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Development of novel tasar cultivation zones and conservation of vanya silkworms in ecologically-restored sites within degraded mined-out areas of Purnapani, Odisha

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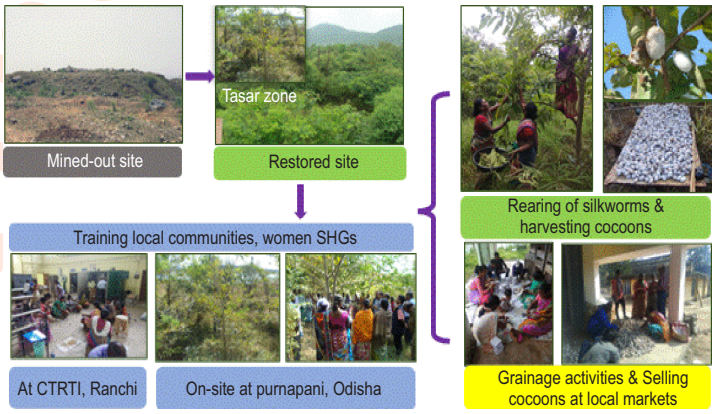
Abstract

Aim: The aim was to develop tasar cultivation zones by introducing diverse tasar host plant species at mined out sites undergoing ecological restoration for generating sustainable livelihood option for local tribals.

Methodology: The site selected for *vanya* sericulture was an integral part of ecologically restored 250 -acres limestone/dolomite mined out area of Steel Authority of India Limited (SAIL).Tasar cultivation zones were developed by planting saplings of host plant species viz, *Terminalia tomentosa* (Roxb.) ex DC., *Terminalia arjuna* Wright & Arn., *Terminalia belerica* (Gaertn) Roxb, *Ziziphus mauritiana* Lam., *Terminalia chebula* Retz. and *Syzygium cumini* (L.) Skeels. These cultivation zones are currently scattered among nine forest communities that were developed by growing saplings of more than 260 native species of trees and shrubs, besides ground vegetation, using ecosystem approach. Women self-help groups were formed and trained in rearing of tasar silkworms as well as making tasar-based products to ensure continuous practice of tasar silkworm culture at these novel cultivation zones.



Results: During early ecological stages of ecosystem redevelopment through restoration of the habitat, it was observed that wild tasar moths laid eggs and silkworms spun cocoons, albeit in very small quantity, indicating suitability of foliage as food for larvae. In the year 2019-2020 alone, an estimated one lakh cocoons were produced from DFLs procured from CTRTI, Ranchi,and sent to the market/stored as seed cocoon. The average income per member of self-help group from sale of tasar cocoons was Rs 7, 855 (INR) annually.

Interpretation: The restored ecosystems in the limestone/dolomite mined-out areas of SAIL at Purnapani serve as an excellent model for conservation of Tasar gene pools and sustainable livelihood development that can be replicated elsewhere. Hence, this practise can serve as an excellent model for replication elsewhere

Key words: Biodiversity, Ecological restoration, Livelihood, Mined out areas, Self-help group, Tasar silkworm

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Introduction

Land degradation is an issue of global concern and one of the biggest threat to human civilization in the 21st century. According to Tilauhun and Zewide, (2021) millions of hectares of productive land are being degraded every year and this includes 30% of forests, 20% of all cultivated areas, and 10% of grasslands which impact over 33% of the earth´s land surface and over 2.6 billion people globally. Estimated land degradation in India due to mining is about 36 lakh ha of land, which is 0.11% of total land area of the country (Singh, 2004). In Odisha, 50% of deforestation (which accounts for 17% of the deforestation of the country) occurred between the years 2001-2019 due to mining-related activities (Mishra *et al.*, 2022). According to World Environment Forum (WEF, 2020) degradation of ecosystems leads to significant alteration in local food chains and food webs threatening biological diversity and peoples' livelihoods. In degraded ecosystems, native plants including host plants of insects have been vanishing, while exotic and/or invasive species have been colonizing fragmented patches (Lindenmayer and Fisher, 2006; Bennett and Saunders, 2010). Loss of habitat not only affects specialist insects that occupy particular ecological niches (like local eco-races of vanya silkworms), but also other common and generalist species (Sánchez-Bayo and Wyckhuys, 2019). The forest ecosystems with rich flora and fauna are home to indigenous primitive tribal peoples who are dependent on forests and forest produce for livelihoods and survival (Panda and Barik, 2011; Dalei and Gupt, 2014).

These ecosystems are also mineral rich and hence, extensively exploited for extraction of georesources through open cast mining leading to degradation of the ecosystems and loss of livelihoods. The United Nations (UN) has responded urgently to the ecological crisis caused by anthropogenic destruction of natural ecosystems by declaring the year 2021–2030 as the UN Decade on Ecosystem Restoration (Lengefeld *et al.,* 2022). "Ecological Restoration" refers to bringing back the dead or degraded ecosystem to its original state with realistic biotic and abiotic thresholds that render it functional and sustainable (Gann *et al*., 2019). Ecological restoration of degraded ecosystems such as mined-out areas is a pressing issue, fueled by the need for rehabilitation of denuded lands; conservation of flora, fauna, and genetic resources; restoration of biodiversity and ecosystem services, and mitigation of climate change (Van Oosten, 2013; Locatelli *et al.,* 2016). The contribution of ecological restoration programs is phenomenal as it not only heals the ecosystem but can also open opportunities for local livelihoods through sustainable harvesting of ecosystem goods and services (Fischer *et al.,* 2021).

Tasar cultivation has emerged as the most viable source of income with minimum investment, and high returns in tribal areas of Eastern and Central India (Jolly *et al.,* 1975; Nath and Modak, 2022).The occupation of rearing of tasar silkworms for cocoons, and its trading has been a part of the socio-economic and cultural practices of tribals in Odisha since times immemorial (Mohanty, 2003; Suryanarayana and Srivastava, 2005). In Odisha, tasar silkworm rearing is being carried out both in wild and semi-domesticated conditions. *Antheraea mylitta is,* a semi-domesticated species has two commercially cultivated ecoraces, Daba and Sukinda. The ecoraces Nalia, Barharwa, and Modal are cultivated as wild varieties (Jolly *et al.,* 1975; Alam *et al.,* 2018). The host plants of tasar silkworm includes *Terminalia tomentosa, T. arjuna, Ziziphus mauritiana* and *Shorea robusta* (Renuka and Shamitha, 2015). Livelihood generation through *Vanya* sericulture is particularly suitable for tribal women as it is a nature-based technology that can be understood easily and adopted by tribal community (Yadav and Jadhav, 2017; Nath and Modak, 2022). According to Hugar *et al.* (2013), training in rearing-related activities can lead to skill development and capacity building, which are integral components for successful implementation of tasar cultivation.

Any successfully restored ecosystem should have a strong component of biodiversity conservation, and productivity in the form of ecosystem services and goods, as this can ultimately empower the concerned local community through livelihood options (Fischer *et al.,* 2021). A successful ecological restoration project often requires the participation of a variety of stakeholders with diverse interests and expertise, but working for the same cause (Weng, 2015). The present paper highlights establishment of *Vanya* sericulture zones and concomitant economic benefits to local people within the larger framework of a successful ecological-restoration program that transformed a former degraded mined-out site in Purnapani, Odisha, into a productive natural ecosystem. This is perhaps the first report on the successful restoration of a mined-out areas where conservation of biodiversity is integrated with the sustainable livelihood of tribal community through tasar cultivation.

Material and Methods

Site description and local livelihood pattern survey: Purnapani village is a part of Sundergarh district of Odisha and is located near Odisha-Jharkhand Border area (Fig.1). It is approximately 30 km away from Rourkela by road. The project area (N22 °24'47.28" E84 °52' 11.4"using Garmin eTrex Vista® H GPS) is part of a limestone (dolomite) mined-out areas of Steel Authority of India (PL&DQ) at Purnapani. The mined-out areas include degraded over-burden dumps (OBD) and voids containing water with no or scarce biological productivity. OBDs were infested with weeds such as *Lantana camara* and *Chromolaena odorata*, etc. and a few scattered trees of *Acacia nilotica*. The site is surrounded by degraded reserve forest area where tribal community live. Approximately 250-acres of OBD mined-out areas and 200-acre mine void reservoir were selected for the ecological restoration. A socio-economic pilot survey was carried out to assess the livelihood patterns during pre- and post-mining periods. The local people were an integral component of the forest ecosystem (Dalei and Gupt, 2014;Ticktin *et al.,* 2018). Accordingly, a site-specific restoration plan was prepared based on the local vegetation types, soil, climate, and needs of the local communities (Fig. 2).

Development of novel tasar cultivation zones: The primary aim for ecosystem redevelopment was to bring back characteristic flora and fauna of the area. The structure and composition of plant communities were formulated in a way to match the existing neighbourhood reserve forest, and pre-mining status. At least one thousand saplings each of more than 260 native species of trees and shrubs at a density of 4000 plants per hectare and ground vegetation characteristic of local forest communities were introduced at the restoration sites (Fig. 2a,b). The tasar cultivation zones were developed as two separate blocks of 20 acres each within the restored areas by introducing saplings of host plant species, especially, *T. tomentosa* (35%) and *T. arjuna* (35%) of the total number of individuals to form forest communities dominated by the primary host plants of tasar silkworm. *S. robusta, Z. mauritiana, T. bellerica* and others species make up remaining 30% of the communities developed (Table1). These plantation areas (tasar cultivation zones) were developed to provide an alternative livelihood for the local community by rearing and harvesting and marketing of cocoons of tasar silkworms. The saplings were inoculated with the forest soil and broth culture of plant growth promoting microorganisms. The ground cover was also established to an extent of 95% at this site.

Formation of self-help group & Tasar sericulture training: Tasar cultivation is a labour-intensive occupation. It involves interlinked activities such as plantation of host plant, rearing of silkworm, transferring of silkworm, harvesting of cocoons, cocoon preservation, grainage activities, and post cocoon associated activities such as yarn making, weaving, and processing of fabric (Ahmed and Rajan, 2011; Dewangan, 2013). For the successful implementation of tasar sericulture, training was imparted in groups. Approximately, 100 participants (mostly women) from neighborhood villages, who were trained and engaged earlier for collection and handling of saplings, seeds, and microbial inoculants of the restoration work, were imparted training in tasar silkworm, after restoration activities were completed. This training was to promote forest-based livelihood by sustainably utilizing the restored ecosystem for enhancing income as well as improving socio-economic status. Local self-help groups consisting of 20 members each were formed and trained in a 2-week training program arranged at the Central Tasar Research & Training Institute (CTRTI), Ranchi for rearing tasar silkworm culture on host plants of restored forest ecosystems and neighboring forests. Various field training programs in the vernacular language were also organized at restored sites for locals to strengthen the practical skills already acquired. With these skills acquired during training they practiced rearing of tasar silkworm on host trees of the restored ecosystems, and also promoted tasar silkworm rearing in the entire village. Apart from the training, regular field interactions with scientists and technical staff were organized for the trained self-help group members to monitor progress and empower competency as well as skill in this *Vanya* sericulture. These trainees were provided with necessary infrastructure and support for practicing tasar rearing on a large scale.

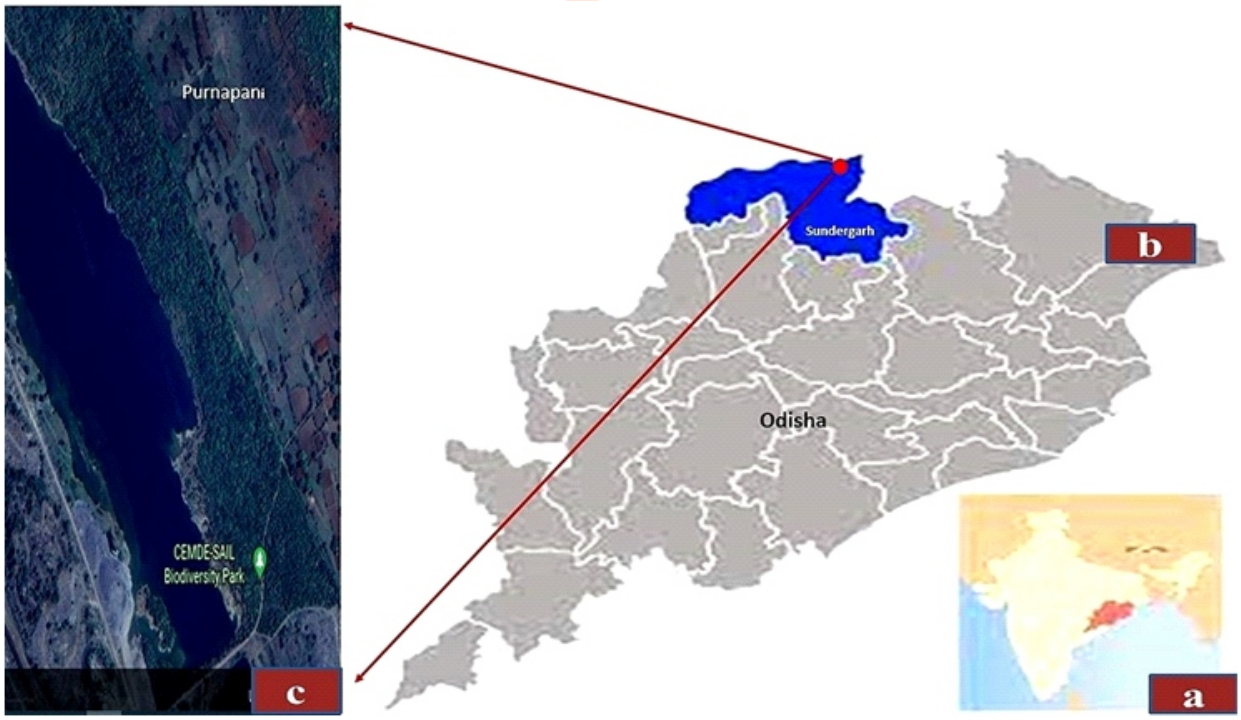

Fig. 1: (a) Map of India showing the location of Odisha state; (b) Map of Odisha state showing Sundergarh district and location of Purnapani and (c) Google earth map showing ecologically restored mined out site and deep mine void of Steel Authority of India (SAIL) at Purnapani.

Fig. 2: Mined out sites before ecological restoration (a) and same sites of figure (a) after 15 years of restoration (b) of Steel Authority of India (SAIL) at Purnapani.

Tasar cultivation: Participants of the self-help groups were provided disease-free layings (DFLs) of *A. mylitta* Drury (Daba) procured from the Central Tasar Research & Training Institute (CTRTI) Ranchi and RSRS, Baripada, Odisha as a part of the ongoing restoration project. Since, *A. mylitta* Drury is a polyphagous insect by nature, larvae were introduced on diverse host species, but the larvae were primarily reared on *T. arjuna, T. tomentosa, S. robusta and Z. mauritiana*. Keeping in view the plants' health status and herbivory stress, the cultivation area was shifted from one plot of host plants to another plot after each crop. Local communities often remained in contact with experts and scientists through video conferences to seek guidance regarding the shifting of insects from one host to another and to monitor the development of larvae as well as the formation of cocoons.

Results and Discussion

The degraded mined-out area of 250 acres under study was restored to a 5-storeyed tropical rain forest with a top canopy reaching 80 feet within 15 years (Fig. 2b). The restored area currently harbors nine plant communities with more than 260 native woody species, some of which are host plant of the tasar silk worm and lac insect, while others produce nectar-bearing flowers. Different species established as through ecological restoration of the habitat started yielding minor non-timber forest produce (NTFP) such as tendu leaves, sal leaves and seeds, mahua flowers and seeds, Amla, Chiraunjee, Ber, Soapnut, herbal medicines and others. Since ecologically-restored sites are surrounded by natural forest areas, movement of wild

Fig. 3: Cocoon developed on the leaves of different host plants (a) *Terminalia tomentosa*; (b) *Terminalia arjuna*; (c) *Ziziphus mauritiana and* (d) *Shorea robusta* growing at restored sites of Steel Authority of India (SAIL) at Purnapani.

silkmoths from neighbourhood forests to foliage-rich restored sites was observed. In fact, oviposition by wild tasar moths and silkworms spinning cocoons were recorded in the tasar sericulture zones, which harbour more than half of total forty-five forest host plants species (Table 1) that serve reported as primary, secondary and tertiary host plants (Srivastav and Thangavelu, 2005). Rearing of tasar silkworm were practiced by self-help groups and cocoons were harvested primarily from *T. arjuna, T. tomentosa, S. robusta and Z. mauritiana* host plants (Fig. 3). The mortality rate of larvae of silkworm was quite low due to negligible pest load because of the rich surrounding biodiversity. It has been reported that the cocoons productivity was higher in fields surrounded by reserve forest as compared to the field without surrounding native vegetation (Panda *et al.,* 2022).

The size of cocoons harvested at the restored sites were large and of high quality. Hence, these cocoons were in high demand in the local co-operative market. The average weight per cocoon ranged from 9.50 g to 12.20 g each. In general, the average weight of cocoons from larvae fed on secondary host plants as well as wild insect cocoons was found to be less than cocoons harvested from primary host plants in the tasar sericulture zones at the restored sites. Tripathi *et al.,* (1988) have also documented that primary host species such as *T. tomentaosa, T. arjuna* and *S. robusta* trees support better growth and development of larvae, which lead to formation of large size cocoons and better yield of tasar silk yarn than other species of host plants. Majority (80%) of the cocoons were sold in the local co-operative market run by Sericulture Department of Odisha, and

Table1: Host plants of tropical tasar silkworm found in the restored ecosystems of limestone mined out areas of SAIL at Purnapani

Scientific name	Local name	Family
Primary host plant		
Terminalia tomentosa (Roxb.) ex DC	Asan	Combretaceae
Terminalia arjuna Wright & Arn.,	Arjun	Combretaceae
Shorea robusta Roth	Sal	Dipterocarpaceae
Ziziphus mauritiana Lam.	Ber (Berkoli)	Rhamnaceae
Lagerstroemia parviflora Roxb.	Sidha	Lythraceae
Secondary host plants		
Terminalia belerica (Gaertn) Roxb.	Bahera	Combretaceae
Terminalia chebula Retz.	Haritki	Combretaceae
Syzygium cumini (L.) Skeels.	Jamun	Myrtaceae
Anogeissus latifolia (Roxb. ex DC.) Wall. ex Guill. & Perr.	Dhaura	Combretaceae
Bauhinia variegata (L.) Benth	Kanchana or Kachanar	Fabaceae
Ficus retusa L.	Pipal	Moraceae
Ficus religiosa L. forssk.	Aswatha, Pipal	Moraceae
Ziziphus xylopyrus (Retz.) Wild	Ber	Rhamnaceae
Ziziphus rugosa Lam.	Ber	Rhamnaceae
Cassia senna L.	Swarnapatri	Fabaceae
Madhuca longifolia (J. Konig) J. F Macbr	Mahua	Sapotacaea
Bombax ceiba (L.)	Simuli	Malvaceae
Dodonaea viscosa (L.) Jacq.	Dodonia	Sapindacaea
Terminalia alata Heyne ex Roth	Asan	Combretaceae
Tectona grandis L.f.	Teak	Lamiaceae

the remaining 20% cocoons were kept as seed for the next crop. In the year 2019-2020 alone, an estimated one lakh cocoons were produced and sent to the market/stored as seed cocoon.

The average income of the self-help group members from the sale of tasar cocoons was Rs 7,855 (INR) per member annually. Interestingly, most of the beneficiaries of tasar cultivation were women, which is common to tasar cultivation sector (Jolly *et al.,* 1975; Dewangan, 2013; Hugar *et al.,* 2013; Yadav and Jadhav, 2017; Nath and Modak, 2022). This suggests that forest-based livelihood fostered by income generating activities like rearing of tasar silkworm at degraded sites undergoing restoration empowered women. Since the local communities (both men and women) were also trained in reeling and weaving activities by CTRTI, Ranchi, this endeavor not only provided opportunities to utilize restored-ecosystems for livelihood, but also provided an incentive for sustaining the restored sites. Similar observations have been reported by Vishaka *et al.,* (2020) where promoting tasar silkworm cultivation not only empowered locals by generating livelihood but also promoted sustenance of restored sites by non-cutting and non-felling of host trees as silkworm cultivation had becomea part of their life.

The results on the socio-economic survey conducted suggests a sectoral change in the livelihood pattern during pre-mining and post-mining periods with the local communities returning to pre-mining livelihood options during restoration period, such as agriculture, fishing, collection of fuel wood and nontimber forest produce (Dalei and Gupt, 2014). It was observed that rearing of tasar silkworms on *T. arjuna, T. tomentosa* and *Z. mauritiana* by self-help groups did not impact the health of the restored ecosystem in terms of tree growth and nutrient cycling. Although rearing of tasar silk worm was restricted to about 5,550 trees and the yield of cocoons was more than one lakh during the year 2019-2020, the host trees showed normal growth and biomass production. This suggests that nutrient cycling was not disrupted due to rearing of tasar silkworm as the larval faecal matter tend to enrich soil nutrients (Mevada *et al.,* 2018).

This study could be perfect model system for government initiative program such as 'Mahila Kisan Sashaktikaran Pariyojana' where Central Silk Board (CSB) in association with the Ministry of Rural Development of Government of India contemplate revolutionizing tasar silk production through development of tasar cultivation zones using ecological restoration methodologies (Sathyanarayana *et al.,* 2018). Successful outcome of this project also showed that approaches based on need and participation of various stake holders (local community, the government and private organizations) was the right strategy for evolving socio-ecological systems (Balana *et al.,* 2010; Gann *et al.,* 2019; Gornish *et al.,* 2021). Hence, linking schemes of multiple partner agencies (Government, Private, and NGOs) on conservation programs, biodiversity research, greening programmes, training and promotion for sustainable development is essential for achieving the objectives of restoration of degraded lands, including mined out areas and making sustainable livelihood an option for locals.

Outcome and key lessons learned from the present study: The ecologically restored mined-out site of SAIL at Purnapani,

Odisha, is exemplary on many counts – within a span of 15 years, barren mined-out areas were restored to a 5-storeyed tropical rain forest ecosystem with top canopy reaching 80 ft height, capable of providing sustainable livelihoods to local communities, besides other ecosystem services. This success can serve as a model for replication elsewhere and act as a demonstration plot for trainees and students on how ecological transformation of degraded landscapes to natural productive forest ecosystems can be achieved leading to sustainable development. The key lessons learned from this study are-

(i) Self-sustaining biodiversity-rich ecosystem– The restored ecosystem should harbor a characteristic assemblage of indigenous species to the greatest practicable extent which is similar to the reference site (Gann *et al.,* 2019). The restored forest ecosystem must be site specific providing ecological services and goods for livelihood of local peoples.

(ii) Linking of multiple stakeholders and programs – Ecological restoration is a complex and highly dynamic process which needs inputs from multidisciplinary experts. Therefore, combined efforts need to be made by all the stakeholders such as researchers, professionals, and policymakers (Balana *et al.*, 2010; Elias *et al.*,2022). Interlinking of government programs, non-governmental organizations, private sector and University research academia is likely to yield rich dividends and be a game changer in restoration ecology of degraded ecosystems with sustainable livelihood generation (Gann *et al.*, 2019).

(iii) Local community participation- Engaging local peoples and indigenous tribals in the planning, implementation, and monitoring of any ecological restoration program is always beneficial (Balana *et al.*, 2010; Gann *et al.*, 2019; Elias et al., 2022). Local communities are primary stakeholders and play a major role in the sustenance of restored sites while they harvest ecosystem goods and services from the restored ecosystem.

(iv) Skill development and awareness- From habitat processing to the harvesting of ecological services, skilled and informed (wo)manpower is needed (Gann *et al*., 2019). Stakeholders having expertise in training of forest-based livelihood generation can play a vital role in conservation of tasar silkworm germplasm.

(v) Restored ecosystems at the limestone/dolomite mined-out areas of SAIL at Purnapani, Odisha, serve an excellent model for establishment of tasar sericulture zone,conservation of tasar silkworm gene pools and sustainable livelihood development that can be replicated elsewhere.

The observations presented in the paper demonstrate successful harvesting of non-timber forest produce (NTFP) viz. cocoons of tasar silkworm as evidence of ecological goods and services as well as livelihood for locals rendered by a successful ecological restoration program for degraded mined-out areas and exemplifies a sustainable development model.

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References

Ahmed, S.A. and R.K. Rajan: Exploration of Vanya silk biodiversity in north eastern region of India: Sustainable livelihood and poverty alleviation. In: International Conference on Management, Economics and Social Sciences (ICMESS'2011) Bangkok pp. 485-489 (2011).

Alam, K., D.Bhattacharya, T. Chowdhury, S. Saha and P. Kar: Biodiversity status and conservational requirements of tropical tasar (*Antheraea mylitta* D)—a review. *Ecol. Environ. Conserv.,* **24**, 1887-1894 (2018).

Balana, B.B., E. Mathijs and B. Muys: Assessing the sustainability of forest management: An application of multi-criteria decision analysis to community forests in northern Ethiopia. *J. Environ. Manag.,* **91**, 1294-1304 (2010).

Bennett, A.F. and D.A. Saunders: Habitat fragmentation and landscape change. *Conserv. Biol. forAll*, **93**, 1544-1550 (2010).

Dalei, N.N. and Y. Gupt: Livelihood sustainability of forest dependent communities in a mine-spoiled area. *Int. J. Ecol. Econo. Stati.,* **35**, 30-47 (2014).

Dewangan, S.K.: Livelihood opportunities through sericulture-a model of gharghoda tribal block, Raigarh Dist. *American J. Environ. Sci.,* **9**, 343-347 (2013).

Elias, M., M. Kandel, S. Mansourian, R. Meinzen-Dick, M. Crossland, D. Joshi,, ... and L. Winowiecki: Ten people-centered rules for socially sustainable ecosystem restoration. *Restor. Ecol.,* **30**, e13574 (2022).

Fischer, J., M. Riechers, J. Loos, B. Martin-Lopez and V.M. Temperton: Making the UN decade on ecosystem restoration a social-ecological endeavour. *Tren. Ecol. Evolu.,* **36**, 20-28 (2021).

Gann, G.D., T. McDonald, B. Walder, J. Aronson, C.R. Nelson, J. Jonson, J.G. Hallett, C. Eisenberg, M.R. Guariguata, J. Liu, F. Hua, C. Echeverría, E. Gonzales, N. Shaw, K. Decleer and K.W. Dixon: International principles and standards for the practice of ecological restoration. *Restor. Ecol.,* **27**, S1-S46 (2019).

Gornish, E., M. McCormick, M. Begay and M.M. Nsikani: Sharing knowledge to improve ecological restoration outcomes. *Restor. Ecol.,* **3**, e13417(2021).

Hugar, I.I., K. Sathyanarayana and A.B. Pande: Revitalization of tribal economy through sustainable tasar culture in Maharashtra. *Int. J. Sci. Res.,* **5**, 1963-1967(2013).

Jolly, M.S., S.N. Chowdhury and S.K. Sen: Non-mulberry sericulture in India. Central Silk Board. Bombay, India (1975).

Lengefeld, E., L. C. Stringer and P. Nedungadi: Livelihood security policy can support ecosystem restoration. *Restoration Ecology*, **30**, e13621 (2022).

Lindenmayer, D. and J. Fischer: Landscape change and habitat fragmentation: an ecological and conservation synthesis. Washington, DC: Island Press (2006).

Locatelli, B.: Ecosystem services and climate change. In: Routledge Handbook of Ecosystem Services, Routledge, pp. 481-490 (2016).

Mevada, R.J., D. Nayak and D.P. Patel: Impact of *Terminalia arjuna* (Roxb.) leaf litter and hosted tasar silkworm excreta on quality of paddy and soil properties. *Int. J. Curr. Microbiol. Appl. Sci.,* **7**, 3781-3789 (2018).

Mishra, M., C. A. G Santos, T. V. M do Nascimento, M. K. Dash, R. M. da Silva, D. Kar and T. Acharyya: Mining impacts on forest cover change in a tropical forest using remote sensing and spatial information from 2001–2019: A case study of Odisha (India). *J. Environ. Manag.*, **302**, 114067 (2022).

Mohanty, P.K.: Tropical Wild Silk Cocoons of India. Daya Publishing House, New Delhi, 202 pages (2003).

Nath, S. and B.K. Modak: Tasar sericulture: an underutilized tool of poverty eradication among the tribals of Bankura district. In: Indigenous People and Nature, (Eds.: U. Chatterjee, A. Kashyap, M. Everard, G.K. Panda and D. Mahata), Elsevier, pp. 437-463 (2022).

Panda, S. and A. Barik: Impact of iron ore mines generated pollutants on peripheral environment and its effective management—a case study of Koira region, Odisha. In: Proceedings of the XI International Seminar on Mineral Processing Technology (MPT-2010). Vol. **2**, No. Section 14. New Delhi, ND: Allied Publishers, pp. 1147-1156 (2011).

Panda, S., P.K. Kar, D.S. Hota and P.K. Satapathy: Nutrients from soil to host plant leaves and its impact on commercial traits of tropical tasar silkworm. *Plant Archives*, **22**, Special Issue (VSOG) 116-121 (2022).

Renuka, G. and G. Shamitha: Studies on the biodiversity of tasar ecoraces *Antheraea mylitta* Drury. *J. Entomol. Zool. Stud.,* **3**, 241-245 (2015).

Sathyanarayana, K., A.V. Manjunatha, C.M. Devika and R.K. Mishra: Mahila Kisan Sashaktkaran Pariyojana (MKSP): Reeling sustainability in the tasar sericulture based tribal livelihoods through alternative market support systems. *Indian J. Agricul. Marke.,* **32**, 107-117(2018).

Sánchez-Bayo, F. and K.A. Wyckhuys: Worldwide decline of the entomofauna: A review of its drivers. *Biol. Conserv.,* **232**, 8-27 (2019).

Singh, S.: Biological reclamation of degraded mined land a sustainability indicator. *Eniviro. News*, **10**, 1-3 (2004).

Srivastav P.K., and K. Thangavelu: Sericulture and Seri-biodiversity. Associated Publishing Company, New Delhi, India, pp. 192-202 (2005).

Suryanarayana, N. and A.K. Srivastava: Monograph on Tropical Tasar Silkworm. Central and Tasar Research and Training Institute, Central Silk Board, Ranchi, India, pp. 1-87 (2005)

Ticktin, T., S. Quazi, R. Dacks, M. Tora, A. McGuigan, Z. Hastings and Naikatini: Linkages between measures of biodiversity and community resilience in Pacific Island agroforests. *Conserv. Biol.,* **32**, 1085–1095 (2018).

Tilauhun, E. and I. Zewide: Causes and impacts of land degradation. *British J. Earth Sci. Res.*, **9**, 28-37 (2021).

Tripathi, A.K., D.P. Sinha and S.B. Singh: Rearing of *Antheraea mylitta* (Saturniidae: Lepidoptera) larvae on nine species of host plants. *Environ. Ecol.,* **6**, 331-334 (1988).

Van Oosten, C.: Restoring landscapes—governing place: A learning approach to forest landscape restoration. *J. Sustain. Fore.,* **32**, 659-676 (2013).

Vishaka, G.V., M.S. Rathore, M. Chandrashekharaiah, H.A. Nadaf and R.B. Sinha: Tasar for tribes: A way of life. *J. Entomol. Zool. Stud.,* **4**, 7-10 (2020).

World Economic Forum (WEF): "The global risks report 2020." In Davos: World Economic Forum. Retrieved November, **15 Editon**, 94 pages (2020).

Weng, Y.C.: Contrasting visions of science in ecological restoration: Expert-lay dynamics between professional practitioners and volunteers. *Geoforum*, **65**, 134-145 (2015).

Yadav, U., and N. Jadhav: Empowerment of rural women through sericulture. *Environ. Conserv. J.,* **18**, 207-209 (2017).