

Forest Management in West Bengal

The state of West Bengal was one of the first locations in India from where large-scale timber extraction was undertaken by the British (Sivaramakrishnan, 1999). The natural forests of the region were a treasure of valuable timber for ship-building and extension of railway tracks in India due to the dominance of sal trees (*Shorea robusta*). Over-exploitation by the British and later, by private land-owners after the introduction of taxation laws, led to the impoverishment of the natural sal forests in the state. In the post-independence period, pressures for fuelwood and fodder from a rapidly expanding population, further contributed to the degradation and reduction of forest cover in the state. In this situation, the West Bengal Forest Department found it increasingly difficult to preserve the forests under its control, being faced with diminishing forest cover on the one hand and hostile local communities on the other, who had to resort to stealth to meet their subsistence needs.

In order to resolve this crisis, the government of West Bengal began an attempt towards the regeneration of degraded forests with the support and cooperation of local communities, in the early seventies. Although the exact arrangements varied from place to place, the basis of the new approach was to allow local people increased access to a delimited forest area near their habitations for collection of plant products and biomass, in return for their increased responsibility for its protection and long-term sustainable use. Officials of the Forest Department worked with local people all over the state to form Forest Protection Committees (FPC's) through which the arrangement was formalised for each village. In many cases, FPC's were formed spontaneously in villages as a response to declining forest resources (Poffenberger, undated). Though the scheme has been experimented with since 1971, it was formalised as Joint Forest Management (JFM) through a state-wide government order in 1989.

Over the last twenty years, since participatory forest management was first experimented with in West Bengal, the impacts of the JFM order have been widespread and impressive. By 1999, large areas of degraded forest land had been regenerated to some extent through community protection and artificial plantations in West Bengal (Palit 1999). In many cases, substantial increases in plant biomass, productivity and species diversity have been recorded as a result of forest protection and wise use by local communities for even five to ten years (Ali et al, undated; Das et al, 2000; Malhotra et al. undated; Mishra et al, 1994; Pant, 1997; Roy et al, 2000). Eighty per cent of West Bengal's forest areas covering 5000 sq.km are now officially administered under JFM (Das, 1997; Palit 1999). Although doubts have been raised as to the long-term sustainability of JFM with respect to ecology, economics and institutional aspects (Banerjee, 1989;; Chatterjee, 1996; Chaturvedi, 1992; Murali et al, 2000; Palit, 1989; Palit, 1999; Rao, 1997; Roy, undated b), JFM has been widely acknowledged as one of the most successful experiments in community-based forest management undertaken by any government.

Although the scheme has been officially underway for more than ten years, there is scanty information on the biological sustainability of forest management practices in areas under JFM (Ravindranath et al, 2000; Saigal et al. 1997; Shah, 1999). In fact lack of information on biological aspects of NTFP collection has been considered by some researchers to be the primary stumbling block to the future success of JFM in India (Rao, 1997; Saigal et. al. 1997). Great controversy exists with regard to the rotation cycles for timber extraction that have been put in place (See for example, Chaturvedi, 1992 and Guhathakurta, 1992). Further, it is believed that unsustainable removal of firewood and NTFP's may be hampering forest regeneration and causing population declines amongst plant species in many areas (Chaturvedi, 2000; Khan, undated; Palit, 1996; Ravindranath et al, 2000). The present research was motivated by the need to bring in considerations of ecological sustainability into the forest management practices that are prevalent in the JFM areas of West Bengal. Research on this issue in this area will be relevant to the management practices that are prevalent in West Bengal, where a large proportion of forests are administered under the JFM scheme.

In order to ensure the long-term sustainability of any large-scale forest management scheme, it is necessary to monitor its ecological impacts so that appropriate adjustments can be made in time. Monitoring creates a pool of common information regarding vegetation structure and dynamics that can be extremely useful in resolving conflicts amongst various forest user-groups or deciding between competing forest uses. Monitoring methods should be easy to execute and rapid, so that members of the local communities can themselves take up the monitoring process in a sustained and regular fashion. Finally, the tested monitoring protocols have to be evaluated, publicised and institutionalised so that these procedures becomes part of the entire JFM arrangement. Based on experiences in the JFM setting in India and other tropical countries, realistic strategies are suggested for such monitoring that can be considered by the stakeholders of JFM for improving the long-term management of forests under their control.

The Ecological Setting

So that questions of sustainability can be addressed with some efficacy, the scope of the study has been delimited to the belt of sal-dominated dry deciduous forest stretching across the south-western part of West Bengal at the eastern edges of the Chhotanagpur Plateau, which forms a fairly homogeneous biome. This region includes the five contiguous districts of Midnapore, Birbhum, Bankura, Purulia and Burdwan in south-western West Bengal, all of which have large portions of their forests under the JFM scheme.

South-western West Bengal is covered by sal-dominated dry deciduous forests on slightly undulating and elevated terrain. The region experiences hot summers and cool winters with a distinct prolonged dry season between October and May. The area experiences a rainfall of 1000-1500 mm annually, concentrated during the monsoon season between June and September. The forest exists on lateritic soil which is prone to erosion and tends to be nutrient-poor. Natural dry deciduous forests of this region are naturally dominated by sal (*Shorea robusta*) which forms up to 95% of the trees while mahua (*Madhuca indica*), kurchi (*Holarrhena antidysenterica*), kendu (*Diospyros melanoxylon*), piya sal (*Pterocarpus marsupium*), haritaki (*Terminalia chebula*), palash (*Butea monosperma*), bahera (*Terminalia bellerica*) and dhok (*Anogeissus latifolia*) form some of its associates. The shrubs in the understorey (layer of plants occurring below the trees in any forest consisting of shrubs and saplings) include *Mimosa rubicaulis*, *Randia dumetorum*, *Combretum spp.*, *Flacourtia indica*, *Cleistanthus roxburghii*, ber (*Zizyphus oenopila*) and date palms (*Phoenix acaulis*). A rich diversity of herbs, climbers and grasses add to the vertical and horizontal heterogeneity of the forest (Malhotra et al. undated; Mishra et al, 1997).

The sal forests of the area have experienced intensive human manipulation over the last few hundred years (Sivaramakrishnan, 1999). Over the last century or more, a majority of the sal forests have been managed as coppice stands, that is, repeatedly cut every few years for their branches and poles which are in demand for scaffolding. The sal forests of south-western Bengal are still intensively used ecosystems that undergo a variety of extraction and management processes throughout the year. People collect a variety of plant products from the forests under their protection for fuel, timber, fodder, medicine, commercial sales and food. In a study of NTFP utilization across 214 households belonging to 12 different FPC's in Midnapore district, nearly 73% of local plant species were recorded as being used by local people for various purposes throughout the year and included leaves, roots, bark, seeds, fruits, shoots or flowers of various plant species (Malhotra et al, 1991b). Commercially and in terms of volume, the important plants being utilised are sal seeds, sal leaves, mahua flowers, mahua fruits, mushrooms, tendu leaves, tendu fruits, honey, kalmegh (*Andrographis paniculata*) and satamuli (*Asparagus racemosus*) (Government of West Bengal, 1997). The forest floor is swept for dry leaves and twigs for fuelwood in most areas (Das et al, 2000). Additionally, there is disturbance in the understorey in the form of fuelwood extraction, fire and grazing during certain seasons (Ballabh et al, 1998; Malhotra and Poffenberger, 1989; Ravindranath et al, 2000). In the sal coppice forests, the sal trees are managed for subsequent pole harvests by thinning of poles and later, cutting away all of the emerging shoots apart from a central one (referred to as multiple shoot cutting or MSC) during the initial years of growth. In most areas, a rotation cycle of ten years or more for the felling of sal trees for timber and poles has been established from which the monetary benefits will be shared between local forest committees and the Forest Department. Cut-back operations are undertaken to convert the uneven sal coppice growth into an even growth in order to build up a series of age-graded sal stands (Palit, 1999). In many villages, areas of barren and degraded lands have been planted over with Australian acacia or akashneem (*Acacia auriculiformes*), eucalyptus (*Eucalyptus spp.*) and cashewnut (*Anacardium occidentale*), all of which are non-indigenous (or exotic) species that have been transported to India during the last few hundred years. In some areas, the forests are managed for specialised activities such as tassar cultivation which is reported to have negative impacts upon local biodiversity of flora and fauna (Ramakrishna Mission Loksiksha Parishad, 1999). In Purulia district, lac cultivation on palash is widespread as an economic activity. In this context, the regeneration of palash is encouraged to the possible decline of other species including sal (T.K.Mishra, pers.comm.). Hunting as a practice is prevalent amongst the tribal community and many species of mammals and reptiles are hunted (Malhotra et al, 1991a). The current vegetational status in the sal belt of southern West Bengal can thus be summarised as a patchwork of regenerating sal forest of various ages, semi-natural stands managed for various purposes, degraded land and plantations of exotic tree species.

OBJECTIVES

The specific objective of the proposed project is to assess the current knowledge on the long-term ecological sustainability of extraction from the sal forests of southern West Bengal, with the aim of identifying lacunae in and devising methods for, improving our understanding of the issue. Specifically, the objectives of the study were as follows:

- To collate the current understanding on the ecological impacts and long-term sustainability of NTFP collection/extraction in the sal forests of West Bengal
- To identify gaps in our understanding of ecological impacts of NTFP extraction in the chosen study area
- To recommend ways of plugging the gaps identified above
- To identify methodologies for impact assessment and monitoring of NTFP collection/extraction, through study of such techniques used in similar ecosystems in India and abroad

METHODS

The project was undertaken through three primary means: library research, internet research (studying contents of journals, discussion groups and websites) and information-gathering from relevant people through correspondence and interviews. Forest department officials, independent researchers, academicians and members of grassroots-level and national NGO's were contacted for their ideas and perspectives on this issue.

A field visit of nine days' duration was undertaken to Calcutta and Midnapore in West Bengal during January 6 to 14, 2002. In Calcutta, several people who have been involved with JFM as forest officials, academicians or researchers were interviewed. The stay in Midnapore was anchored by Dr. T.K. Mishra, a professor at the Raja N.L.Khan Women's College who heads the Center of Natural Studies, Midnapore (CNS). He has been involved in ecological research related to forest management in the region for several years. From Midnapore, visits were undertaken to forests under the control of four different FPC's in Midnapore district, namely, Arabari, Murakata, Kamalapura and Laljal, with the help of Dr. Mishra's students who have an intimate knowledge of local forest ecology, ethnobotany and forest management practices. Observations were made on economically important plants, the use of forests by local people, and ecological diversity. Later, a presentation on the findings of the current project was made at the Centre of Natural Studies at the Raja N.L. Khan Women's College at Midnapore where Dr. T.K. Mishra and his post-graduate students were present. This was followed by a discussion on the critical ecological research issues that need to be tackled in the area of JFM in south-western West Bengal.

In the present report, the issue of biological sustainability has been dealt with under two main headings, (1) sustainability of forest product extraction and (2) indirect effects upon the ecosystem. The sustainability of forest product extraction implies the ability of local populations of a particular plant species to sustain extraction of a product in the long term. Indirect effects include the varied and complex effects on the ecosystem brought about by resource extraction and/or related forest management practices. These two components are intricately linked and their interdependence has been summarised for easy reference in Figure 1.

FINDINGS

Sustainability of forest product extraction

In ecological terms, extraction of a given resource is considered sustainable if the harvest has no long-term deleterious effect on the local population of the species under consideration so that production of the resource can be maintained indefinitely (Hall and Bawa, 1993). The direct effects of intensive forest produce collection may include decline in density, productivity and/or regeneration of the targeted plant species, depending on the part of the plant that is utilized. Collection of fruits and seeds is likely to reduce the natural regeneration of plant species which may affect their abundance in the future. Collection of leaves can reduce photosynthetic ability of plants which in turn may reduce plant growth rates and future fruit yield. Many forms of collection such as that of roots, boles or bark may destroy entire plants and lead to a decline in the density and productivity of commercially important plant species. Over-exploitation of natural gums and resins has also been found to lead to local population declines and extinctions in some tree species. Thus the effects of resource extraction from a given plant species can ultimately be measured by impacts on local population density and regeneration status (see Figure 1).

It was found that apart from a few plant products, there has been no study of direct impacts for any species out of the nearly two hundred that undergo commercial and subsistence-level exploitation in the study area. The few products that have been covered are sal poles, sal leaves and fuelwood.

a. Sal Poles

One of the most economically important items that is extracted from the forest lands under JFM in south-western West Bengal are sal poles that are in demand for construction scaffolding. A rotation cycle of ten years or more has been established for the extraction of poles from these areas. Already during 1995-96, 3023 ha of sal coppice forests underwent felling with 25% of the monetary benefits accruing to the households of the concerned forest protection committees (Palit, 1999).

However, the issue of sustainability of sal pole extraction has been highly controversial and has been debated at length in the pages of Wasteland News, a prominent Indian journal in the field of forest management. Guhathakurta (1992) contends that the management of coppice sal forests on short rotations of 10-12 years must be sustainable since the practice has been going on for the last century and the sal stands are still producing poles. He feels that with the correct management practices, ie, retention of standard trees and cutting of multiple shoots from correct place on sal stumps, it should be possible to maintain the current felling cycle (see also Mishra, Nandi and Banerjee (1994) for best management practices to maximise individual sal shoot growth). Guhathakurta also believes that a longer rotation cycle may not lead to increase in productivity since older sal trees tend to develop fungal infestations in the heartwood ultimately leading to low outputs. In support of his contentions, Guhathakurta quotes time-series sequence of pole and firewood harvest figures from two periods: 1944-1959 and 1954-1969 from three forest divisions in southern part of the state (Guhathakurta 1993). There are certain discrepancies in this data, however. First, there is an overlap between the two 15-year periods that have been studied so that it is difficult to discern a trend in production, if any. Second, out of the three divisions from where data was collected, a loss in yield of 23.74 cu.m. (30% decrease) per hectare annually appears to have taken place lately in one. Thus the conclusions drawn from the data do not appear justifiable. Sarkar and Chattopadhyay (1998) find that after coppicing, sal stumps produce lateral shoots from under the ground which causes gradual ‘stump-shifting’ in sal trees. Many of these shoots develop into new independent trees. They feel that this is one of the reasons sal forests have been able to survive intensive coppicing, over rotations as short as six years in some cases, for over a century.

Chaturvedi (1992), however, is strongly opposed to the short rotation cycle and believes that after a few cycles, the productivity of the sal trees is likely to decline as does Roychowdhury (1998). They believe that the clearfelling for poles, exposes the forest floor to micro-climatic stresses of various kinds and exposes the trees to disease, all of which may have adverse effects on tree productivity and growth. T.K. Mishra of the CNS, who has been carrying out ecological studies in forests under different management regimes, also believes that productivity of sal poles is bound to decline in the long term given the large-scale export of nutrients from the system that takes place with every round of pole extraction, which is not compensated by nutrient inputs in any form. Sarkar and Chattopadhyay (1998) also report loss of vigour in sal coppice forests in Midnapore district due to repeated cutting in 5-6 year rotation cycles. However, the data on which this is based, is not given.

Controversial as the debate on sal management may be, there is little information on the possible effects of the rotation cycle on the growth, productivity or mortality of coppiced sal trees, based on experimental studies of any kind. As described above, our current knowledge on the sustainability of this practice is based purely on conjecture and observations.

The crux of the issue appears to be the reliability of the information regarding the historicity of the practice of coppicing in the Bengal forests: how long it has actually been going on and whether there has been a declining trend in annual production over the years. Additionally, external changes in forest ecosystems due to intensive human use over the years may also impact the sustainability of timber management. For example, changes in microclimate, soil fertility and faunal diversity may have caused sal trees to have become far more susceptible to fungal infection now as compared to earlier times. It appears that during the recent sal-borer epidemic in Madhya Pradesh, sal trees growing inside Kanha National Park, a relatively undisturbed forest, were relatively unaffected while just outside the Park in disturbed areas, sal-borer infestations were very high (P. Pande, pers. comm.). Possible reasons could include presence of a greater diversity of predators of the beetle in protected forest. In addition, the susceptibility of trees to pest attack could be greater in degraded forest as compared to forests inside the National Park, due to unfavourable microclimatic conditions and lowered fertility status of soils in degraded forest.

Detailed studies are required on the ecological impacts of the ten-year rotation cycle for sal trees. Such studies can only be undertaken by comparing growth rates of sal saplings in coppiced forest with those in old regenerated forest that are still extant in a few Forest Preservation Plots (FPP). FPP's are patches of forests protected for observation purposes by the Forest Department for several decades. Another way to detect declines in productivity is to keep careful records of pole production from a clearly defined forest patch over the years. Such records can easily be maintained by FPC's. However, care has to be taken in assessing biomass of poles extracted, rather than numbers or income generated, because both of the latter can have a variable relationship with biomass, from year to year.

Another problem related to long-term sustainability of sal pole production, is the loss of genetic variability amongst sal trees due to the almost complete lack of regeneration from seed. It is observed that sal seeds do germinate during the monsoon but almost none survive the long and harsh dry season. Consequently, there is near-total dependence on vegetative propagation or asexual reproduction (via coppicing and stump-shifting) which implies that natural selection has virtually come to a standstill in these sal stands. This is likely to result in a lack of ability of the species to adapt to changing environmental conditions or stresses in the future. The impact of this may be visible only years from now such as when the trees are exposed to pathogens or climatic stress of various kinds.

There are many possible reasons for lack of recruitment of sal saplings (i.e., reaching a stage where the sapling is likely to grow into an adult tree) such as lack of appropriate micro-climatic conditions due to fairly open canopy, inappropriate soil conditions, die-back due to fungal infections, grazing by livestock and trampling of young seedlings and saplings by humans and livestock. Systematic experiments are required to investigate the reasons for lack of sal recruitment from seeds. As a preliminary study, it would be useful to compare ecological conditions between sites where sal recruitment is taking place naturally, as in Preservation Plots and areas of coppice sal where there is no regeneration from seed. When some of the possible reasons for lack of recruitment are narrowed down, systematic experiments can be undertaken using treatments such as varying soil moisture, level of canopy shade and protection from grazing. It may be possible for the Forest Department to undertake such experiments as they have begun to attempt sal regeneration from seed in a number of experimental plots in the study area (pers. obs.). With some modifications in their experimental set-up, they may be able to answer this vital question, at least in part.

b. Sal seeds

So far there has been no scientific study on the ecological impacts of sal seed collection in the study area or elsewhere although commercially, it is one of the most important products being extracted from the forests of south-western West Bengal. However, anecdotal observations indicate that both seed collection and the practices accompanying the collection process, such as the burning and sweeping of the forest floor, may be causing loss of regeneration of trees via seed (Rai, 1996). In addition, since sal seeds are highly nutritious, containing about 19% fatty acids, they are likely to be a ‘keystone’ food resource for herbivores during the dry season (Rai, 1996; see Terborgh, 1986 for explanation of keystone species concept). Complete removal of seeds during the mass-fruiting season of sal could lead to drastic population declines amongst the bird, mammal and insect species that depend on this resource. The commercial collection of sal seeds began in 1974 (Rai, 1996) and thus it may be too early to observe the impacts of collection on animal diversity.

A study could be designed along the lines of Prasad (2001) to study the dependent faunal community, and document sal regeneration in areas of intense seed collection with those where seed collection is stopped. It may be possible to set aside a plot for such experiments with the cooperation of FPC's (T.K.Mishra, pers. comm.).

c. Sal leaves

Collection of sal leaves is one of the most important economic activities in the study area and may form the only source of cash income for many families. Leaves are collected from sal saplings up to about three years when the coppice is thick and thinning operations have not yet begun (Pachauri, undated; Malhotra et al., undated). Apical leaves are left on the saplings while lateral shoots are harvested for leaves.

In a study on the extraction of sal leaves, Deb (undated) believes that leaf collection from sal trees is not harmful to the trees, for two reasons: (1) only 5 to 8% of leaves on a given tree are actually collected by a harvester due to accessibility reasons; and (2) there is an effective limit on the number of leaves collected per day imposed by the exigency of having to stitch plates overnight in time for supply to the market before the leaves dry up. Based on simple calculations, he has concluded that the collection of sal leaves is not likely to have a deleterious impact upon the productivity or growth of sal trees. In addition, leaves are collected only upto three years, after which the saplings are too high to reach. It appears that vertical growth of sal shoots is not affected, as only lateral leaves are collected.

However, as in the case of sal poles, Deb's contentions are not backed by systematic scientific studies but only inferences from other published literature. It is possible that there are long-term effects upon growth and/or mortality of young sal trees which are not evident from pure observations. In addition, there may be accompanying practices that exacerbate the effects of sal leaf collection on young trees that have not been considered in his study such as low soil fertility due to repeated leaf manure collection, changes in micro-climate, and pollarding of trees.

Scientific studies are required on the impact of sal leaf collection on growth rates of sal saplings which can be done through simple experiments. In these experiments, groups of saplings growing under different management regimes would be subjected to different degrees of leaf collection. Simultaneously, growth rates of saplings, as measured by girth and height increments, can be compared across treatments.

(d) Fuelwood

Fuelwood comprises a large proportion of the entire biomass that is extracted from the forests by local people, in some cases, up to 90% (Mishra, pers. comm.). Economically too, fuelwood occupies an important place in the village economy (Mahapatra et al 1998; Ramakrishna Mission Loksiksha Parishad, 1999). Due to its importance in the village economy, extraction of biomass for use as fuelwood is an area that has been subjected to far greater scrutiny by scientists than most other NTFP's and consequently, a number of studies have been undertaken on this aspect.

In the study area, the two primary sources of biomass which are used as fuelwood are dry leaf litter and twigs (obtained through forest floor sweeping) and cutting of shrubs and saplings in the understorey of the forest. In areas with low population pressure, as little as 9% of leaf litter produced is collected while in others, almost the entire mass of dry leaves is collected (see Mishra and Roy, undated). Apart from this, twigs and branches generated during thinning and multiple shoot cutting operations that take place from time to time, are also collected for use as fuelwood.

The primary approach adopted by scientists in assessing sustainability of fuelwood extraction is to compare net primary productivity (NPP) of the forest with actual biomass extraction by people on an annual and area-wise basis. NPP is the biomass added to the forest as a whole due to plant growth and is also referred to as Mean Annual Increment (MAI) by some authors. The third aspect of studying sustainability is the calculation of the sustainable extraction limit for biomass.

Productivity in the understorey of sal coppice forest has been calculated by several authors. In the village Bhagabatichowk in Midnapore district, the productivity of biomass in coppiced sal forest was calculated as approximately 5813 kg/ha/yr or 5.813 t/ha/yr (Mishra, 1998). In an overview of the results obtained through research in the Ecological and Economics Research Network (EERN) (formed as a technical support group for JFM in 1996), the estimates for MAI ranged from 2.18 in Kharikamathani to 5.33 t/ha/yr in Kaluasar (Ravindranath et al, 2000). For Bhagabatichowk, the figure is 3.38 t/ha/yr which is far less than that quoted for the same village in Mishra (1998). In some cases, the NPP has been calculated as 2.84% of the growing stock using a regression equation but the basis for this equation has not been specified (Ravindranath et al, 2000). Das et al (2000), in a study undertaken as a part of the EERN, undertake a similar exercise in five villages of Midnapore district. One assumes that similar methods have been employed as in Ravindranath et al (2000) since the latter is a compilation of researches carried out under EERN.

The next step in assessing sustainability is to find out what proportion of the MAI should be extracted. The proportion recommended is one-third to one-half (Ravindranath et al, 2000). However, the basis for using this rule has not been given nor has it been tested in a field situation. Research is needed to calculate the sustainable extraction level using field experiments (see next section) which should include a consideration of possible indirect impacts upon flora and fauna that depend upon deadwood and/or standing dead trees including birds such as woodpeckers, barbets and parakeets, wood-boring beetles and fungi of various kinds.

The final step is the calculation of the requirement of fuelwood by an average household in the region. A survey indicates that consumption of fuelwood per annum per household is 3699 kg in Nutandihi and 3405 kg in Garhmal (Ballabh 1998). Ravindranath et al (2000) report a wide range of annual consumption from 83 kg/hs/year in Kapasgaria to 2400 kg/hs/year in Nemainagar. Das et al (2000) calculate an average of 2100-2200 kg/hs/yr over five different villages of Midnapore district. The wide range of estimates could be due to (1) varying processing needs of NTFP's or agricultural produce in different villages and (2) different methodologies adopted for estimation. In most of the studies, the exact methodology adopted for calculating household requirement of fuelwood has not been explained and therefore it is difficult to understand the reasons for wide range of estimates. Shankar et al (1998b) give a detailed explanation of the various methods that can be adopted in calculation of fuelwood consumption for a given forest area and the limitations of various approaches, such as footpath surveys, use of questionnaire and actual observation, which can be used in developing efficient methodologies for this purpose.

However, it is not enough to calculate extraction rates (here defined as the percentage of productivity extracted by people) to assess sustainability status. Along with estimates of the extraction rates, a health index based on simple plant and animal indicators, should be calculated in every FPC. If the calculated health index is graphed against estimates of the extraction rate for each FPC, one can determine a range of sustainable extraction rates. It is very likely that extraction rate is directly proportional to the forest-to-household ratio for each FPC (which is a testable assumption) and thus these calculations can help to assess the ideal forest-household ratio (refer to Figure 2). Rationalisation of forest areas allotted to each FPC based on such estimates may be vital to ensuring the sustainability of forest use in the long run. These calculations could be used to assess the validitiy of the often-used assumption that the ideal ratio is 1 ha per household (see figure 2; Malhotra and Poffenberger, 1989). This approach is similar to that adopted by researchers in the Biligiri Rangan Hills in Karnataka where the ecological impacts of NTFP collection on vegetational characteristics were compared between sites distant from and close to human habitations and that were therefore subjected to different harvesting intensities (Shankar et al, 1998).

The study of the ecological factors that influence productivity in the understorey of coppice sal stands is also extremely relevant to management and been the subject of detailed study by T.K. Mishra and colleagues at the CNS in Midnapore. Mishra et al have studied the influence of strict forest protection on net productivity of biomass in the understorey of regenerated coppice sal forest in four different FPC's in Midnapore district. It appears that annual productivity in FPC-managed areas may be slightly higher than that in strictly-protected areas that are free of extraction (Mishra, 1998). One of the reasons for this counter-intuitive result is that due to sustained extraction, the dominance of certain fast-growing understory shrubs is reduced. In the absence of such 'disturbance', a single species *Combretum* begins to spread aggressively in the understorey, out-competing other saplings and shrubs. *Combretum* is also a species that is preferred for fuelwood by local people and that may contribute to its control in FPC-managed areas. However, further statistical analysis is required to verify this result (see also Mishra and Banerjee, 1995-98).

The impact of canopy cover on understorey productivity was also studied by T.K.Mishra and colleagues in one of the most comprehensive ecological studies in the region, covering 225 FPC's in south-west Bengal (Centre for Natural Studies, Undated). It appears that moderately open canopy cover in the range of 25-30% may allow maximum productivity amongst herbs and shrubs in the understorey. This implies that more open canopy conditions as compred to that inside a natural forest, would be necessary for maintenance of a productive understorey.

(e) Fodder

Along with fuelwood, fodder is extracted in large quantities from the forests of the region under study. Malhotra and colleagues found that nearly 47% of the biomass utilised by people is that for fodder (Malhotra et al. undated). Despite the importance of this product, there has been little attention paid to its management and sustainability. During this literature survey, no literature was found on the sustainability of fodder collection from the FPC forests.

Studies are needed on the distribution and abundance of the plant species utilised preferentially for livestock fodder. Intensive study is also required on the ecological impacts of grazing and realistic strategies for their minimization. Chaturvedi (2000) estimates that 1 ha of forest can sustainably support only one head of livestock but the basis for this estimate has not been given.

(f) Kendu Leaves

Kendu is a pioneer tree species generally found growing on the edges of forest patches, outskirts of villages and in degraded forests (Malhotra *et al* undated). Kendu is generally shaded out as the sal trees grow taller during the process of regeneration. Kendu is a good coppicer, rarely grazed (due to high concentration of secondary compounds in its leaves), fire-hardy and has extraordinary powers of proliferation due to the ability to propagate through suckers. Tendu trees or bushes are pruned during the months of March to April, so that fresh leaves are induced during the period up to June, when the leaves are collected.

Due to its hardiness, the species is considered to be invulnerable to declines. However, it is possible that if protection of sal forests continues for more than fifteen years, the kendu trees can get shaded out in certain areas. Sarkar (1997) estimates that a tree density of 10 sq.m. per ha per year is ideal for kendu leaf production, in economic terms. Further work is required on productivity of kendu leaves under different management regimes.

(g) Medicinal Plants and other commercially useful NTFP's

There is very little information on the status of medicinal plants and other commercially useful plants in the forest regions of south-western West Bengal. Although several ethnobotanical studies have been undertaken in the region, there has been no attention to ecology or the biological sustainability of extraction levels prevalent in the region. Long-term researchers think that *Rauwolfia serpentina* and kalmegh are in danger of extinction from the region. Talks with people at Murakata FPC revealed that there is a general perception of decline in abundance of medicinal plants in the forest over the years.

Detailed ecological studies are required to calculate sustainable extraction levels of commercially important plant species in the study area. Details on how to go about collecting data for calculation of sustainable extraction limits of plant species, depending on the part of the plant which is utilized, are given in an easy-to-understand format in C.M. Peters (1994) and explained further in the section of this report entitled ‘Overview of Required Research’ (see also Figure 1).

Indirect effects of forest management practices

Sustainable harvest requires that resource extraction should have no discernable adverse effect on other species in the community or on ecosystem structure and function such as animal diversity, nutrient cycling or microbial ecology. In addition to the direct impacts on plants, intensive forest use can indirectly lead to visible habitat degradation (Murali and Hegde, 1996; Shankar et al, 1998a*; pers.obs*.). The sustained use of forests for produce collection and grazing can lead to reduction in tree regeneration, tree species diversity, canopy cover, understorey diversity and structural heterogeneity over a period of time (Ganeshaiah et al, 1998; Shankar et al, 1998a). Such changes are often followed by the invasion of exotic plants and changes in microclimatic and soil conditions, as seen in many places. Finally, changes in forest structure and plant composition are likely to impinge upon the existence of native animal species that depend on specific microhabitats in the forest ecosystem (see Prasad, 2001). Groups of animals that are especially vulnerable to population declines in such areas are fruit-feeding birds and mammals that depend on a diversity of plants and specialized herbivores such as many insect groups. Among these animal groups are several species of seed dispersers and pollinators whose presence is necessary for the regeneration of plant species (Nabhan, 1997). Thus adverse impacts on the local animal community is likely to lead gradually to general impoverishment of the ecosystem in the long term (see also Terborgh, 1998).

(a) Plant species diversity and composition

There is no doubt that the landscape of south-west West Bengal has undergone dramatic change after the initiation of JFM. Large tracts of previously degraded and barren lands have been transformed into greenery due to the regeneration of sal forests. Numerous studies have documented the increase in tree regeneration, plant species diversity and plant biomass due to protection afforded by FPC’s over the last two decades (Ravindranath et al, 2000; Roy et al, 2000; Rural Development Centre, IIT, undated; Tata Energy Research Institute, 1999).

However, it also feared by many that mixed sal forests that occurred in the past have gradually been transformed into species-poor stands where sal trees predominate and that many other species are declining in abundance over large areas (Palit 1999; T.K.Mishra, pers.comm.). There is evidence to suggest that biotic pressures over the last two centuries, may have converted originally multi-species sal-dominated forests to almost monocultural stands of sal due to a process of weeding out of species that regenerate only from seed, are shade-tolerant and cannot tolerate repeated cutting, fire or grazing. The concept of 'akaath' (species that can be cut for household use) and 'kaath' (species that cannot be cut), propagated from the time of British rule, is still highly prevalent in this region, which has also contributed to the preservation of sal at the cost of other species. Clearfelling for sal poles additionally exposes the soil to the ravages of wind and water erosion, solar drying and invasion by weeds and may also be a contributing factor in gradually reducing the proportion of shade-tolerant species present in the forest. Similar changes in species composition have been found in the thorn scrub forest of Biligiri Rangan Hills where dry deciduous forest is suspected to have degraded into scrub due to intensive human use over the years (Shankar et al, 1998a).

Several ecological studies and observations support the hypothesis of gradually changing species composition in coppice sal forests under intensive human use. Mishra and colleagues (pers.comm.) find that in areas subjected to relatively lower rates of extraction for various NTFP's, such as in Kakrajhor in Midnapore district, the relative density of sal is lower and the forest is more mixed as compared to areas under heavy extraction pressure. Das *et al* (2000) also report low densities of *Adina cordifolia* and mahua (species that regenerate only through seeds) in protected forest stands of villages in Midnapore district. In a comparative vegetational study of plantations, coppice sal forests and relatively undisturbed forests in Midnapore and Bankura, Mishra and Banerjee (1997) have found further evidence that the natural vegetation of the region was mixed and that several species are not reaching the canopy in FPC-managed areas due to repeated disturbance. For example, *Cleistanthus collinus* which commonly grows as a shrub in many coppice sal stands was seen as a tree in Sutan Preservation Plot in Midnapore district. In addition, the dominance of sal was much less in the Preservation Plot in comparison to that in coppice sal forests. In one of the few large-scale studies of human impact carried out in the study area, Ramnarayan *et al* (undated) compared vegetational status amongst four sites located along a gradient of disturbance and human use in Bankura and West Midnapore districts of West Bengal. The most disturbed study site (an 8-year old sal coppice forest) had been subjected to biomass extraction, grazing and floor-sweeping of a number of plant products while the least disturbed was a twenty-three year old sal stand where there was little forest use. It was found that tree species diversity was highly depleted in the most disturbed sites with only sal and tendu reaching adult stages. In contrast, undisturbed sal stands harboured up to ten species of trees. In a study in Bankura North Forest Division, Lal et al. (1993) studied mature trees, saplings and seedlings at sites located in three forest ranges, each of which was administered under JFM for some years. These sites were reportedly subject to intensive forest produce extraction, grazing and fire. The low species diversity of these sites was brought out by the results: only nine species of mature trees were recorded over all three sites. However, high diversity was found in the seedling class, yielding between 14 and 33 species in the understorey. These observations are highly indicative of renewed regeneration after a prolonged period of disturbance in the study area. Local perception, gauged by some researchers, also falls in line with this hypothesis. In Bamunmara FPC in Midnapore District, interviews with elderly people suggest large-scale decline in tree species diversity (Ali et al., undated). Particular decline was noted in the case of mahua, a species whose regeneration is known to be susceptible to grazing and fire. Mahua was also identified as a species in decline by local people in Laljal village during the present study. However, the hypothesis of increasing sal-dominance due to intensive human use is based on conjecture rather than hard data and further research is required to confirm this idea. The best way to test this idea would be to establish experimental plots of up to 1 ha, which would be left undisturbed. Long-term vegetation monitoring of these plots would indicate the change in pattern of tree recruitment and community diversity and could help in delineation of forest management strategies in this area (see section 'Overview of Required Research'.

Apart from detailed data on species richness and species composition, simple calculations of basal areas of trees per ha and number of trees above a certain girth class indicate that the forests in the study area are still far from attaining the volume and density of trees to be expected in natural dry deciduous forest. For example, basal areas in five FPC's Kaluasar, Kharikamathani, Uthannayagram, Kapasgeria and Bhagwatichowk in West Bengal were recorded as 21, 4, 24, 11.32 and 10.48 sq.m. per ha, respectively (Ravindranath et al, 2000). In contrast, simple calculations from a fifty-ha study plot in Mudumalai Wildlife Sanctuary in Tamil Nadu, an area of secondary dry deciduous forest (now under protection for a few decades), indicate basal area of 55.19 sq.m. per ha (Sukumar et al, 1998). Although the two areas are not strictly comparable, dry deciduous forest exists in both places due to similar climatic regimes and one can draw some general conclusions from such data. Additionally, there is a preponderance of small girth classes in the forests under protection and utilization in the study area as compared to dry deciduous forests under strict protection. Only 10-12 % of all stems in the West Bengal FPC's are greater than 10 cm in dbh while in Mudumalai, 66.5% of stems are greater than 10 cm in dbh. This also suggests that the forests in the study area have not reached even close to the climax stage where they would be similar to natural forest in structure and diversity.

The plantations of exotic species that have been established by the Forest Department, also have adverse impacts upon local plant species diversity and composition. In a comparison of coppice sal stands with plantations, only seven plant species were found to thrive in association with exotic species as compared to 122 in coppice sal stands (Malhotra et al. 1991a). Again, in comparison to sal and teak plantations managed by the Forest Department, forests under FPC's exhibit much higher species diversity in the understorey and amongst herbs, a phenomenon attributed to intermediate levels of disturbance due to extraction and consequently, reduced dominance amongst competing species (Banerjee and Mishra, 1996; Mishra and Banerjee, 1997). In a study carried out by Ramakrishna Mission's Loksiksha Parishad, the impact of tasar cultivation on plant diversity, growth and biomass production was studied (Mahapatra et al, undated). There was no difference in plant species diversity between sites where tasar is cultivated and adjoining forest areas without tasar cultivation, as measured by species richness of trees and shrubs. Additionally, the ranking of five most abundant species was found to be essentially the same in both areas showing that the species composition in the two areas is comparable. However, the sampling scheme in this study has not been clearly laid out nor has any statistical analysis been carried out. Consequently, it is difficult to evaluate the validity of the conclusions.

Detailed studies are thus required on the impact of artificial plantations on local plant species diversity and composition, which would help to delineate management strategies for the future, especially in deciding which species to plant on degraded lands. Some exotic species are seen to allow the regeneration of native plant species under them, in certain soils and under specific management regimes, and pave the way for regeneration of native forest in degraded areas where there is no rootstock remaining (pers. obs.). This is possibly due to development of fertile topsoil layer and alteration of microclimatic conditions which can then allow the germination and growth of shade-tolerant forest tree species. Research on this aspect can be extremely useful to forest restoration in this region.

(b) Soil Fertility and Microbial Ecology

It is widely felt that the soils in the study area have become infertile due to floor-sweeping for twigs and dry leaves (which would otherwise decompose and contribute to soil fertility) as well as the practice of sal pole extraction. Ramnarayan et al (undated) compared soil fertility status amongst four sites located along a gradient of disturbance use in Bankura and West Midnapore districts of West Bengal. Almost all indicators of soil fertility such as organic carbon, nitrogen and phosphorus were highly depleted in the heavily used sites compared to the least used ones. Mishra et al (1993) have also studied physico-chemical attributes of soils in various plantation types. However, little can be concluded from the latter study regarding the impacts of various types of forest management practices on soil fertility due to the lack of statistical testing.

However, some types of landuse may be enhancing soil fertility as found by Mahapatra et al (undated) in a comparison of soils in protected coppice sal forests with those of forests managed for the breeding of the tasar silkworm. Areas where silkworms were bred areas showed higher concentration of organic carbon and phosphorus than non-breeding areas, most likely due to the addition of excreta of silkworms to the soil (Mahapatra et al, undated).

In perhaps the only quantitative study of microbial ecology in the area, Mishra and colleagues found that populations of fungi, actinomycetes and bacterial counts were generally higher in the soils of sal and teak plantations in comparison to those of akashneem and eucalyptus plantations (Mishra et al, 1993). This study shows that there may be an adverse impact of exotic trees on soil properties and also that there is a general depletion of soil flora and fauna caused by leaf litter extraction and clear-felling over the years. However, termites (insects of order Isoptera) are common in coppice sal forests and appear to have taken over the functions of decomposition in this region (T.K. Mishra, pers. comm.). Areas where silkworms were bred, showed higher concentration of microorganisms than areas with no breeding, commensurate with findings of higher soil fertility in the former areas (Mahapatra et al, undated).

The effects of depletion of soil nutrients on plant and animal diversity may be seen in their entirety only after several years or decades. There may be effects on plant growth, plant reproduction, regeneration and other vegetation properties. Long-term studies are required to assess the full impacts of soil nutrient depletion on the ecosystem.

c. Animal Species Diversity and Composition

There is no doubt that, over the years, animal diversity has shown an increase due to regeneration of coppice sal forests in the study area. In particular, small mammal diversity is reported to have improved and wild dogs, pangolins, jackals, hares and hyenas have reappeared in many areas (T.K.Mishra and Debal Ray, pers. comm.). Talks with people at Murakata village revealed that butterfly diversity has also increased over the years of protection. One of the prominent changes since the improvement of tree cover in Midnapore district is the appearance of herds of wild elephants in the area, reported to be migrating from Dalma Hills in adjoining state of Bihar. The elephants appear to have been encouraged by presence of tall tree cover that provides shelter to them during the daylight hours. However, the elephants mainly feed on agricultural crops such as paddy and consequently, crop damage and human deaths due to trampling have become common in Midnapore district since the beginning of JFM.

On the other hand, it is also clear that all is not well with the forests of the study area with regard to animal species diversity and composition. Although several species have reappeared in the area after a gap of several decades, several groups of animals are also conspicuous by their absence such as chital deer, sambar deer and mouse-deer that are typical denizens of sal forests in other parts of India. Carnivores such as tiger and leopards are not reported anywhere in these parts. A few groups of birds that are dependent on standing dead trees, such as woodpeckers, and those that require very old forest stands, such as hornbills, also appear to be impoverished in the regenerating forests and plantations. There are also indications that faunal diversity is much higher in mixed forests as compared to coppice sal stands or plantations of exotic species, as seen during a visit to Laljal village where a sacred hill still contains remnants of natural forest. In Laljal it was noticed that many trees and creepers of different species were in full bloom during the time of the visit, in sharp contrast to coppice sal stands where few plant species are allowed to reach reproductive maturity. A variety of birds were seen in the mixed forests, foraging on the flowers and on the insects that are attracted to flowers.

It is also likely that the practice of clearfelling coppice sal stands for obtaining sal poles is likely to be highly deleterious to faunal diversity. Working the forests on a coppice rotation of ten years opens up the canopy for long periods, while cut-back and multiple shoot-cutting operations reduce the complex vertical structure of a sal-dominated mixed forest to a highly simplified stand of uniformly-sized trees of mainly a single species, which outwardly resembles a monocultural plantation. It is well-known that simplification of forest structure (both in terms of species and canopy layers) drastically reduces the niches available to insects, birds, mammals and reptiles and consequently, adversely impacts native faunal diversity (Greenberg et al, 1997; Shahabuddin, 1997; Shahabuddin and Ali, 2001; Thiollay, 1995; Terborgh, 1998). Short rotations do not permit attainment of reproductive status by many mature-phase tree species which are important as wildlife food resources (Terborgh, 1998). However, fruits are the primary resource base that support a large proportion of the animal biomass in most tropical forests and thus the lack of fruiting trees is likely to cause a depletion in local populations of fruit-eating birds and mammals (Terborgh, 1998). Finally, larger seeded trees that provide much of the food for wildlife in intact forest are unable to disperse and regenerate in large forest gaps that are necessarily created during clear-felling operations (Terborgh, 1998). Studies in Indian dry deciduous forests have also found that populations of animal-dispersed plant species are more vulnerable to human disturbance than wind-dispersed species, thus implying that food sources for animals are likely to be affected in the highly manipulated forests of the study area (Ganeshaiah et al, 1998).

Survey of the available literature indicates that there is not a single study related to the impact of the various forest management practices on animal diversity in the study area. An essential start to such an assessment would be to compare the abundance of various indicator groups of animals of forest lands under different management regimes with that in relatively undisturbed forests such as FPP's or protected areas (wildlife sanctuaries and national parks). For example, Sutan Preservation Plot appears to be an appropriate 'control site' (site without human use or manipulation) for study of this issue in the study area. Further investigation is required to see if mixed sal stands of Similipal Tiger Reserve in Orissa (see Banerjee and Sastry, 1998) or Dalma Wildlife Sanctuary in the adjoining Singhbhum district of Bihar could also be utilised as control sites for comparative studies of animals with sites in the hilly tracts of Midnapore and Purulia districts. The indicator groups that could be studied with relative ease, are those of birds and butterflies. Such studies will give indications as to what extent the native animal diversity of the region can be conserved if the current forest management practices continue in the study area. Later, more specific and long-term studies can be undertaken with possible experimentation. For example, long-term studies on animal diversity can be undertaken in appropriately manipulated experimental forest patches to study the effect of forest produce extraction on native animal diversity. The serious problem of crop damage and loss of lives by elephants, needs urgent study at the landscape level through a combination of computer-based GIS (Geographic Information Systems), field investigations and study of elephant biology.

(d) Distribution and Control of Invasive Species

Two invasive shrub species of neotropical origin have attained prominence in the forests of the area in recent years, *Lantana camara* and *Eupatorium spp*. (T.K.Mishra, pers. comm.; see also Mishra et al 1994). In some areas, these weeds have become so common that village people have begun to collect them for use as fuel. These species appear to invade mostly in disturbed forest and plantation areas and gradually 'move in' from the edges such as from forest trails. In a comparative study of plantation types in the study area, Mishra and Banerjee (1997) report that *Lantana* invades teak plantations more frequently than sal plantations that are managed by the Forest Department.

The adverse effects of exotic weed species on local biodiversity and productivity are well-known and documented the world over (see Hobbs and Humphries, 1995; Usher, 1988). Invasion by exotic weeds can drastically (and often, irretrievably) change local species composition of plants and habitat conditions for fauna and result in local species extinction in the long run. It has been observed in many parts of India that no other species can grow under the thick shrubbery of *Lantana camara* (pers. obs.). Continued spread of these exotics may result in large-scale habitat deterioration which will likely affect both local biodiversity and the productivity of these forests for various NTFP's.

The reasons underlying the patterns of distribution and abundance of exotic weeds in the study area requires investigation. Reasons for the relative commonness of these weeds under different management regimes could be related to soil conditions, degree of exposure of the forest floor to the sun, degree of habitat disturbance, degree of competition with other shrubs or allelopathic effects of other plant species. The role of various factors in encouraging spread of exotic weeds could be studied using field experiments. Experiments could also be taken up to study the effectiveness of different control measures on the spread of the weed so that suitable control measures can be adopted and forest management practices can be modified accordingly.

Overview of Required Research

The present study reveals that the quantum of knowledge available on biological sustainability of NTFP extraction and forest management practices in the sal forests of south-western West Bengal is very scanty. For example, of the approximately 150 plant species being utilized for various purposes in the study area, less than five have been studied for sustainability of extraction. Even for these species, the kind of information is mainly speculative, rather than based on scientific data. Some amount of research has been done on the indirect ecological impacts of various forest management practices. However, in the available scientific literature, there is a general lack of attention to adequate sample size, problems associated with pseudo-replication, incorrect statistical analysis and experimental design and inadequate interpretation of collected data. In the absence of statistically viable or systematically collected data, much of our knowledge regarding the direct and indirect ecological impacts of forest management practices in the study area remains at the anecdotal level. Consequently, few concrete strategies for long-term management can be derived from the studies currently available.

In this section, I discuss three different options available for further researching the ecological impacts of forest produce extraction in the study area which can be used to design sustainable management strategies. While a variety of research studies can be designed for the purpose (see Hall and Bawa, 1993; Freese, 1997), the purpose here is to outline strategies that can effectively answer specific management issues of concern, utilize inexpensive time-efficient means and are simple enough to be carried out by the informed layperson, such as members of local NGO's or FPC's. In addition, the general areas of research required are summarised in the conclusion of this report.

(a) Long-term Monitoring of Vegetation

In attempting a study of ecological impacts of forest management, it is important to remember that there are many demands upon a patch of forest and that the effects of each type of use can be cumulative and often interconnected, and therefore, difficult to separate. For example, the lack of sal regeneration in many areas could be due to one or a combination of factors including grazing, drought, collection of sal seeds or forest floor sweeping. Therefore it is necessary to assess and manage the overall ecological impacts on forest habitat in a holistic manner at the ecosystem-level. One way to do this is to carry out annual monitoring of vegetation to detect trends in abundance of various species and then use the information to adjust management practices each year. The emphasis in long-term monitoring of vegetation is on relative change or population trends rather than counting absolute numbers of each plant species.

Long-term vegetation monitoring should ideally be carried out at exactly the same time each year using exactly the same methods, to ensure comparability from year to year. Ideally, permanent plots should be established that are easy to locate and can be surveyed year after year. Utilizing permanent plots saves the time required to re-establish quadrats each year, which often is the most time-consuming part of vegetation monitoring (pers. obs.). Long belt transects are most effective in capturing the landscape-level diversity of plant communities available in the area since plants tend to occur in clumped fashion in most forests. Belt transects can be established along existing forest trails, instead of marking new areas. The number of plots to be surveyed depends on the local plant diversity and care has to be taken to include sufficient number of individuals of the rarest species so that there is enough data on a species-by-species basis for detecting annual declines. The data from such exercises typically consists of frequencies or abundance of three categories of plants: trees, shrubs and saplings and seedlings. Analysis required for this type of monitoring is usually simple enough to carry out with paper and pencil. It is even possible for local communities to carry out such vegetation monitoring given a certain amount of training (see section on ' Participatory Vegetation Monitoring Systems' for details)

The advantage of a holistic monitoring procedure is that a wide variety of plant species can be studied and a large number of questions related to forest management can be answered, using the same set of permanent plots. For example, the status of rare medicinal plants, in an FPC can be monitored and depending on information from the given year, adjustments in harvesting can be made from time to time. At the same time, data can be obtained on regeneration of a tree species that are likely to suffer population declines due to fruit or seed collection.

(b) Systematic trial-and-error

Another approach to developing long-term management strategies for forest conservation in the study area is the establishment of experimental plots where specific management strategies can be tried out. In this scenario, a consensus has first to be reached amongst various stakeholders on the specific management goals for the FPC, such as maintaining the harvest of a particular NTFP species indefinitely, maximising biodiversity to reduce the indirect impacts of resource extraction on the forest ecosystem or optimizing sal pole production with respect to NTFP production. Management strategies would be devised based on the existing knowledge of the local ecology amongst local communities and researchers. Once the experiment is in place, regular monitoring has to be carried out to ensure that the objectives of ecosystem management for the area are being met.

An example of a management experiment where the ultimate objective would be to maximise forest biodiversity for long-term biological sustainability, is given here as an illustration. From all accounts and a basic knowledge of ecology, it would appear that maximisation of biodiversity of local flora and fauna could be achieved by establishment of a selective logging regime instead of the clearfelling operation that is currently in place for sal poles. Additionally, a few large trees of each species would be marked for preservation in each FPC so that they can reach reproductive maturity. These steps would ensure the maintenance of a certain degree of openness in the canopy and at the same time, lead to establishment of a more species-rich and multi-storeyed forest. Monitoring of economic values and biomass extracted from the forest by various stakeholders would be conducted alongside to assess the feasibility of such a management strategy in the long term.

Such experimentation with various management strategies may be possible in FPC's where the population density is relatively low and people can afford to keep aside some forest-land (of up to a hectare) for experimental purposes. Experience suggests that such experimentation is not an unrealistic idea. Researchers at the CNS in Midnapore have been successful in fencing off forest areas for long term studies even in areas with high population density (T.K.Mishra, pers. comm.). Observations also indicate that officials of the Forest Department may be cooperative in attempts to carry out experiments in the area. As an example, *Buchanania lanzan* saplings and trees have been preserved in Kamalapura FPC during the recent clear-felling operations in an effort to preserve this high-value commercial species.

c. Species-wise approach

As mentioned earlier, it is suspected (both by researchers and local people) that several plant species being collected for household or commercial purposes, may be endangered in south-western West Bengal. Thus along with ecosystem-level studies of indirect impacts, it may be necessary to study some species in detail, such as *Rauwolfia serpentina*, kalmegh and mahua, that are reported to be in decline in the study area.

A rapid method for finding out whether the population of a species is declining is to examine annual production figures for the given NTFP's at the district level. Assuming that there is little or no change in harvesting effort (measured as area of collection or time spent in collection) from year to year, a declining trend in collection may signal decline of the resource over time. This analysis may form the first cut in narrowing down the species that require detailed study. However, it remains to be seen whether the kind of data required for this type of analysis is available at all, as value of forest products is often quantified by government agencies in terms of economic returns, rather than volume.

As described earlier, all of the various types of resource extraction on plants ultimately lead to discernable effects on local population density and regeneration (girth- or size-class distributions; see Figure 1). Changes in population density with time can only be detected by long-term monitoring studies. Lack of regeneration due to seed collection can be detected in the early stages through an examination of girth-class distribution. A girth-class distribution refers to the frequency of stems in each size class measured by girths, in a given forest area, estimated through sampling. The shape of the curve formed by plotting these frequencies can give a preliminary idea regarding any problems in regeneration and therefore, future productivity of the product (Peters, 1994).

Species-level studies for sustainable extraction, require detailed data on local population densities, regeneration rates, resource productivity, and extraction levels and practices. Peters (1994) gives a lucid account of the studies required to calculate sustainable extraction limits for a given plant product. Ideally, a comparison of population density and regeneration of a plant species in harvested and unharvested areas would give important information regarding sustainability of resource extraction (Hall and Bawa, 1993). However, comparison between ‘pristine’ and harvested sites is often not possible under Indian conditions since the degree of harvesting often depends on accessibility and accessible areas are frequently also different in topography (which is one of the prime influences on local plant densities) (Freese, 1997; pers. obs.).

Koliyal (1997) studied the impact of fruit harvest on the regeneration of three commercially important species (amla, mahua and chironji) in dry deciduous Central Indian forests. The girth-class distribution of individuals in harvested sites in Betul (Madhya Pradesh) was compared with those of individuals growing in unharvested sites nearby located inside the Satpura National Park. Shankar et al (1996) and Murali et al (1996) also use comparison of girth-class distributions in harvested and unharvested areas, yield studies and population density for the calculation of sustainable extraction limits for fruit of amla (*Phyllanthus emblica*).

The disadvantages with this approach, which nevertheless, may have to be adopted in certain cases, is the intensive time and effort required to answer questions related to sustainable extraction. In addition, each locality would require separate studies, due to the spatial variation in plant productivity, plant species composition caused by differences in human use, soils and topographical gradients. Finally, long-term studies are required to incorporate the variability in plant productivity from year to year (see Freese, 1997).

Participatory Vegetation Monitoring

The IBRAD has undertaken pioneering work in village-based participatory vegetation monitoring for forest management in several FPC’s in Midnapore and Bankura districts since 1998 (IBRAD, undated). Initially, participatory vegetation monitoring was started as an exercise to develop a feeling of belonging and responsibility for local forests amongst village people through a process of learning and intra-village cooperation, apart from assessing the health of the forest. Vegetation monitoring is now being used to answer specific management questions and resolve disputes regarding resource use.

IBRAD researchers initiate discussions and the process of monitoring and with some training, data recording and analysis is usually taken up by the people themselves (D. Mukhopadhyay, pers. comm.). Since the local people are extremely familiar with the plant species occurring in the area, they have faced no problems in plant identification during the process of monitoring, an area that poses some difficulties to most university-trained biologists. It is also widely recognized now that the local communities have a comprehensive knowledge regarding the successional stages and ecological conditions necessary for different kinds of products, silvicultural practices for different forest products including fuelwood, poles and timber (Roychowdhury, 1998). They are therefore well-qualified for the role of designing and implementing vegetation monitoring exercises. Some examples of vegetation monitoring are set forth below.

Since 1996, people of Kapasgeria and Bethlota villages in Midnapore district have been involved in vegetation monitoring exercises initiated by scientists of IBRAD (Sarkar, Roy and Yadav, 2000). Specific objectives of the vegetation monitoring exercises were to first, to assess the biodiversity of the forest area under protection and second, estimate the relative abundance of economically important species in order to decide upon management strategies of species that are vulnerable to population declines. In these two villages, the process of vegetation monitoring is being undertaken regularly at six-month intervals so that the long-term effects of forest management can be assessed. Roy (undated a) describes several other cases where successful monitoring has been undertaken by scientists and local people, mainly for answering management questions. In the village of Bandhgaba, the issue of the detrimental impacts of the peeling of tree bark for tying headloads was resolved through vegetation monitoring. Through simple sampling methods, it was found that roughly 70% of trees in their forest had their bark peeled off which was likely to lead to high mortality rates in the near future. This piece of information galvanised the local people into action who then found alternative materials for tying of head-loads. In the village of Ghugimura, vegetation studies were carried out to study the effects of closing forest areas to cattle-grazing. Roy and Dey (1997) also report a case of successful monitoring by local people in the village of Moirapukur in Bankura district where the information gathered became a basis for initiation of discussions on the ecological impacts of forest protection and forest management practices. Roy et al (2000) describe a comparative survey across three different villages (Kapasgeria, Langmara and Bhagawatichowk) in Midnapore district carried out with the help of village people and aimed at ascertaining the effects of forest protection on vegetational diversity and biomass. An innovative study involving the monitoring of NTFP flows from a single village using the services of primary school children was carried out by Ramakrishna Mission Loksiksha Parishad (Mahapatra et al 1998; RMLP, 1999). The enthusiasm and energy among schoolchildren ensured that this was a highly productive exercise.

Although vegetation monitoring has been successful in several FPC's in the initial stages, there remain several questions with respect to sustainability of these initiatives on a longer time-frame and over a wider area. The final test of the success of these initiatives will be seen in the ability and interest of local communities in continuing the monitoring on their own after the initial few years and in the proportion of FPC's where it will be taken up on a regular basis. Another point of concern is whether local communities will be able to design and implement vegetation monitoring procedures on their own, in the future or whether continued involvement of researchers from IBRAD (or other institutions) will be required.

IBRAD has already laid the foundations for a robust, user-friendly and time-efficient monitoring system that has been tested in a variety of locales over the last few years. Now the challenge is to extend this monitoring protocol over the entire region of south-western West Bengal where JFM is underway. This can only be accomplished though widespread training and capacity-building programmes for FPC's involving discussion of the need for vegetation monitoring, demonstration of the procedures involved and consensual interpretation of results obtained.

CONCLUSION

There is a general lack of rigorous scientific research on the issue of biological sustainability of forest produce extraction from the sal-dominated forests of south-western West Bengal. A number of basic ecological questions require answering before realistic strategies can be designed for sustainable forest management in this region. The following areas require research urgently if the success of JFM is to be sustained in the long term:

- Distribution, population status and sustainable extraction limits of commercial NTFP resources that are considered threatened
- Estimation of sustainable forest area-to-household ratios for the sal region
- Effects of forest management practices (both in coppice sal forest and in plantations) on the local diversity of native flora and fauna, especially pollinators and dispersers
- Restoration of native forest in areas currently degraded and under plantations of exotic tree species
- Control of crop damage due to elephant migration through Midnapore district
- Reasons underlying failure of sal regeneration in the study area
- Sustainability of the sal felling cycle
- Effects of forest management practices on soil properties
- Effects of forest management practices on microbial ecology and nutrient cycling processes
- Ecology and control of invasive weeds in forests and plantations
- Sustainability and effectiveness of various participatory biodiversity monitoring procedures for ecosystem management
- Experimental testing of various forest management strategies for long-term biological sustainability

A high degree of empowerment amongst local communities, high levels of awareness regarding the need to conserve forest resources and the involvement of the intelligentsia in the issue of JFM in south-western West Bengal, have together created an atmosphere that is conducive for carrying out relevant ecological research addressing the issue of sustainable forest management. The issues in the region also offer tremendous scope for inter-disciplinary studies involving ecologists, economists, social scientists, geographers and others. Indian ecologists should take the present opportunity to undertake socially relevant ecological research in this area, which can go a long way in ensuring the sustainability of community forest management in the years to come.

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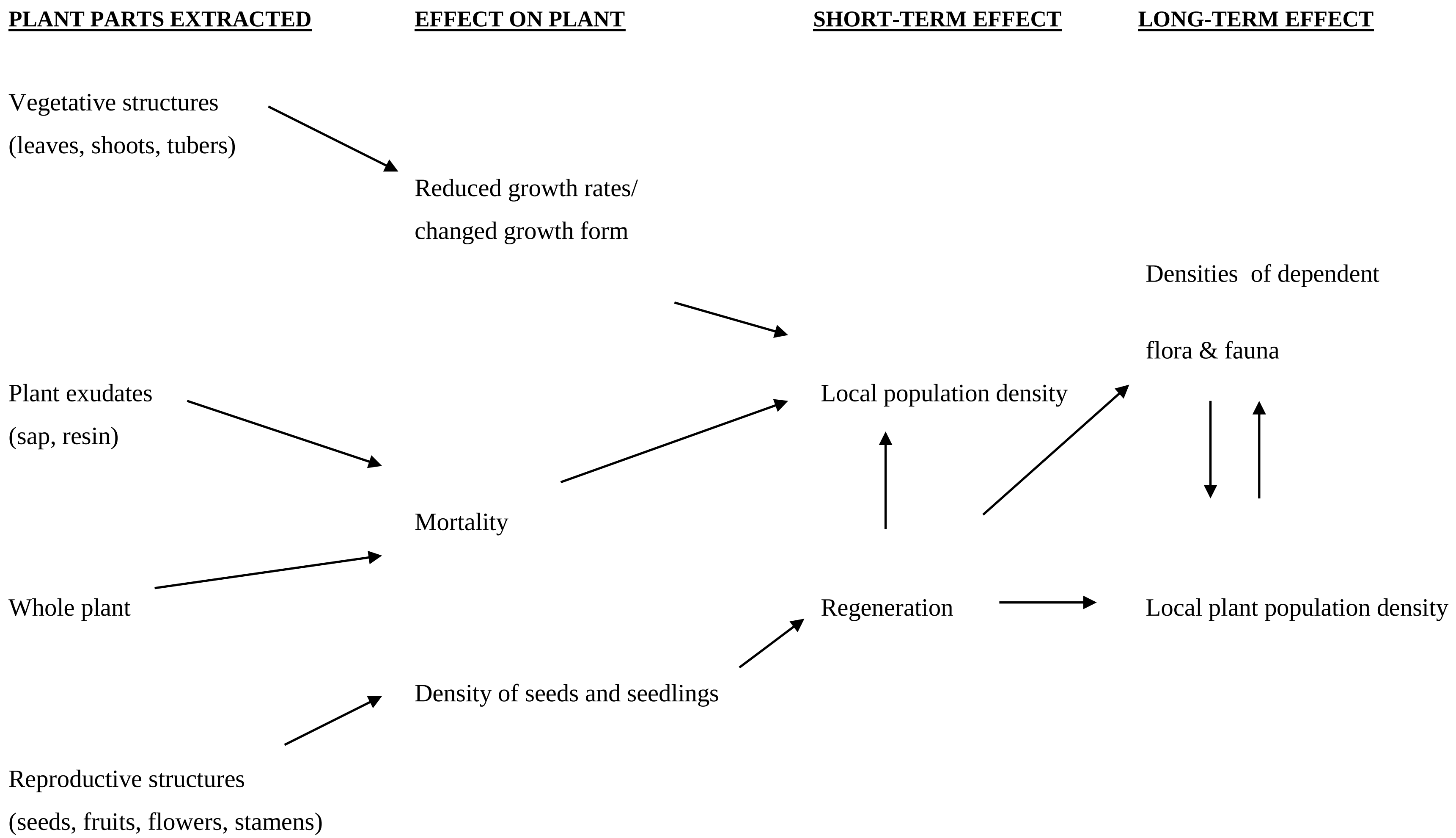
FIGURE 1: STUDY OF ECOLOGICAL IMPACTS OF FOREST PRODUCE EXTRACTION



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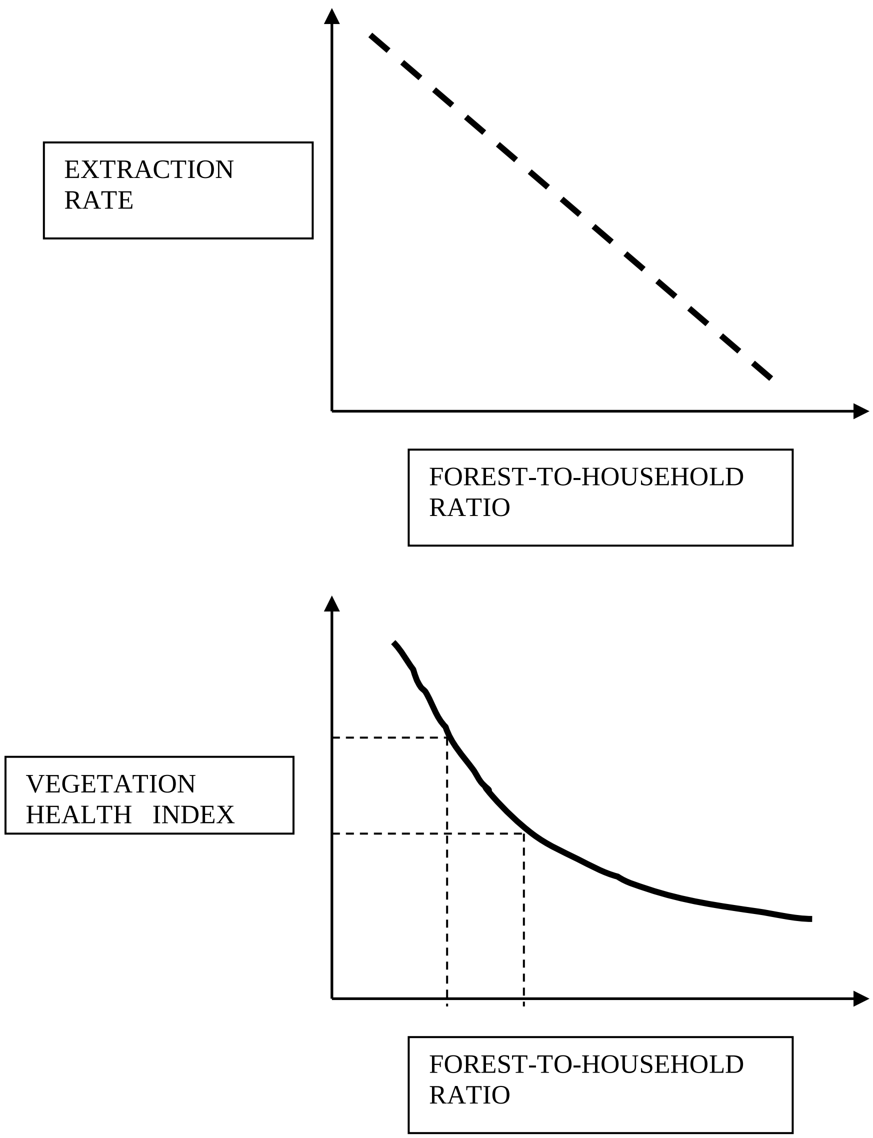

FIGURE 2. POSSIBLE RELATIONSHIPS BETWEEN EXTRACTION RATE OF A FOREST PRODUCT, VEGETATION HEALTH INDEX AND FOREST-TO-HOUSEHOLD RATIO