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Forest Insect Industry in Collaborative Forest Management: An Overview

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Abstract

In India, forest based insect enterprises has never been linked up with any forest management activity, either as a forest conservation strategy or to reduce the poverty in forested area. This investigation indicated that when forest dependent people are associated with forest insect industry (FII) like forest sericulture, lac culture or apiculture; this income generating activity links livelihood with forest conservation, and generates a viable model of collaborative forest management (CFM). In this model different stakeholders work together as a coherent entity for unified goal of managing the forest for well-being of the poor people in fringe areas. Article summaries and evaluates the prospect of India specific forest insect industry, and discusses how and to what extent integration of FII could be a viable livelihood component in CFM to conserve the forest and insect biodiversity. We analysed a case study on forest-based rearing of tropical tasar silkworm rearing in Central India from CFM perspective. Arguments in this communication are intended to provide forest managers and policy-makers with necessary input to consider location specific FII in CFM mode to provide a continuous source of small income to forest dependent people to ensure long lasting success of their forest management endeavours.

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Introduction

India is a nation with over 330 million poor people[1] (Thampi, 2012), a number that has barely declined over the last three decades of development. Forests in India support the household income of 833 million rural people (Census, 2011) in one way or other, but for about 200 million poor people[2] who live in 1.73 lakh fringe villages[3], forests are the only source for their livelihood (Nayak *et al*., 2012). High population density of India (382 person/Km^2) that is twelve time higher than the USA, reduces per capita forest availability to just 0.057 ha that is 11 time lower than the world average of 0.64 ha. Moreover, India with 2.5% of the world geographical area supports

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17.5% of the human population and 18% of the cattle population[4] in the world (Census, 2011). In India, two-third of the total forests is distributed in 188 tribal districts, where state of rural poverty[5] is more than 50% (FSI, 1997). Studies have indicated that majority of forest dependent regions in India are poverty ridden (Shah and Guru, 2004), and one such study suggested that fifteen out of the twenty poorest regions in India, remained in the list of poorest region right from 1983 to 2000 (Shah, 2010).

On the other hand, recent data of International Monitory Fund (IMF) shows that India overtakes Japan to become third-largest economy in purchasing power parity (PPP) during 2011after US and China (Banerji and Shah, 2012), and very recently, a US intelligence community report released on 10th December 2012 predicted that by 2030, surging India along with decelerating China, would straddle global commerce and dominate the world economy amid the gradual decline of the west Rajghatta (2012). However, report also cautions that existing inequalities between urban and rural sector would further widen due to infrastructural and educational deficiencies (NIC, 2012). In India, youth bulges are very high and in next 15-20 years, the country will be challenged very high to find new jobs for its large youth population[6].

Poverty in developing countries is the biggest problems and its alleviation is the greatest challenge for all governments. This study underlines the emerging role of forest insect industry (FII) in livelihood security of forest dependent people and evaluates the major impact of FII on forest ecology and management. We propose that location specific FII should be linked with CFM as a livelihood component to reduce poverty in forested area. Arguments in this communication are intended to provide forest managers and policy-makers with necessary inputs to consider FII as a viable commercial vehicle in CFM.

Materials and method

Comprehensive literature survey was carried out to observe the efficacy of forest insect industry in livelihood delivery of the forests in terms of improved household income and its impact on poverty reduction. Main findings ware considered to make an informed discussion about India specific viable FII. Results of Bhatia *et al*. 2011 on "Improving livelihood of tribals in Chhattisgarh: Adopted rearing of tropical tasar silkworm Antheraea mylitta Durry" is analyzed from CFM prospective.

Result and Discussion

Forest insect industry (FII) and its emerging role in poverty alleviation and forest management

In recent years, numerous actions for sustainable exploitation of forest resources have been undertaken (Muafor *et al*., 2012), but only few actions deals with commercialization of forest insects (De Foliart, 1992). Most studies on tropical forest insects focus on their distribution, abundance and the environmental goods and services they provide to humans (Hunter, 1999). Many people and some forest managers still consider insects mainly as a pest; however, they tend to be much less aware of the poverty alleviation potential of commercial forest insects. Forest insect industry (FII) is a labour-intensive activity that does not require any major capital investment or landownership and is more suitable for women and children living in forest fringe areas and in buffer zones around protected forests. Several tree based insects products like silk, honey, wax, lac, dyes, manna, etc can be linked with forest conservation activities to provide livelihood services of different economic scales to forest dependent people.

Many forest insects are popular foods in different cultures all over the world, but only few are commercialized (de Beer and McDermott, 1996). Women and children mostly collect edible insects from forest (FAO, 2012) and their trades makes significant contribution in household economy of many forest dependent people in Sub-Saharan Africa (Vantomme *et al*., 2004). The most commonly eaten forms of insects are larvae and pupae, and about 1 700 insect species are reported to be used as human food (Johnson, 2010). Worldwide, Coleopteran, Hymenopteran, Orthopteran, and Lepidopteron account for more than eighty percent of the total edible forest insect species, (Ramos-Elorduy *et al*., 1997).

Apart from the contribution of forest insects in food security, investigations have indicated that they contribute significantly to livelihoods earnings in both rural and urban areas (Stack *et al*., 2003). Forest insect collection, their processing, transporting and marketing provides business opportunities to an undetermined number of poor people around the world (Johnson, 2010).

In Central Africa, caterpillar of *Imbrasia* species that feeds on the leaves of sapele tree, *Entandrophragma cylindricum* are dried and sold for up to US$14 per kg (Vantomme *et al*., 2004). In southwest Cameroon many forest dwellers are engaged in

commercial beetle collection from different forest trees like *Vernonia amygdalina* Delile, *Vernonia conferta* Benth, *Carapa grandifolia* Sprague and *Nobotonia mannii* Benth and are earning a complementary household income by beetle's trading through intermediaries led marketing chain, which are further exported to Europe, Asia, and America, through internet business negotiations. Among all forest beetles, white forms of *Goliathus goliatus*, *Fornasinus aureo- sparsus*, and blue *Stephenocrates preussi* are the most expensive specimen that attracts very high pricing. Forest beetle collection has a nominal impact on forests insect ecology, because most often they are collected on a very small scale (Muafor *et al*., 2012).

Further, in Papua New Guinea (PNG), the Queen Alexandra's birdwing butterfly (*Ornithoptera alexandrae*) is exploited for the rural household income. The Papua New Guinean government has created an Insect Farming and Trading Agency (IFTA) that controls its conservation and trading to assure livelihood delivery of this forest insect to the local people. Caterpillars of birdwing butterfly feed only on *Aristolochia diehlsiana* vines found in lowland rainforest of northern PNG. Dead specimens in good condition command more than US$2000. IFTA yearly sales about US$ 400 000 worth of insects to collectors, scientists, and artists around the world and generates substantial livelihood earnings for the poor people. In PNG, the Queen Alexandra's birdwing butterfly has acted as a flagship insect species for forest conservation and attracting external funding for maintenance and establishment of forest reserves. In PNG, the local people have now learned the significance of maintaining forest habitat to increase their household incomes (Cranston, 2009).

The mopane worms (MWs), an edible larva of Saturniid moth, *Imbrasis beilina* is another forest insect species of mopane woodland in southern Zimbabwe, Botswana and in northern Transvaal, which is collected from *Colophosperum Mopane* tree to supplement the income of forest dependent people (Bradley and Dewes, 1993). Stack *et al*. (2003) analyzed the livelihood function of MWs in Southern Africa and found that that all categories of households in Zimbabwe, except to religious groups, takes advantage of MW collection as a free forest resource. Normally, MWs are collected by women and are used as food or sold for cash income to pay school fees or to purchase small items like kitchen utensils and clothing. Their livelihood analysis suggested the need for a technical and institutional innovation in mopane harvesting and trading to maximize its poverty reducing efficiency in different forest areas of Africa.

In Java, Indonesia, larvae and pupae of Asian weaver ant, *Oecophylla smaragdina* (Hymenoptera: Formicidae), called 'Kroto', is collected by the poor people from *Archidendron paucifloruma*, *Artocarpus* spp., *Mangifera indica*, *Lansium domesticum*, *Nephelium* spp., *Syzygium aqueum*, *Tectona grandis*, etc throughout the year for additional income. Kroto is used as songbird food and fishing bait, and in Jakarta, which is the main outlet for kroto in West Java; about 100 kg of *kroto* are sold every day (Holldobler, 1983). In Thailand and Philippines, larvae and pupae of *O. smaragdina* ants are eaten (Cesard, 2004) and in Bastar region of Chhattisgarh, India, its larvae are used as medicine for treatment of rheumatism and stomach infections (Oudhia, 1998). In addition to livelihood and medicinal function, *O. smaragdina* is also used as a natural control agent against insect pests of many tropical crops. Commercial collection of *O. smaragdina* does not affect its species richness in the natural forest, because ants have a quick population recovery, which is normally completed in 17-24 days (Paimin and Paimin, 2001).

Further, in northeast Thailand, around 3 000 poor families are engaged in the rearing of house crickets, *Acheta domesticus*, as a sideline business activity, and earning a year round income of US$ 130 to US$ 1 600 a month per family. Farmed crickets are sold in city markets of Bangkok to earn livelihood by poor people and are exported to cricket-consuming nations like Laos and Cambodia (Johnson, 2010).

In addition, bamboo borer caterpillar, *Omphisa fuscidentalis*; sago grubs, *Rhynchophorus ferrugineus*; grasshoppers, *Acrydium* spp.; dung beetles, *Heliocopris bucephalus*; vespa wasps, *Vespa* spp, silkworm species like *Samia cynthia*, *Antheraea proyeli*, *A. assama* etc are the other important forest insects, which are collected by the poor for food or for trade to earn cash income in different world region. Location specific forest insect industries can safely be integrated with CFM as a livelihood component to reduce poverty in many developing countries.

India specific forest insect industry (FII) and their livelihood potential

In India, commercial forest insect and their product have been traditionally associated with many tribal communities as a part time livelihood activity. However, in India, forest insect industry (FII) has never been linked up with any large-scale

forest management activity or as a forest conservation strategy to reduce poverty in forested area. Moreover, most of the forest managers have little knowledge about manipulation of forest vegetation or harvest practices to maximize or sustain the population of forest insect to derive their livelihood function. However, forest managers can choose FII as one of the strategic priorities to increase contribution of forest to improve household earnings of poor people in forested area and concomitantly foster its impact on forest management. Secondly, owing to inconsistent livelihood delivery of many traditional NTFPs in India, FII can be an additional livelihood option rather than sole reliance on NTFPs and third; commercialization of forest-based insect enterprises can create many employment opportunities for bulging youth population in rural India.

Among many forest insects, wild silkworms, forest honeybee, and lac insects have great promise in CFM. A brief account on how and to what extent these FIIs can be a beneficial adaptation in various geographical regions of the India are discussed below;

Integration of forest based sericulture (FBS) into CFM

Natural Silk, an insect protein fiber of silkworm cocoon marks class and excellence to the rich people but for the poor families who rear the silkworms and the reelers and weavers who finish it into eco-friendly textiles, silk stands for a natural source of livelihood. Commercial silk producing insects of order Lepidoptera are classified into mulberry and non-mulberry sector. In India, non-mulberry or wild silk is now called Vanya Silk that includes tropical tasar or Indian tasar silkworm, *Antheraea mylitta* Drury, temperate oak tasar, *Antheraea proyeli* J., muga silkworm, *Antheraea assama* Ww and wild eri silkworm, *Samia cynthia* Drury. All the vanya silkworm species are polyphagous and tasar and muga silkworms are reared outdoor on different forest tree species, however mulberry and eri silkworms are reared indoor.

Among all forest insect industry (FII) in India, forest-based sericulture (FBS) is the largest human-insect interactions in terms of associated insects and forest tree species, number of poor families linked with and the forest area that it relates. Silkworm larvae are reared or grown naturally on different forest trees in or outside the natural forest. Production process of FBS is divided into pre and post-cocoon sectors. Pre-cocoon sector is forest-based and on-farm activity dealing with protection and management of the forest host tree for silkworm rearing to produce cocoons for raw silk production; however, reeling, spinning (yarn production from cocoon), and weaving are the post-cocoon and off-farm activity.

In India, FBS can be an ideal livelihood avenue for forest dwellers due to its low gestation and high economic return feature (CSB, 2012) that can provide vibrancy to rural economy by satisfying the equity concern of tribal women in their society, because FBS is predominantly women oriented business. Efficiency of forest-based sericulture (FBS) can be enhanced by training the forest communities in skills necessary for scientific rearing of different silkworm species. State Forest Department (SFD) can link JFMCs[7] with State Department of Sericulture (DOS) for transfer of technology (ToT) and other extension support; Central Silk Board[8] (CSB) can be associated for area specific R &D, training support and supply of silkworm seed; Credible NGOs may be linked up to ensure fare marketing of cocoon or finished yarn on competitive prices through viable market linkages, because in Vanya silk sector, there is no competitive marketing and State operated marketing agencies are some time blamed for institutional corruptions. Therefore, SDF, DOS, CSB, and NGOs can work together as a coherent entity to promote an effective model of CFM for unified goal of managing the forest for well-being of the poor people.

Tropical tasar silkworm, *Antheraea mylitta* Drury

Forest rearing of *A. mylitta* D. uniquely suits to the forest dwellers in India and being a treasured tradition, it constitutes a way of tribal's life in tropical forest area of Bihar, Jharkhand, Chhattisgarh, Madhya Pradesh, Orissa and touching the fringes of West Bengal, Andhra Pradesh, Uttar Pradesh and Maharashtra (CSB, 2012). *Antheraea* species have built up different forms of ecological population called "ecorace" in all tropical moist deciduous, semi evergreens, dry deciduous and tropical dry deciduous forests in India (Rao, 2001) and till now, 64 ecoraces have been recorded (Rao *et al*., 2003). Among different ecoraces, Daba of Chota Nagpur plateau in eastern India, Raily of district Bastar in Chhattisgarh state, Sukinda and Bogai of Odisha, Sarihan and Laria of Jharkhand, Bhandara of Maharashtra and Andhra local in Andhra Pradesh are the important commercial ecoraces of *A. mylitta* D. (Rao *et al*., 2003).

Table 1. Performance of tribal women's tasar silkworm rearing in Surguja, Chhattisgarh

Year	No of forest dependent people	Reared DFLs* (Number)	Produced Cocoons (Number)	Total amount earned (`)	Per Farmer Income (`)
2002-03	38	3085	200000	1,11,880.00	2,944.00
2003-04	77	7000	272755	1,63,212.00	2,120.00
2004-05	87	7750	323180	1,85,769.00	2,135.00
2005-06	31	4600	157363	73,614.00	2,375.00
2006-07	50	4200	266649	1,70,081.00	3,402.00
2007-08	70	10730	526136	3,27,964.00	4,685.00
2008-09	70	10125	499970	3,20,429.00	4,578.00
Mean	60	6784	320865	1,93,278.43	3,177.00
SD	21.0	2967.7	141901.0	97255.0	1094.5
SE	34.72	43.74	44.22	50.32	34.45

*DFLs stands for disease free layings containing 200-225 eggs of tropical tasar silkworm. (Source: Bhatia *et al*. 2011)

In nature, *A. mylitta* D. is found on different 45 forest tree species being primary, secondary, and tertiary host plants. However, *Shorea robusta* Roxb., *Terminalia arjuna* Bedd., *T. tomentosa* W.&A. are primary host tree, *Lagerstroemia parviflora* Roxb., *L. speciosa* Pers., *T. chebula* Retz., *T. belerica* Gaertn., *Anogeissus latifolia* Wall. are the important secondary host tree (Suryanarayana *et al*., 2005), which are largely distributed in tropical and sub tropical forests of India. Egg, larva, pupa, and adult are the four stages of *A. mylitta* D. Larval period varies from 30-35 days in first crop (July-Aug), 40-45 days in second crop (Sept-Oct), and 50- 60 days in third crop (Nov-Jan). In addition to forest rearing, *A. mylitta* D also thrive naturally and tribal people collect cocoons in January when they are easily seen on leafless trees. One family can at least earn `13 000 per annum through cultivation of tropical tasar silkworm in the forest (MoEF, 2004), and if integrated package of rearing is followed, this earning can be increased up to `21 937.00 (Srivastav and Thangavelu, 2005). *A. mylitta* D. produces high quality natural silk that has some peerless qualities like controlling blood cholesterol, antibacterial functions, and UV absorption properties (Akai, 1998). Huge availability of Vanya silkworm's host trees (131.48 lakh ha) and associated number of large tribal families (2.35 lakh) provides an effective base for multiagency linked CFM in India, however, presently 95% of the total forest tasar flora (11.16 m ha) is still unexploited in India (Ojha and Panday, 2004) that constitute a vast scope to link JFMCs for tropical tasar linked CFM in India.

In order to assess the impact of forest-based sericulture in livelihood improvement of the forest dependent people, and the role of this activity on forest management; Bhatia *et al*. (2011) conducted a study in collaboration with multiple agencies in six villages of Surguja district from 2002 to 2009, where 423 forest-dependent families were covered. The involved agencies were State Forest Department (SFD), State Department of Sericulture (DOS), and Central Silk Board (CSB), Govt. of India. Their results shown that tribal women engaged in this activity were the poorest of the poor living below to the poverty line with an annual family income of `11,850.00 or less. Their seven-year's success story of forest based tasar Seri-business from 2002-03 to 2008-09 clearly indicated that there has been an aggregate per farmer average annual income of `3198.00=00, which stands around 27% of their total annual income. Considering the economic significance of time and energy spent by forest dependent people, this seasonal avocation of forest-based sericulture corresponded a tremendous impact in improving their livelihood earnings, especially women, to earn more and grow out of poverty and to curtail down the exploiting role of the local moneylenders (Table 1). They found that their seven-year continuous tasar silkworm rearing conserved the allotted forest area and their additional earnings helped them to improve their livelihood. In this way, different stakeholders worked together as a coherent entity for a unified goal of managing the forest for well-being of the poor people. It was a good example of linkages among govern-

ment agencies to manage the forest in CFM mode. In this way, different stakeholders worked together as a coherent entity for a unified goal of managing the forest for well-being of the poor people.

In their study, Bhatia *et al*. (2011) involved few of the Joint Forest Management Committees' members of six villages in district Surguja as a major stake holder; State Department of Sericulture (DOS) worked as a nodal extension agency; Central Silk Board (CSB), worked as a technological facilitator and provider of silkworm seed and; State Forest Department (SFD) acted as a chief coordinating agency. This amalgamation of classifiable entities facilitated the cognitive process of multiple knowledge system; insured constant flow of information; facilitated joint problem solving; created a network for learning; achieved a workable association between scientific and traditional management system and; ensured a beneficial adaptation in a complex socio-ecological condition. All these attributes of tropical tasar silkworm rearing (TTSR) promoted an effective model of CFM to re-harmonize the tribal communities with improved earnings.

Temperate oak tasar silkworm, *Antheraea proyeli* J.

Temperate oak tasar silkworms, *Antheraea proyeli*, *A. frithi*, and A. compta that feeds on different species of oak viz. *Quercus serrata*, *Q. dealbata*, *Q. griffithii*, *Q. incana*, *Q. himalayana and Q. semecarpifolia* (Singh and Singh, 1998) produces finer variety of tasar silk. In India, oak tasar silkworm rearing was started in 1970s, when *A. proyeli* was evolved by crossing *A. roylei* of India and *A. pernyi* of China. Oak forests (2.5 m ha) in India are distributed along the western sub-Himalayan range at 700-1500 m in Uttarakhand, Himachal Pradesh, Jammu and Kashmir, West Bengal, Manipur, Meghalaya, Sikkim, Assam, Arunachal Pradesh, Mizoram, and Nagaland (Jolly, 1970), but only 1% of the total oak forests are being used for rearing of oak tasar silkworms (Singh and Mishra, 2003).

In north-eastern states of India, rearing of oak silkworm is the major forest insect industry that play a crucial role in rural economy (Unni *et al*., 2009) and on an average, a farmer earns `4598.00 (Kant *et al*., 2004). Paucity of quality silkworm seed and lack of adequate extension support are the main constraint for development of oak tasar in India that is still in infancy and requires some concrete actions from SFD to link forest dwellers with DOS, CSB, and credible NGOs to increase its commercial viability. Oak dominating forests in India can generate additional livelihood opportunity for 1.5 lakh poor people to arrest their migration from sub Himalayan region to urban area.

Muga silkworms, *Antheraea assama* Ww.

A. assama Ww. is a semi domesticated multivoltine forest silkworm species endemic to northeast India and Indo-Burma region (Ahmed et al., 1998). Muga silkworms produce attractive golden hue silk that is famous for its lustre, UV resistance, and tensile strength properties. After *A. yamamai*, the Japanese tasar silkworm, muga silk is the second most expensive silk in the world. In whole world, muga silkworms are confined only to the natural forest in Brahmaputra valley of Assam and foothills of east Meghalaya and about 30 000 families are engaged in muga culture. Primary host tree of A. assama Ww. includes *Litsaea polyantha*, *L. citrata* and *Machilus bombycine*, whereas *L. salicifolia*, *Cinnamomum glaucescens*, *C. glanduliferum Actinodaphne obovata*, *Michelia champaca*, *Magnolia sphenocarpa*, Zanthoxylum rhetsa, *Gmelia arborea*, *Celastrus monosperma*, *Actinodaphne angustifolia* are the secondary host trees. When *A. assama* Ww. feeds Mejankori (*Listaea citrate*) leaves, it produces a special kind of silk known as *mejankori silk*, which is admired for its durability, lustre, and creamy white shade (Jolly *et al*., 1974). Life cycle of *A. assama* Ww. lasts for 40-50 days in summer and 110-120 days in winter, and normally 4-5 crops arc taken in a year. The average holding of muga plantation by a farmer in Assam is less than half an acre, but it is intact as such since last 20 years (Chakravorty, 2004).

Literature survey indicates that *L. monopetala*, a primary food plant of *A. assama* Ww. is uniformly distributed throughout Uttarakhand state at 800-2700 m. Khatri *et al*. (2004) conducted experimental rearing of *A. assama* Ww. and harvested 3470 cocoons from 100 DFLs (one disease free laying contains about 200 eggs). This productivity is comparable with the average productivity of *A. assama* Ww. in Assam. This study indicates that *A. assama* Ww. can be promoted by SFD through institutional linkages of DOS, CSB and NGOs in Uttarakhand state, where only 14.02% of the total reported area (53 485 Km^2) is under agriculture and majority of the people are forest dependent. Muga silkworm rearing is very remunerative and a farmer can earn `37

500.00 from 150 tree by conducting two crop in a year. This income can be doubled, if cocoons are converted into yarns (Singh and Sinha, 2000).

Eri silkworm, *Samia cynthia* Drury

Wild eri silkworm Samia cynthia D. syn. *Philosamia cynthia* Grote is univoltine or bivoltine wild silkworm species found on different forest tree species like *Heteropanax fragrans*, *Manihot* utilissima, *Evodia fragrance* in Assam, Manipur, Bihar, West Bengal, Odisha, Andhra Pradesh, and Karnataka, and 1.5 lakh poor families are engaged in eri sector. Ericulture in northeastern states of India is mainly practiced for protein rich edible pupae; a delicacy for the tribal's, and produced silk is treated as by-product.

Eri silkworm is the only wild silkworm that is domesticated indoor up to an altitude of 1525 m, where larval period lasts for 30-40 days. Host tree leaves are hung over the rearing tray and larvae climb and feed the leaves. Cocoon filament of eri silkworm is neither continuous nor uniform in thickness, which is hand reeled only. Tribals use produced silk indigenously for preparation of chaddars (wraps). Eri silk can be blended with cotton, wool, jute, or mulberry silk for jackets, suiting materials, furnishings, etc. Owing to polyphagous nature, hardy breed characteristics and indoor nature of rearing, eri silkworm raring can be integrated at large scale with CFM all over India.

Forest based sericulture (FBS) and Indian Forest (Conservation) Act, 1980

Recognizing the role of FBS in livelihood support to the poor families and contribution of this activity in forest conservation, Ministry of Environment and Forest, government of India issued guidelines for vanya silkworm rearing under Forest (Conservation) Act, 1980. According to this act, plantation of forest trees on which vanya silk worms could be reared without undertaking a monoculture plantation shall be traded as forestry activity, and no prior permission of the Central Government under Forests (Conservation) Act, 1980 is required. Provided that, such plantation do not involve any felling of the trees and while undertaking such plantations, at least three species are planted of which no single species covers more than 50% of the total planted area (MoEF, 2004).

Forest based sericulture and forest ecosystem

Forest based silk products are generated through ecological interactions between wild silkworms and their host trees. Insect eating green tree leaves in forest is an integral part of the forest ecosystem. Population build-up of insects are regulated by biotic, abiotic, density dependent, and density independent factors, and if natural regulatory mechanisms like parasites, predators, and pathogens are active, insects do not attain the status of pests and their population remains below to the economic injury level (EIL). There is no record that any saturniid has ever caused an outbreak in forest.

Functionally, annual primary production is an indicator of healthy forest ecosystem and forest productivity is the function of leaf area index (LAI). However, relationship between LAI and photosynthesis is not linear, because due to self-shading some leaves of the tree canopy receive so little light that their rate of respiration exceeds the rate of photosynthesis, which declines the function of net primary production against LAI. High leaf availability and corresponding increase in gross photosynthesis at high leaf area index is offset by increased respiration (Odum, 1975).

Silkworms are reared on forest host tree in small compact patches at outskirts of the forests and host trees are used once a year for 30-60 days. Host tree suffers a temporary photosynthetic loss, but the total production of forest stand does not likely to be affected, because foliage loss after silkworm feeding allows understory trees and other ground flora to get much light that compensates temporary photosynthetic loss of partially defoliated host tree. Secondly, after silkworms' feeding, secondary foliage grows in 30-45 days and foliage losses are not only compensated, but the total LAI exceeds in comparison to the un-damaged trees. Third, the thickness of the secondary foliage is less than the primary foliage and has better photosynthetic efficiency in comparison to the older leaves, which were consumed by the silkworms. Fourth, increased longevity of newly grown leaves on silkworms' fed trees extends the usual leaf fall period and this extended period of leaf on crown provides a positive photosynthetic gain to the utilized host tree. Therefore, as far as the foliage loss is concerned, new foliage offsets it and apparently, no loss takes place in annual primary production of the forest due to silkworm feeding. Furthermore, the roots of host trees grow more vigorously by utilizing increased nutrients contents due to

enhanced microbial activity on larval fecal materials at the forest floor. Bhandari (2003) reported that forest silkworms are forest insects and have no adverse effect on growth and increment of the forest.

Integration of forest based apiculture (FBA) as a livelihood component in CFM

Honeybees are the important pollinators that ensure functioning of many ecosystems. According to FAO (2009), honeybees pollinate one third of all the plant products consumed by the humans. In US, Berenbaum (2007) estimated that bees pollinate over 90 crops for a value of more than US$15 billion in a year. All the four species of honeybee viz., *Apis cerana*, *A. mellifera*, *A. florea*, *A. dorsata* are found in India, but forest bee, A. dorsata (Sivaram *et al*., 1993), contributes the major portion of honey. However, commercial exploitation of forest bee is very limited (Sivaram & Anita, 2000). In forest, *A. dorsata* build single comb attached to the branches of many forest tree species and their nests are up to one meter wide (Rouquerte, 1995). It is estimated that around two million *A. dorsata* colonies are available in forests all over India (Thomas *et al*., 2001) that can be exploited in scientific way to create an additional income for forest dependent people.

Beekeeping is not a labor-intensive activity and can easily be accommodated in the daily routine of forest dependent people. Bee keeping has high earning potential where one can earn `1 70 000 from 100 bee colonies @ 20.11 Kg honey per hive and according to Sivaram (2012), if these colonies are put under diversification plan, this profit can be further increased up to ` 3 19 150 per year. Beeswax is twice costlier than honey; bee-collected pollen, propolis, bee-venom, and royal jelly are several times costlier than beeswax; and all are in great market demand. Honey can be easily stored, sold, or consumed in the times of need.

Forests are known to provide organic honey, nectar, pollen, and propolis of high quality without any insecticidal residue that can be sold at premium prices in western markets through viable market linkages under CFM. In India, forest dependent people apply a very crude and destructive method of honey hunting to earn their livelihood and contribute 45.85% of the total honey production (85 000 MT) (Sivaram, 2012). They crush and squeeze the comb along with larvae and pollen grain that makes honey turbid and fetch low market price. Secondly, 40-50% forest bees discontinue their breeding cycles every year due to unscientific honey harvesting. Third, honey hunters use fire to facilitate honey collection that some time constitutes a source of forest fire.

FBK can be promoted through collective action of SFD, JMFCs, FRIs (Forest Research Institutes), and NBB (National Bee Board) in an adoptive CFM module, where forestry people and apiculture scientists can work together for safe honey extraction in forestry sector. FBK can increase the customary use of forest resources for equitable benefits sharing, forest conservation and poverty alleviation in forested area of the country. The important areas of interventions are capacity building for improved honey production, adoption of improved technologies for migratory bee keeping, nucleus stock maintenance, processing, and quality control of bee products. Beekeeping can be introduced as a special scheme in reforestation programmes by paying special attention to use native melliferous forest tree species to provide rich and varied source of nectar and pollen for forest honeybees. Secondly, bee-reserves can be established with exclusive access for beekeepers, as has already been done in United Republic of Tanzania (MNRT, 1998).\

Integration of forest based Lac culture (FLC) in CFM to alleviate poverty in tropical India

Lac is the only known commercial resin of animal origin secreted by female scale insect *Laccifer lacca* Kerr (Hemiptera: Lacciferidae). Lac is an eco-friendly non-toxic product and has many industrial applications like natural dye, oil painting, candy coatings, leather finishing, electrical insulation, glue for glass and metals, hair spray, coating of pills and processed food etc. Stick lac, seed lac, shellac, button lac, garnet lac, bleached lac are the different forms of the lac. India is the principal lac producing country in the world and produces 20 000 metric tons of raw lac annually that fulfils 60% of the world demand, besides domestic consumption. In India, Jharkhand, Chhattisgarh, West Bengal, Uttar Pradesh, Madhya Pradesh, Maharashtra, Bihar, and Odisha are the major lac producing states that contribute 90% of the total lac production.

Lac insects are reared on *Butea monosperma*, *Zizyphus marutiana*, *Schleichera oleosa*, *Acacia catechu*, *A. arabica* and *A. auriculiformis*, which can be raised and utilized for rearing within

5-6 years of plantation. Like forest silkworms, lac insects are also a pest on their host trees, but they enjoy a privilege for not being treated as pest, because insect's damage is temporary and provides household earnings to the poor people in forested area and also helps to protect forest and improves biodiversity. Six month's life cycle of lac insect passes through egg, nymph, pupa, and adult stages. Crimson-red first instar nymph called crawlers start secreting resin from the glands distributed under cuticle throughout the body, except mouthparts, breathing spiracles, and anus. The resin secreted is semi-solid that hardens on exposure to air into a protective covering. After life cycle is completed and next generation is about to begin, the resin encrusted branches are scraped off, dried, and processed for various lac products. A portion of brood lac is retained for the purpose of inoculation to new trees. To produce 1 kg of lac resin, around 300,000 lac insects give up their life.

Lac cultivation is simple that does not require any large investment and needs only part-time attention. The mean lac productivity varies from 1-10 kg per tree depending on host tree species and climatic conditions. Average net profit from one tree is `109 for *B. monosperma*, `202 to 1 060 for *Z. mauritiana* and `1 320 for *S. oleosa* per crop cycle (Sharma *et al*., 2006). In some cases, livelihood contribution of forest lac culture can be as high as 30-55 % to the total annual cash flows (CSTRD, 2012) and in Jharkhand, 20-38% of total income of poor tribals are contributed by lac cultivation (Sharma *et al*., 2006).

Transfer of technology (ToT) to deep tribal hamlet and timely supply of the quality brood lac are the important interventions to augment lac production in India, which can be ensured through institutional linkage of JFMCs with lac related R&D institute like Indian Lac Research Institute, Ranchi. Presently, only 15% of the available lac host trees are being utilized for lac cultivation. There is a vast potential for lac linked CFM in India.

Forest insect industry (FII) and insect biodiversity

Insects constitute more than fifty percent of the total biodiversity in tropical forests (Novotny *et al.*, 2006) and have enormous economic value in terms of ecological services they provide to humans. In a study, the total annual value of insects' services in United State amounted to more than US$ 57 billion (Losey and Vaughan, 2006), and if such a study is extended to entire world, the total value of insect services would be staggering. In comparison to the most temperate ecosystems, tropical forests are characterized by extraordinarily high insect diversity (Novotny *et al*., 2002) and their rate of degradation and destruction are higher than any other biome (Sala *et al*., 2000). Combination of these two facts indicates that the potential loss of insect diversity in tropical forests through anthropogenic actions is enormous and FII in tropical forests can compensate these losses of insect biodiversity up to some extent.

Diversity in the life style of an insect shows its capacity to adjust in different ecological conditions. For example, biodiversity of tasar silkworm reveals its potentiality and the genetic adaptability through interaction with environment to struggle and sustain in varying ecological niches through evolution of regional ecoraces. Overall, forest insect industry (FII) has a favorable impact on the conservation of insect and their habitat. For example, Holden (1991) observed a reduced frequency of bushfires in caterpillar harvesting areas of Zambia, where villagers sought to protect the sustainability of insect populations in natural forests. It is also reported that few edible insects enhance their habitat in specific ways, e.g. leaf-cutter ants in South America cultivate fungus gardens that convert cellulose into carbohydrates and in Africa, termites increase local plant species diversity, because some plants can only grow on termite mounds (De Foliart, 1997). Forest insect industry (FII) promotes conservation of insects in forest ecosystem by maintaining and encouraging the forest reserves by utilizing the forest buffer zone and it helps in maintaining heterogeneity of landscape by promoting concept of land sparing outside the forest reserves area (Samways, 2007).

Why and how to accommodate forest insect industry in CFM

Improved incentives encourage participation of local people in CFM

Forest insect industry (FII) has tremendous potential to contribute household income of forest dwellers in developing country. However, to link conservation with livelihoods, it requires an implementation model. Incentive linked forest management model acts as driving force for conservation and encourages the local communities to participate in forest management that provides them a direct stake in conservation efforts (Salafsky and Wollenberg, 2000). Such incentives become most attractive, when they are derived from sustainable

use of forest biodiversity without threatening its resource base. Forest insect industry (FII) is a good option to realize these benefits, because it gives quick rewards and use renewable forest resources. Second, FII is technically simple and easily adoptable. Third, it encourages women participation and does not produce any chemical effluents in whole production process. Fourth, FII can serve a safety net function by creating employment to avoid poverty, and some of the poor people may grow out of poverty through continuous household earnings.

Institutional linkages encourage multi-governance mechanism under CFM

Community based conservation is conceived and implemented only at the local level and community institutions are only one layer in a multi-level world (Berkes *et al*., 2006). However, local community can be used as an abridged label for decentralized governance that starts from ground level and involves a network of interactions at various upper levels. Institutional linkages is an important aspect for co-management, because such linkages provide ways to deal with multi-level governance (Kooiman, 2003); have multiple objectives (Brown *et al*., 2005) and deliver multiple knowledge systems to creates a network for learning and joint problem solving (Carlsson and Berkes, 2005).

CFM encourages democratic way of functioning

Integrating the goals of forest conservation with livelihood requires capacity building that can be effectively addressed in CFM. Working together of different agencies addresses several socio-economical issues and decelerates tribal migration from forested area. Institutional linkages under CFM encourage democratic decision-making process and all the stakeholders have space and capacity to make them heard. Secondly, they communicate and transfer their knowledge and skills in multiple directions. Third, they jointly act to manage a conflict and fourth, there is a shared and intentional social learning and experimentation in forest management process, planning, and decision-making that clearly reflects a link to the desired future (Fisher *et al*., 2007).

There is a good scope to integrate FII with CFM in India

In India, about 13 m ha forests are available with silkworm related forest flora as dense, open, and scrub forest (Srivastav and Thangavelu, 2005) that can be utilize to expand economic benefits of forest based sericulture (FBS) to a large number of forest dependent people. *Secondly*, forest sericulture, apiculture and lac culture can serve as an alternate for Shifting or Jhum cultivation (slash and burn cultivation) that is practiced by 4.433 lakh families as a livelihood activity. Shifting cultivation involves 3869 km^2 forest area annually in northeastern states of India (Tripathi and Barik, 2003). Earlier, shifting cultivation cycle was for 15-20 year, which has now reduced to 2-3 years only and is causing large-scale deforestation and loss of insect biodiversity. If shifting cultivating poor tribals are linked with location specific forest insect industry under CFM module, the problem of shifting cultivation and its associated ecological losses can be reduced.

Third, edible insects collected from forest are generally clean and free from chemicals and are the cheapest source of protein compared to animal meat and fish. In India, edible insect are largely consumed in northeastern region and there is almost no entomophagy in rest of India. However, there exists a very good scope to widen economic potential of edible insects for a large number of poor people in forested area through their collection or by commercial rearing for cash income through evolved market linkages with insect consuming countries. Rapid reproduction rate and high fecundity feature of forest insects are the preferable commercial traits to use them in forest insect industry.

Fourth, forest management strategy that could promote dual product systems for example, eri silkworms for natural silk fabric and pupae as food; honey, beeswax, propolis, bee-venom, and royal jelly as a commercial product and honeybee brood as food, etc can be prioritized under CFM.

Conclusion

JFM is the principal forest management strategy in India, but its potential for forest management and livelihood delivery is declining due to lack of institutional linkages and want of incentives to encourage community participation. JFM in India can be better utilized for location specific institutional linkages to realize commercial viability of FII. State Forest Department (SFD) may join other organizations beyond the forestry sector to reduce poverty in forested areas. Associative relation between different agencies with local community can better identify the hidden livelihood opportunity in the forest area and their viable integration can change the attitude of local communities by

demonstrating the real potential of forests in terms of improved earnings. Such initiative by forest managers and policymakers will make forest-edge communities to aware of the precious value of forest insects in their life and the need to safeguard them; and by learning about the role of these commercial forest insects in forest ecosystems, people will better understand and appreciate the value of forests.

Endnotes

1. As per Census 2011, total population of India is 1210 million, equal to the combined population of USA, Brazil, Indonesia, Pakistan, Bangladesh, and Japan.

2. There is no census figure for forest dependent population in India. Different estimates put the figures from 200 million (See ICFRE, 2012) to 400 million (See MoEF, 2009).

3. As per the 2011 census, there are 6.41 lakh total villages in India.

4. As per the 18th Livestock Census 2007, livestock population of India is 530 million (See MoA, 2010). Thirty eight % of livestock depend on fodder derived from forest by direct grazing or by harvesting (See ICFRE, 2012).

5. In India, anyone monthly earning below to `672.8 (`22.42 per day) in the rural area and `859.6 (`28.35 per day) in the urban area is considered below the poverty line. Bihar (53.5 per cent), Chhattisgarh (48.7 per cent), Manipur (47.1 per cent), Jharkhand (39.1), Assam (37.9 per cent), and Uttar Pradesh (37.7 per cent) have high incidence of poverty. Among social groups in the rural areas, Scheduled Tribes suffer the highest level (47.4 per cent) of poverty, followed by Scheduled Castes (42.3 per cent) and Other Backward Castes (31.9 per cent) as against 33.8 per cent for all classes. In rural Bihar and Chhattisgarh, nearly two-third of the SCs and STs are poor where as in Manipur, Odisha and Uttar Pradesh it is more than 50 per cent. (See Planning Commission, 2012).

6. Over 35% of India population is below the age of 20 and 70% of India's population is below the age of 35 years (See Census, 2011). By 2020, it is expected that 325 million people in India will reach working age, which will be the largest in the world.

7. JFMCs are village-level institutions of forest communities that are constituted democratically for the protection and development of forests and sharing of the benefits arising out of the managed forests, including NTFPs.

8. Central Silk Board (CSB) is a statutory and autonomous body under the administrative control of Ministry of Textiles, Govt. of India. CSB is an apex body, with responsibility of overall development of silk industry and sericulture in India.

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