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ECOSYSTEM SERVICES APPRAISAL OF TROPICAL SAL FOREST IN WEST BENGAL, INDIA AND ITS ROLE IN LOCAL LIVELIHOOD

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Forest provides ecosystem services (ES) for community well being through local livelihoods. Tropical sal forest of West Bengal, India is not an exception, rather the tribal communities in forest fringe villages rely on it. The present study aims to quantify and estimate the values of provisioning and regulating ES and their contribution towards local livelihoods. The study revealed variation in provisional services quantity among the villages with highest percentage contribution by fodder and highest monetary value for fuelwood. Estimated monetary value of provisioning ES was INR 1859.00 person^{-1} year^{-1}. Regulatory services that included carbon stock estimation (68.71 tC ha^{-1}) have potential to sequester 252.17 tCO_2 ha^{-1}. Estimated monetary value of trees under regulatory services was INR 25,0221.00 ha^{-1}. The stakeholder perception of such services showed positive responses, supporting the results of ES estimation and valuation. Income from forest products contributed 24% of total household income. Total economic value of ES in the study area was INR 13.052 billion year^{-1}. Thus, studies are required for better understanding of the ES contribution to human well-being of a region to develop sustainable livelihood framework and proper forest management strategies for biodiversity conservation.

Keywords: Ecosystem services, quantification, valuation, forest dependency, carbon stock

INTRODUCTION

Ecosystem services (ES) are linked with the social well being of a community. It deals with the benefits obtained from ecosystem for human well being, both direct and indirect contributions (Sagie et al. 2013, Cruz-Garcia et al. 2016, Englund et al. 2017, Battisti et al. 2020). The Millennium Ecosystem Assessment (2005) defined the ES as the benefits obtained from ecosystems by humans and categorised the services as four types: provisioning services (PS), regulatory services (RS), cultural services (CS) and supporting services (SS). The concept of ES is also a recent development (Hernandez-Morcillo et al. 2013, Aznar-Sanchez et al. 2018). It came into higher focus after the Millennium Ecosystem Assessment (MEA 2005), The Economy of Ecosystems and Biodiversity (TEEB 2010) and the Intergovernmental Science-Policy Platform on Biodiversity and ES (IPBES 2012), which can benefit policy-makers to formulate decision based on scientific evidence (Aznar-Sanchez et al. 2018).

Although the ES provides several values to the society, the relevant market does not exist where the values can be expressed (Zhongmin et al. 2003). About 70% of terrestrial biodiversity is sustained by forests that not only helps in climate regulation, but directly and indirectly acts as a livelihood support system for over 1.6 billion people globally (MEA 2005, de Beenhouwer et al. 2013, Gunderson et al. 2016, Tekalign et al. 2018). The tropical forests are considered as the richest source of biodiversity, which is indeed crucial for mankind to fulfill their needs in terms of food, medicine and raw materials for industries (Ramachandra et al. 2016, Tekalign et al. 2018). Even though ES has enormous economic, cultural and ecological significance, the value of ES to humanity is undervalued, which is causing ecosystems around the world to continuously deteriorate. The lack of knowledge on ES by the local inhabitants, especially in the developing countries, is the main reason for improper forest ecosystem management. Thus, the valuation of ES is crucial for forest management (TEEB 2010).

The ES are highly influenced by environmental decisions as it links the ecosystem function with anthropocentric activities. Embedding the ES in decision making policies face several hurdles considering the inconsistency with which scientists have conceptualised the delivery of ES to the society (de Groot et al. 2010, Tallis et al. 2012). The European Union has great consideration for ES (TEEB 2010, European-Commission 2011, Hauck et al. 2013). However there is scientific limitation of ES concepts as how ES are related to each other, production of ES, quantification of ES and how land use change impact on future ES delivery (de Groot et al. 2010, Hauck et al. 2013).

Number of initiatives were taken to develop conceptual framework for assessing ES and to bridge the gaps between different missing links in relation to biodiversity, ecosystem and human well being. Such initiatives influenced ES assessment and policy formulation. Many government and non-government sectors started adopting UN MEA (2005) framework that leads to a better understanding of the concept and awareness (Tallis et al. 2012). The TEEB (2010) aimed to assess the economic benefits of biodiversity and ES globally and measured the cost of their loss. Many countries adopted TEEB to exhibit the value of their ecosystems and incorporated within their policy (TEEB 2010). In mid 2009, the UK National Ecosystem Assessment (UKNEA 2011) took initiatives to analyse UK's natural environment in terms of its benefits towards the society and how it continues with economic prosperity. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem (IPBES) aimed to bridge the gap between science and policy and provided a mechanism recognised by both the scientific communities and policy makers to evaluate relevant information and knowledge generated by government and non government organisation globally (IPBES 2012). Researchers used diverse methodological approaches for different studies on ES (Mengist & Soromessa 2019). Keeping in view of different initiatives and concepts, the conceptual framework is developed in the present study (Figure 1).

Few studies have been made to estimate the current economic value of ES and percent contribution of energy sources from natural resource base (Table 1). Although quantification and valuation of PS was carried out by several researchers, the assessment on estimates of RS was limited. However, the study on estimates of carbon stock was done based on biomass determination (Table 1).

Understanding the significance of ES valuation, the present study aimed to quantify and estimate the value of ES in the forests of Sarenga, Bankura district, West Bengal, commonly known as jangal mahal, as the district is surrounded by

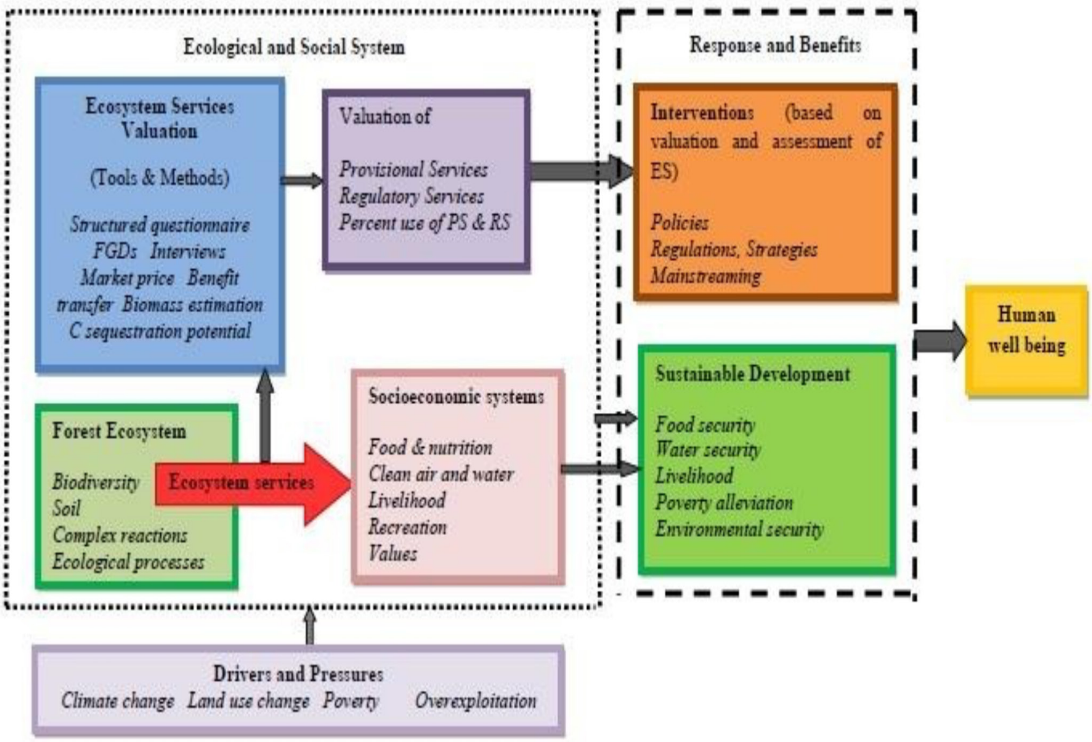

Figure 1 Conceptual framework for ecosystem services assessment for the study

Table 1 Studies on ecosystem services valuation

Particulars	Economic valuation / percentage of contribution / C estimates	Reference
Current economic value of ES provide by Earth's ecosystem	USD33 trillion/year	Costanza et al. 1997
ES of regional Himalayan forests	USD1150/ha/year	Singh 2007
Removal of woods from forests annually during 2003-2007	USD100 billion	FAO 2010
Biomass (the fuel wood)	11% of world's energy	IEA 1998
Non-commercial sources of energy in the state of Karnataka	54%	Ramachandra et al. 2000
In India, 20% of the total plant species available yields NTFPs	0.8% species are commercially developed	Maithani 1994
Valuation of Uttrakhand forest	Rs 16,192 billion	Verma et al. 2007
Valuation of Western Himalayan forests annually per village for Oak forest	Rs 2,164,247	Josi & Negi 2011
Valuation of Western Himalayan forests annually per village for Pine forest	Rs 1,589,642	Josi & Negi 2011
Net value of NTFPs in Mantadia National Park, Madagascar	USD673,000	Kramer et al. 1995
Total C stock in Indian forest	7124.6 Mt	FSI 2019
Total C stock Tropical dry deciduous forest, India	2158.1 Mt	FSI 2019
Total C stock in the forests of West Bengal	147.7 Mt	FSI 2019

NTFPs = non-timber forest products, FAO = Food and Agriculture Organisation, IEA = International Energy Agency, FSI = Forest Survey of India

large areas of forest. This is the first attempt in the state of West Bengal. The study area selected was gaining importance in the state in terms of forest cover and the tribals, mostly Santhals, residing in the fringe areas, who are highly dependent on forest resources, and have poor economic conditions. Therefore, the study also deals with the dependency of tribals upon forest. The study aimed to fill the gap between the utilisation of forest resources by tribals and how the forest ES are valued in the area, as well as its significant role in generating livelihood. The economic valuation and perceived valuation of ES for forests would be extremely beneficial for signifying the economic efficiency of various natural resources and their extraction. Basic information regarding the ecosystem structure, function, yield, production, use rate, socio-economic pattern and understanding the attitude of the people towards forest conservation can be gained through such valuation. The ES assessment and valuation would help the natural resource managers, social planners and foresters to develop proper forest management strategies and design livelihood framework related to social well being in the area, which can further be replicated in other places upon initial assessment of ES. Thus, the study addressed the missing link between the stock of natural capital, stored in the area, and its use pattern by the inhabitants, and what percent is contributed to local livelihoods. The inhabitants of the study area have a strong sense of social cohesion and definite cultural background, possessed through their ancestors. However, the cultural ES are not considered in the present study, in view of poor economic condition of the villagers and their social status. Moreover, the study area was selected because the villagers, who are unable to grow crops in the non-monsoon season, are highly dependent on sal forest. During February to April, shedding of leaves is a boon to forest-dependent villagers. Without disturbing the ecosystem, the villagers can collect the broad sized leaves (15 cm × 25 cm) for different purposes. The sal leaves are used as mulches, and is various usefulness have been proved, especially in the dry tracts of Eastern India. Thus a synergy between farming and forestry can fulfill the goal of sustainable development. The novelty of the present research is the evaluation of the ES that acts as the building block of economic growth for the underprivileged commons, where economic growth is the key-driver of sustainable development. The study holds uniqueness, as the regulatory services assessment and valuation is carried out along with the provisioning services, and how it contributes to the livelihood of local inhabitants.

MATERIALS AND METHODS

Study area

The selected study area, jangal mahal, Bankura district, West Bengal, under Bankura (South) Forest Division, falls under Group 5B, i.e., northern tropical dry deciduous forest type covering 4648.03 ha of forest land. The local climate is hot summer (45 °C) from March to June. During winter, the temperature drops below 25 °C in December. Monsoon continues from June to September with an average rainfall of about 1400 mm. Bankura district, rich in biodiversity in the southern part, is one of the underdeveloped district of the state. Majority of inhabitants are scheduled castes and tribes, mainly Santhals.

Five villages were selected in the area for survey based on close proximity to the forest (Figure 2). Three main criterias used for the selection of the villages were: (1) absolute dependence of the people on forests, (2) marginal farmers or landholdings < 1 ha and/or landless and (3) a wide range of human and livestock populations of these villages that represent various extraction regimes of ES from the surrounding forests. The criterias on which the sample villages were selected can also be applied for other tropical regions in many parts of India, provided the forest fringe dwellers are dependent on forests resources.

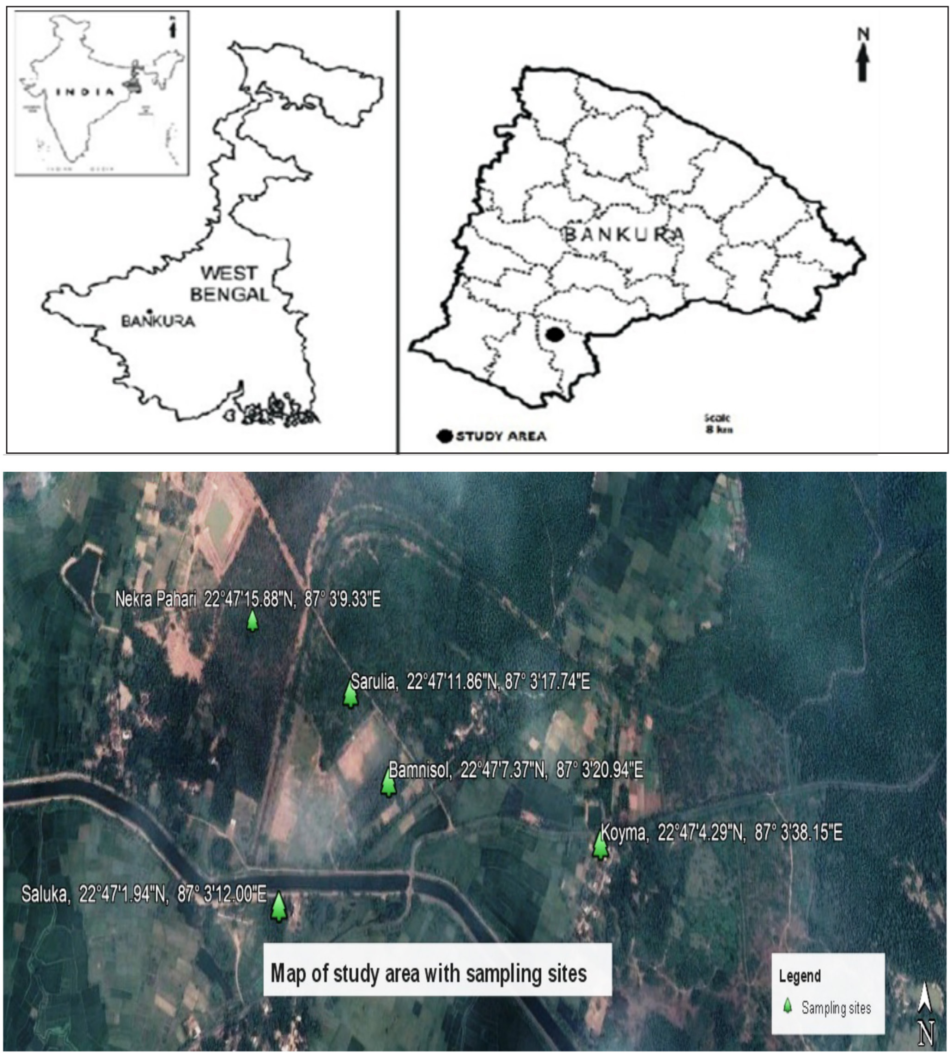

Figure 2 Location map of the study area

Sample households were drawn from the villages, namely, Bamnisole (n = 10), Koyma (n = 10), Nekra Pahari (n = 10), Saluka (n = 20) and Sarulia (n = 30). List of villages were obtained from the forest department and the number of households were randomly selected (N = 80) and 10% of the total household in each village was surveyed. The head of the selected households were interviewed, and opinions from females were noted as they take part in collection of fuelwood and fodder. Focus group discussions (FGDs) were conducted in each village. Separately, elderly people were also interviewed to explore the background information related to PS collection.

Identification of ecosystem services (ES)

The ES were identified through FGDs in each village where listing and paired ranking was performed (Stark et al. 2009). It was found that PS as non-timber forest products (NTFPs) were fodder, fuel wood, litter, medicinal plants and edible parts (fruits, roots, shoots). These PS were valued as per the equations in Table 2 based on market price (Ramachandra 2016). The identified RS were purified air, water, soil erosion control, soil moisture, soil fertility and precipitation.

Ecosystem services (ES) valuation framework

The framework for valuation of ES and its significant contribution towards sustainable livelihood is depicted in Figure 3. The work entails:

(i) Quantification of goods and services

The PS collections were listed during FGDs and were ranked using paired ranking method to establish the score for different items collected by the villagers, and find the most important PS in the area. Compilation of data from both

Table 2 Equation used to determine the provision services and goods (Ramachandra et al. 2016)

Provisioning services (PS)	Equation
Sal leaves	$V_{\text{sal leaves}} = \sum_{i=1}^{5} Q_i \times P_i$ Q = quantity of sal leaves, P = price of sal leaves, i= number of villages
Mahua flowers	$V_{\text{Mahua flowers}} = \sum_{i=1}^{5} Q_i \times P_i$ Q = quantity of mahua flowers, P = Price of mahua flowers, i= number of villages
Kendu leaves	$V_{\text{Kendu leaves}} = \sum_{i=1}^{5} Q_i \times P_i$ Q = quantity of kendu leaves, P = price of kendu leaves, i= number of villages
Kaju fruits	$V_{\text{Kaju fruits}} = \sum_{i=1}^{5} Q_i \times P_i$ Q = quantity of Kaju fruits, P = price of kaju fruits, i= number of villages
Fodder	$V_{\text{fodder}} = \sum_{i=1}^{5} Q_i \times P_i$ Q = quantity of fodder, P = price of fodder, i= number of villages
Fuel wood	$V_{\text{fuelwood}} = \sum_{i=1}^{5} Q_i \times P_i$ Q = quantity of fuelwood, P = price of fuelwood, i= number of villages
Litter	$V_{\text{litter}} = \sum_{i=1}^{5} Q_i \times P_i$ Q = quantity of litter, P = price of litter, i= number of villages
Food (mushroom)	$V_{\text{mushroom}} = \sum_{i=1}^{5} Q_i \times P_i$ Q = quantity of mushroom, P = price of mushroom, i= number of villages
Medicinal plants (kalmegh)	$V_{\text{medical plant}} = \sum_{i=1}^{5} Q_i \times P_i$ Q = quantity of medicinal plant, P = price of medicinal plant, i= number of villages
Others (tasar)	$V_{\text{tasar}} = \sum_{i=1}^{5} Q_i \times P_i$ Q = quantity of tasar, P = price of tasar, i= number of villages

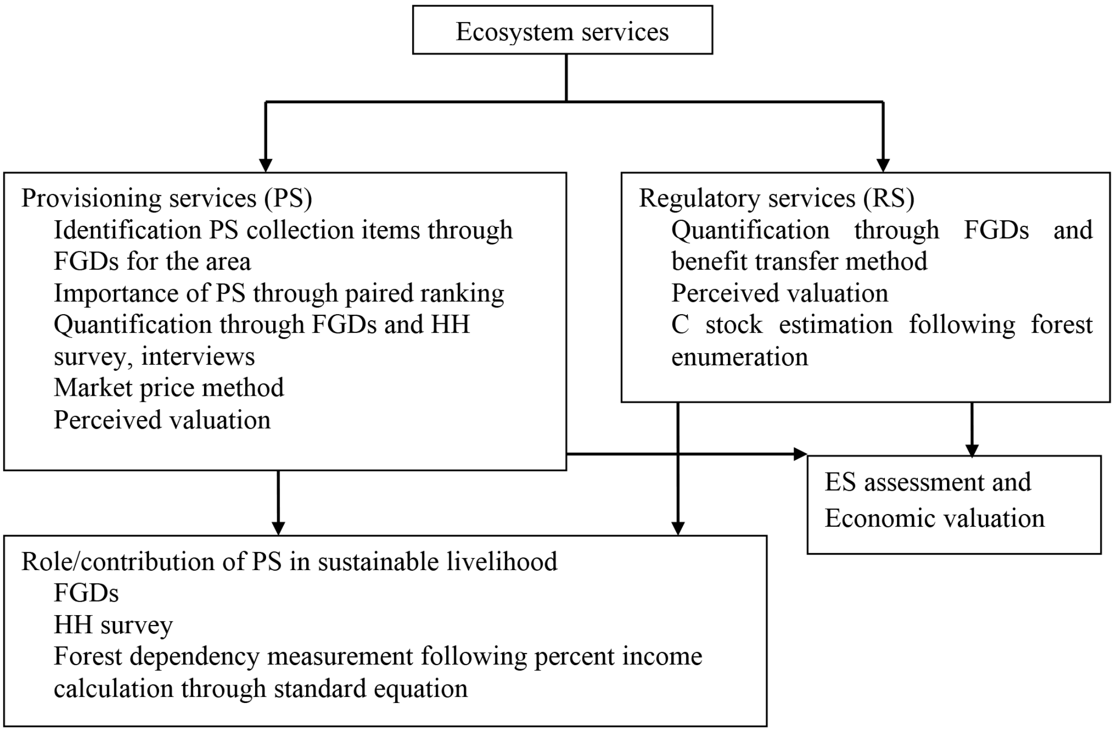

Figure 3 Ecosystem services (ES) valuation framework and role of valuation towards sustainable livelihood, FGDs = forest group discussions, HH = household

primary (field investigations) and secondary level (published literatures, government agencies, etc.) was carried out to quantify the goods and services. Socioeconomic data were collected to understand the household characteristics as well as the livelihood pattern of the forest fringe dwellers in the study area. The household survey included demography, household size, literacy levels, resource endowments, occupation, collection and types of forest products, sources, consumption pattern, trade and market value. Quantification of RS was done through valuation of carbon sequestration in the study area, where biomass was estimated and carbon stock was measured accordingly (IPCC 2006).

(ii) Valuation of ecosystem services (ES)

The present study included two approaches of valuation, the market price and benefit transfer technique (Ramachandra 2016). The PS were valued through market price method. Market value of forest products were assessed through FGDs, household questionnaire and market survey. It helped to capture the prices of different forest products that are traded in the local markets, which were used to value the amount of forest products consumed by the households and added to the household income, to evaluate the relationship of livelihood pattern of the inhabitants in the study area. Those goods and services which did not pass through the market transaction process was valuated by the benefit transfer technique. This technique involves the applications of value estimates, functions, etc., to address similar resource valuation question in an alternative way. In this technique the cost of surveys in terms of time and money are avoided, and such kind of method is used to valuate regulatory services. Therefore, in the present study, perceived value of PS and RS were also recorded. All listed attributes were valued/assigned with a score based on the scale of 0–10, 0 being no value to 10 being highest value of importance. The regulatory services in terms of climate change and carbon sequestration was estimated through forest survey.

Forest survey

Nested quadrat was laid in 25” × 25” grid divided with the help of Arc GIS software within which vegetation enumeration was carried out at tree level only (National Working Plan Code 2014). Tree height was measured through laser range finder. Diameter at breast height (DBH) of the tree was measured using a measuring tape.

Circumference was measured following equation 1 (Mandal and Joshi 2014):

$$C = \pi * DBH \quad (1)$$

where C = circumference of tree = 3.14, DBH= diameter at breast height. Therefore, DBH = C/π.

Tree basal area (TBA) is calculated based upon the formula area (A) = πr^2, equation 2 (Mandal and Joshi 2014).

$$\text{Tree basal area (TBA)} = \left(\frac{DBH}{200}\right)^2 \times 3.14 \quad (2)$$

where, DBH = diameter at breast height in cm, π = 3.14.

Tree volume is calculated by the following equation 3 (Mandal and Joshi 2014):

$$\text{Tree Volume } (m^3) = \left(\frac{DBH}{200}\right)^2 \times 3.14 \times \left(\frac{\text{Height}}{3}\right)$$

$$\text{Or Tree Volume} = \left(\frac{TBA}{3}\right) \times \text{Height} \quad (3)$$

Volume (m^3 $tree^{-1}$) of each tree in a sampling quadrat obtained is converted into the volume on hectare basis.

Above ground biomass and below ground tree biomass was calculated according to IPCC (2003). The carbon storage for each species was computed by multiplying total biomass with a constant factor, 0.50 (IPCC 2006). Accordingly CO_2 sequestration and its monetary value was calculated (one ton C @ USD13).

Statistical analysis

Descriptive statistics were used to illustrate the demographic characteristic of the representative households in the study area. The quantity and values of different ES goods were assessed and data were analysed using the statistical software (MINITAB 14). Pearson correlation was performed to access PS and livelihood diversification.

Forest dependency measurement

The relative forest income was estimated by the ratio of total forest income to household total income. The relative forest income gives the share of net forest income upon total household income, calculated by equation 4 (Langat et al 2016):

$$\text{Relative Forest Income (RFI)} = \frac{TFI}{TI} \quad (4)$$

where TFI is the total forest income and TI is the total household income. In this study the gross annual income was considered.

RESULTS

Household characteristic

Mean family members of households are 5.24 ± 2.19 with 44% male, 39% female and 17% children. The female to male ratio was 0.885. About 51% of the sampled population fell under scheduled tribe (Santhals) followed by scheduled caste (26%) and general caste (23%). Entire surveyed households were below poverty line. A total of 17% of the sampled households were illiterate, while 12% can read but can't write, 71% can read and write, and only 10% were graduates. A total of 98% of the household relied on agricultural activities which form the primary occupation, and 2% of the households' primary occupation depended on daily wages. Every household in the area depended on the forest as shown by the survey. Average land holding was 0.325 hectares and village wise average livestock population was 425. Gross annual income (from agriculture, forest, livestock and wage) of the households ranged between 39,000 to 139,000 INR.

Provisioning goods and services quantification

The provisioning ecosystem goods and services from the Sarenga forest range included the assessment of NTFPs, viz., sal leaves, mahua flowers, kendu leaves, kaju fruits, fodder, fuel wood, litter, medicinal plants and others, mainly the collection of Tasar silk moth (Table 3). Variable quantity of ecosystem goods and services were found among the villages which is due to the differences in human and livestock populations among the villages (Table 3). The principal ecosystem goods, the collected NTFPs, were sal leaves, fodder, fuel wood, litter, food and medicinal plants. The percentage contribution of provisioning goods and services in each village are shown in Figure 4. The overall percentage contribution of different provisional goods was found to be highest for fodder (72%) followed by fuel wood (11%), litter (8%), medicinal

Table 3 Quantity of provisioning goods and services derived from sample villages of Sarenga Forest Range

Provisioning goods and services	Villages					Mean
	Bamnisole	Koyma	Nekra Pahari	Saluka	Sarulia	
Human population	468	476	182	1031	1320	695.40
Livestock population	238	251	252	660	726	425.40
NTFPs						
Sal leaves (bundle of 1000pc)	10,920	10,800	5040	3360	15,360	9096.00
Mahua flowers (kg)	–	30	–	–	7680	3855.00
Kendu leaves (bundle of 1000pc)	630	8100	3024	–	9660	5353.50
Kaju fruits (kg)	56	–	–	40,400	5929	15,461.67
Fodder (kg)	209,254.50	376,953.70	928,877.55	764,076.4	794,240	614,680.44
Fuel wood (kg)	59,878	56,001.6	26,292	144,931	176,640	92,748.51
Litter (mazdoor load of 10 kg)	57,330	52,650	32,130	90,900	126,720	71,946.00
Food (mushroom) (kg)	700	9450	2520	1120	30,820	8922.00
Medicinal plants (kalmegh) (kg)	6370	27,000	9891	60,600	36,900	28,152.20
Others (tasar) (number)	–	–	–	60,000	–	60,000.00

NTFPs = non-timber forest products

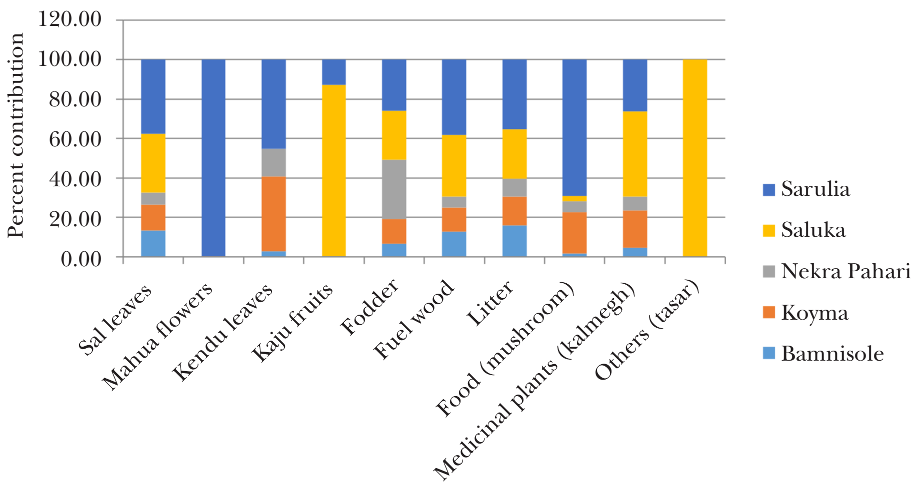

Figure 4 Percent of contribution of different provisioning goods and services in different villages

plants (3%) and sal leaves (2%). Kaju fruits, food (mushroom), mahua flowers, kendu leaves and others (tasar) contributed 4% of the total collected NTFPs. The mean value of the provisioning ecosystem goods and services from Sarenga Forest Range was estimated about INR 1,103,497 village^{-1} year^{-1}, which works out to INR 1859 person^{-1} year^{-1} (Table 4). Irrespective of the villages, the access to PS in the area is statistically significant at p value < 0.01 (Table 5).

The perceived value of PS was also derived from the sample fringe villages (Table 6). The mean values of PS considering NTFPs were found to be highest for sal leaves (9.78 ± 0.41) followed by fuel wood (9.17 ± 0.76), fodder (6.51 ± 2.70), medicinal plants (6.02 ± 1.19), food (mushroom) (5.07 ± 2.58), litter (3.74 ± 0.84), kendu leaves (3.27 ± 2.72), kaju fruits (1.82 ± 3.30), others (tasar) (1.48 ± 3.35) and mahua flowers (0.61 ± 1.51).

Table 4 Monetary value of provisioning goods and services derived from sample villages of Sarenga Forest Range (in INR)

Provisioning goods and services	Villages					Mean
	Bamnisole	Koyma	Nekra Pahari	Saluka	Sarulia	
Sal leaves	1,638,000	1,620,000	756,000	363,6000	4,608,000	2,451,600.00
Mahua flowers	–	2400	–	–	614,400	308,400.00
Kendu leaves	31,500	405,000	151,200	–	483,000	267,675.00
Kaju fruits	2800	–	–	2,424,000	355,740	927,513.33
Fodder	627,763.50	1,130,861.20	2,786,632.70	2,292,229	2,382,720	1,844,041.31
Fuel wood	598,780	560,016	1,051,680	5,797,238	7,065,600	3,014,662.88
Litter	143,325	131,625	80,325	22,7250	77,050	131,915.00
Food	42,000	567,000	151,200	67,200	1,849,200	535,320.00
Medicinal plants	38,220	162,000	59,346	363,600	221,400	168,913.20
Others (tasar)	–	–	–	180,000	–	180,000.00
Total value (INR village^{-1} year^{-1})	3,143,388.50	4,585,152.22	5,039,833.65	14,995,917.60	17,663,060.00	1,103,497.11
Per person value (INR year^{-1})	6716.64	9632.67	27,691.39	14,545.02	13,381.11	1858.60

Table 5 Correlation analysis between the provisioning services (PS) access at Sarenga Forest Range

Name	Sal leaves	Mahua flowers	Kendu leaves	Kaju fruits	Fodder	Fuel wood	Litter	Food	Medicinal plants
Sal leaves	1								
Mahua flowers	0.751*	1							
Kendu leaves	0.301*	0.689*	1						
Kaju fruits	0.537*	-0.108	-0.459	1					
Fodder	0.285*	0.327*	0.094*	0.329*	1				
Fuel wood	0.957*	0.716*	0.213*	0.614*	0.541*	1			
Litter	0.187*	-0.503	-0.637	0.822*	-0.219	0.152*	1		
Food	0.674*	0.962*	0.857*	-0.207	0.254*	0.610*	-0.550	1	
Medicinal plants	0.757*	0.222*	0.016	0.879*	0.363*	0.781*	0.616*	0.208*	1

*Indicates significant correlation at p value of < 0.01

Regulatory services quantification

The total basal area, volume and biomass of the study area were recorded as 18.23 m^2 ha^{-1}, 71.02 m^3 ha^{-1} and 137.42 t ha^{-1}, respectively. The C stock of trees in the area was estimated as 68.71 t ha^{-1} which sequestered 252.17 t ha^{-1} CO_2. The C stock was positively correlated with tree volume and biomass p = 0.999. The total monetary value of trees were estimated as INR 250,221.45 ha^{-1} (Table 7). The monetary value of climate regulation at Bamnisole, Koyma, Nekra Pahari, Saluka and Sarulia was estimated as INR 24,508.67, INR 30,954.49, INR 120,613.20, INR 41,078.42 and INR 8558.00, respectively, per hectare basis of forest area.

The perceived value of RS was derived from the sample fringe villages (Table 8). These included air purification (clean air), water purification (drinking water), prevention of extreme events

Table 6 Perceived value of provisioning goods and services derived from sample villages of Sarenga Forest Range

Provisioning goods and services	Villages					Mean
	Bamnisole	Koyma	Nekra Pahari	Saluka	Sarulia	
Sal leaves	9.90 (0.31)	9.55 (0.52)	9.70 (0.48)	9.85 (0.35)	9.90 (0.31)	9.78 (0.41)
Mahua flowers	0	4.50 (0.70)	0	0	4.00 (0.70)	0.61 (1.51)
Kendu leaves	7.00 (0.12)	5.11 (1.05)	5.00 (1.05)	0	5.67 (0.70)	3.27 (2.72)
Kaju fruits	8.00 (0.01)	0	0	7.71 (0.48)	7.33 (0.57)	1.82 (3.30)
Fodder	6.30 (3.46)	6.22 (2.58)	6.70 (2.58)	8.00 (0.53)	5.60 (3.06)	6.51 (2.70)
Fuel wood	8.90 (0.87)	9.22 (0.83)	9.10 (0.73)	9.37 (0.74)	9.30 (0.67)	9.17 (0.76)
Litter	3.80 (0.63)	4.22 (0.83)	3.20 (0.91)	3.37 (0.74)	4.10 (0.73)	3.74 (0.84)
Food	5.00 (0.10)	4.56 (0.72)	5.22 (0.97)	5.00 (0.03)	5.57 (0.53)	5.07 (2.58)
Medicinal plants	6.20 (0.91)	6.11 (1.26)	6.10 (1.28)	6.25 (1.48)	5.37 (1.06)	6.02 (1.19)
Others (tasar)	0	0	0	8.75 (0.70)	0	1.48 (3.35)

The values within the bracket depicts the standard deviation

Table 7 Quantity and monetary value of regulatory services derived from sample villages of Sarenga Forest Range (biomass and carbon stock estimation of trees)

Villages	Total basal area (m^2 ha^{-1})	Volume (m^3 ha^{-1})	Biomass (t ha^{-1})	C stock (t ha^{-1})	CO_2 sequestration (t ha^{-1})	Monetary value (INR per hectare basis)
Bamnisole	2.88	5.99	13.46	6.73	24.70	24,508.67
Koyma	2.00	7.81	17.00	8.50	31.20	30,954.49
Nekra Pahari	6.47	36.98	66.24	33.12	121.55	120,613.2
Saluka	3.12	12.47	22.56	11.28	41.40	41,078.42
Sarulia	0.878	1.78	4.70	2.35	8.62	8558.00
Mean	3.07	13.01	24.79	12.40	45.49	45,142.56
Total	18.23	71.02	137.42	68.71	252.17	250,221.45

and soil erosion, soil moisture retention, soil fertility maintenance and climate regulation (rainfall interception). Mean perceived values of RS were found to be highest for prevention of extreme events (9.05 ± 0.81), followed by purification of air (8.61 ± 0.94), purification of water (8.52 ± 0.90), soil fertility maintenance (8.08 ± 1.10), rainfall interception (7.68 ± 1.08), soil moisture retention (6.16 ± 1.23) and prevention of soil erosion (5.95 ± 1.19).

Forest dependency

It was observed that all the households were highly dependent on forest resources at Sarenga for different products and services, contributing to the gross annual income of the households (Figure 5). Highest level of dependence was noticed at Bamnisole village (33%) followed by Saluka (29%), Koyma (26%), Nekra Pahari (21%) and Sarulia (12%).

Table 8 Perceived values of regulatory services derived from sample villages of Sarenga Forest Range

Regulatory services (RS)	Villages					Mean
	Bamnisole	Koyma	Nekra Pahari	Saluka	Sarulia	
Purification of air (clean air)	8.89 (0.81)	9.00 (0.86)	8.20 (1.03)	8.62 (1.06)	8.20 (0.78)	8.61 (0.94)
Purification of water (drinking water)	8.34 (0.51)	8.89 (1.05)	8.10 (1.19)	8.00 (0.75)	9.20 (0.63)	8.52 (0.90)
Prevention of extreme events	9.00 (0.67)	9.22 (0.83)	9.50 (0.52)	8.62 (1.18)	9.10 (0.73)	9.05 (0.81)
Prevention of soil erosion	5.34 (0.94)	6.22 (1.48)	5.50 (1.08)	6.50 (1.41)	6.33 (0.86)	5.95 (1.19)
Soil moisture retention	6.22 (0.91)	5.22 (1.39)	6.20 (1.23)	6.75 (1.38)	6.90 (0.99)	6.16 (1.23)
Soil fertility maintenance	8.00 (1.32)	8.22 (1.20)	8.70 (0.48)	9.00 (1.06)	7.70 (0.94)	8.08 (1.10)
Climate regulation (rainfall interception)	7.56 (0.85)	8.11 (1.26)	7.70 (1.25)	7.50 (0.92)	7.10 (0.99)	7.68 (1.08)

The values within the bracket depicts the standard deviation

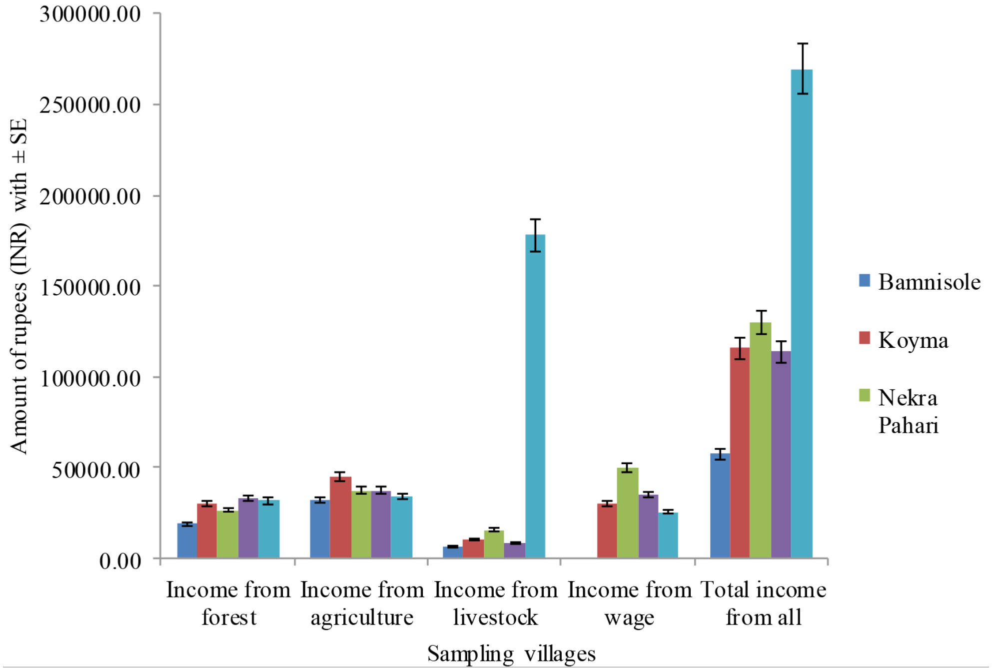

Figure 5 Gross annual income of households (± SE) at Sarenga Forest

DISCUSSIONS

The study presented a linkage between ES valuation and its significance towards sustainable development and well being of a community. The socio-economic factors, largely, influenced the inhabitants to utilise and mange the forest resources. The average family size of the study area was found to be higher than the national average family size of 4.8, while for West Bengal state it is 4.5 (MOHFW 2007). The trend of PS with respect to economic valuation showed the pattern as fuelwood > sal leaves > fodder > kaju fruits > food > mahua seeds > kendu leaves > tasar > medicinal plants > litter, while according to their perception the valuation of PS stands as sal leaves > fuelwood > fodder > medicinal plants > food > litter > kendu leaves > kaju fruits > tasar > mahua seeds. The differences was due to the lack of knowledge on market value of different products, and mostly the inhabitants gave scores to the goods as per the availability of the respective resources in their village and from which goods they earn higher benefits in terms of monetary gain as well as household consumption. The trend of RS valuation as per people's perception showed the pattern of prevention of extreme events > air purification > water purification > soil fertility maintenance > climate regulation > soil moisture retention > soil erosion prevention. This suggested that people were suffering from extreme drought conditions, and were aware of the issues related to climate change and the importance of their forests.

The prime occupation of most of the households was agricultural activities. Earning of households also depended upon wage, small cattle rearing and a major part involving forests resource extraction. The gross annual income in the study area was attained through various activities, viz., rearing of small animals/livestock, agriculture, wage and forests that follows the trend as livestock > agriculture > forest > wage. At Bamnisole, the trend of income was agriculture > forest > livestock with no wage labourers in the sampled HH, at Koyma, the trend followed agriculture > forest > wage > livestock, at Nekra Pahari it was wage > agriculture > forest > livestock, at Saluka and Sarulia the income trend showed agriculture > wage > forest > livestock and livestock > agriculture > forest > wage, respectively. Although most of the household possessed small piece of cultivable land but the crop productivity were much lower than the state average, mainly due to prevalence of drought and poor irrigation facilities in the area. Therefore, diversification of income sources were evident among the communities, which was consistent with studies conducted on livelihood diversification in rural communities. Extreme events, climate change and the anthropogenic activities largely influenced the PS and RS, thus reducing the potentiality of the services, impacting on both forest and crop productivity that immensely affected the livelihood of rural, compelling diversification. As ES were affected, the diversification of different livelihood options was gaining importance in the area. It was also recommended to opt for sustainable livelihood management strategies, viz., climate resilient agriculture, alley cropping, etc., in the area. However, the primary occupation being agricultural practices in the study area, the livelihood diversification mainly included collection of NTFPs, livestock rearing and working as wage labourers that contributed to about 73% (forests 21%, livestock 32%, wage 20%) of the total gross annual income of the respondents in the area. The correlation analysis of different livelihood opportunities prevailing in the area showed significant contributions from livestock rearing along with the income from forests, at p value < 0.01 with correlation value of 0.267. Livelihood diversification and contribution to well being has also been reported from western Himalayan region, Arunachal Pradesh and central Western Ghats (Ramana & Patil 2008, Joshi & Negi 2011, Kumar & Chaudhry 2015). Collection and marketing of NTFPs are one of the most important tools to address the poverty and well being of rural communities. About 14% of Indian forest is covered with *Shorea robusta* (sal) trees. Different states of India, namely, West Bengal, Odisha, Madhya Pradesh, etc. depend upon sal leaves collection and making leaf plates, as it is a predominant traditional vocation of the scheduled tribes and scheduled castes that contribute to their livelihood (Panda 2018), which was evident in present study. The collection of PS prevailed in the area but its amount was much lower compared to the forest in Gujrat, and higher in Arunachal Pradesh (Sarmah & Arunachalam 2011, Yadav 2019). However, the income from medicinal plants was found to be extremely low due to destructive harvesting that has reduced its abundance in the forest and market driven prices. The collection of fuel wood exerts immense pressure on forest ecosystem, and apart from consumption, many used to sell firewood in nearby markets (Boskovic et al. 2018).

The economic value of NTFPs in forest ecosystem per hectare in Western Ghats of India ranged from INR 634 (dry deciduous zone) to INR 801 (evergreen zone) with mean value of INR 1159 ha^{-1} $year^{-1}$ (USD 1 = INR 47, April, 2003). The present study showed valuation of provisioning ES of INR 1859 $person^{-1}$ $year^{-1}$ which was lower than the value estimated for western Himalayan region of India (Joshi & Negi 2011). Forests in Gujrat estimated the monetary value of NTFPs as INR 307.4 million $year^{-1}$, while for West Bengal jangal mahal of Sarenga is INR 44.575 billion $year^{-1}$ (Saha 2018, Yadav 2019).

The present study estimated the mean economic value of PS as INR 13.052 billion year^{-1} which is low compared to the entire state data. The low value is due to the rapid destruction of forest area with additional biotic pressure (Datta & Sarkar 2012). However, the valuation of PS among the villages also differed in the study area due to easy access to PS, as well as the availability of natural resources, mainly at Nekra Pahari with a lowest population size of 182.

The INR, with reference to carbon sequestration potential of forests, recorded 71.02 m^3 ha^{-1} of volume, 137.42 t ha^{-1} of biomass, 68.71 t ha^{-1} of C stock and 252.17 t ha^{-1} of CO_2 sequestration, and its monetary value were recorded as INR 250,221.45 ha^{-1} of forest land. The value of total biomass accumulated in the forests of Uttarakhand recorded INR 3.82 billion (Singh 2007). Total economic value of Himachal Pradesh forests records INR 1066 billion year^{-1}, while the average value of ES from Arunachal Pradesh records US$41.6 billion year^{-1} (Verma 2000, Chaudhry 2009). In relation to carbon pool estimates, central India estimated above ground biomass at 78,170.72 mg, 81,656.91 mg and 7470.45 mg C in mixed, degraded and Sal mixed forests, respectively, and estimated maximum carbon storage of 22.97 to 33.27 mg ha^{-1} (Bijalwan et al. 2010, Bijalwan 2010). Total C stocks from northern Haryana were estimated at 12.96 Tg (Kumar et al. 2011). Closed natural forests of Barnawapara Wildlife Sanctuary in Chhattisgarh recorded a maximum total carbon of 208.22 Mg ha^{-1}, while C stocks in tropical deciduous forest at Nallamalais recorded biomass and C stock of 56.47 Mt and 26.34 Mt respectively (Rao and Rao 2015, Lal et al. 2016)). Other studies in other tropical forests of Bodamalai hills of Tamil Nadu and Savannah ecosystem of Kanyakumari Wildlife Sanctuary showed C stock of 38.92 tC ha^{-1} and 216.2 MgC ha^{-1} respectively (Pragasan 2015, Sundrapandian & Subhashree 2017). Therefore, it was evident that for the assessment of regulatory services, the estimation of biomass and C stock were considered. A systematic review was carried out by Salunkhe et al. (2018) to summarise the biomass and C stock estimation, however, the estimates from the states of Bihar, Odisha and West Bengal is missing. The economic valuation of such ES from different parts of India is lacking.

The forest system helps in carbon sequestration of a considerable amount of carbon, as depicted in the study, which in turn improved microbial activities. Thus, the soil physical, chemical and biological activities were improved. Due to carbon sequestration, the structure of the lateritic soil of the study area improved and promoted the root growth of crops. Therefore, agroforestry systems could be encouraged in the area. In the alley of forest species, crops like ginger, pulses, soybeans, groundnut can be grown which will promote the diversification of crops and livelihood of the local communities. Such interventions will be of immense significance that contribute towards the well being of the community, influenced by the regulatory ES of the area. Thus, the present study paves the way to enhanced returns from the forest ecosystem through adaptation of a agroforestry system. However, the percentage of total income can be evaluated only after the intervention of alley cropping. Thus, the present findings only recommend strategies to be adopted.

The dependencies on forests for livelihood by the locals were evident from the study. The highest contribution to household forest income comes from fuel wood (31%), sal leaves (25%) and fodder (19%), while others contribute about 26% which includes mahua flowers, kendu leaves, mushroom, medicinal plants, etc. The higher percentage of these services were due to the involvement of higher number of households in collection, availability of resources in the forests and the higher local market value. The results also confront the research by Langat et al. (2016). The mean annual income from forests per household was found to be INR 879 ha^{-1}. However, the total percent of forest dependency upon the total livelihood income in the study area was recorded as 24%. This is consistent with the study by Saha (2018) which reported 20.21%, higher than Chittagong hills of Bangladesh (Miah et al. 2012). Considering the different areas, the percent of contribution from the forest ranged from 12 to 33%, which can be explained as lowered tree growing investments in the area, increased demand of forest resources and gradual degradation of forest land. However, the study findings were similar with other studies and confirmed the importance of forest resources to the livelihood or income of households.

The correlation analysis of different PS showed significant correlation, depicting that throughout the year the inhabitants collect forest resources that eventually contribute to their gross annual income. From the study, it is also revealed that per person valuation of PS follows the trend, Nekra Pahari > Saluka > Sarulia > Koyma > Bamnisole considering all the villages. Similarly for RS the trend follows the pattern, Nekra Pahari > Saluka > Koyma > Bamnisole > Sarulia.

CONCLUSION

In the study area, forest played a crucial role in providing provisioning ES and goods towards direct and indirect benefits of the large forest dependent community, besides adding substantially to their regular income. Perceived value for the respective services also supported the dependency on forest resources. A total of 24.20% income of the households comes from forest, depicting the dependency of local people on forest resources. The PS valuation among the villages differed in the study area due to easy access to PS, and showed a significant correlation, thus contributing towards household income throughout the year by collection of forest resources. A clear perception of the stakeholders were found regarding the use of forest resources to enhance the ES and human well being in the study area. The area revealed a high potential of ES (PS and RS) with a value of INR 13,53,718.56 year^{-1}. Such services play a crucial role in the livelihood of locals, however, lack of skills in non-destructive harvesting of resources, improper forest management, lack of awareness, prevalence of extreme event of drought and market value eventually reduce the ES potentiality, causing hindrance in achieving sustainable livelihood opportunities in the area. Productive ecosystems provide options for improving the livelihoods of future generations, whereas ecosystem depletion and species extinction reduce capacity to adapt to future stresses such as climate change, and respond to opportunities such as the marketing of ecological services.

Increased demand for resources in coming years may exert pressure on forest resources. Therefore, the recommendations to enhance livelihood and local biodiversity conservation are to (1) lower the extraction of fuel wood following proper forest management protocol, (2) restrict collection of medicinal plants and introduce capacity building on non-destructive harvesting to the communities, (3) strengthen local institutions and promote plantation through agroforestry interventions and (4) establish livelihood framework based on baseline survey, and introduce climate resilient agriculture for sustainable farm incomes that would enhance livelihood and help conserve the local biodiversity of the region.

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