Valuation of provisioning ecosystem services and household dependency for livelihood: Empirical evidence from a tropical dry forest, India

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Abstract

The present study investigated the contribution of provisioning ecosystem services (PES) to the annual incomes of rural households in Vindhyan highlands, India. Household surveys, focus group discussions and key informant interviews were used to collect data, which was stratified by household size. A total of 225 households were chosen for further investigation from three villages adjacent to the forest. We employed one way ANOVA and Pearson's correlation to analyze the quantitative data. The findings demonstrate that PES are critical in supplying rural livelihoods with fuelwood, fodder, leaves, wild edibles, medicines, oil seeds and resins. The overall value was estimated to be 24,781.66, 25,552.95, 16,494.46 INR per household per year for large size and 5467.39, 2671.12, 2029.62 INR per household per year for small size among the three villages. The results revealed that large households earn more than middle and small households in study area. The relationship between variables (household size, age, education, distance to forests and time spent) and PES income was tested using Pearson's correlation. The results exhibited that socio-economic factors impacted PES income substantially ($p < 0.01$, $p < 0.05$) in this study. The findings of this study can help policymakers to create mechanisms in conservation policies and regulations so that adjacent forest households can benefit from ecosystem provisions.

Introduction

Forests play an important role in a wide range of ecosystem functions. People living in tropical areas close to natural forests rely on ecosystem services for a significant portion of their needs and income (Langat et al. 2016). These products are referred to as "provisioning services," which are defined as "services supplying tangible assets, finite albeit renewable, that can be claimed, quantified, and traded" (Maass et al. 2005). Globally, between 1.1 billion and 1.7 billion people are believed to rely on forests for their livelihood, with over 200 million people living in or around dry forests being entirely dependent on forests (Chao 2012). Environmental resources in developing countries are expected to provide 20–25 percent of rural people's income (Vedeld et al. 2007), and they function as safety nets during critical periods (FAO 2016).

The ecosystem provisions are in more demand in the international market. In 1980, the overall value of worldwide forest product exports climbed by 36% and 70% in 2000. In 2017, the value of exports increased to US$ 247 billion, indicating a higher worldwide demand for ecosystem goods (FAO 2017). China ranked first among countries in the export of ecosystem goods followed by India, United States, Germany and Egypt (Yildrim and Kose 2018). In tropical forest areas, harvesting of ecosystem provisions could generate more income than logging (Peters et al. 1989). Forest goods enhance the income of rural populations in various countries of Latin America, Sub-Saharan Africa and Asia (Babulo et al. 2009).

Several studies have been conducted to analyze the contribution of forest products to household income provision (Sunderlin et al. 2004; Kalaba et al. 2013; Kamwi et al. 2015), with the results demonstrating that forest products are critical in meeting the needs of rural households. Provisioning ecosystem services (PES) have been shown to play an essential role in sustaining rural household income

(Rasmussen et al. 2017). Hickey et al. (2016) also mentioned the importance of wild foods in promoting food security and nutrition. For example, people who live in the vicinity of forests have easy access to forest goods such as wild fruits, green leafy vegetables and meat (Ickowitz et al. 2014; Powell et al. 2015). Fuelwood, medicinal herbs, construction materials and fodder are among the other goods that contribute significantly to household subsistence (Rasmussen et al. 2017).

The availability of these provisions is linked to a variety of socio-economic factors, including household size (Adhikari et al. 2004, Cordova et al. 2013), age, education level and household income (Coulibaly-Lingani et al. 2009), all of which have significant impact on the usage of forest provisions. Education level has been observed to lessen both absolute and relative forest income by increasing the opportunity cost of spending time for collecting forest provisions (ecosystem goods) since it enhances other employment opportunities (Kamanga et al. 2009). The extraction activities may be influenced by the distance between households and the forest. According to studies, forest products are crucial to rural earnings for households living in distant villages with limited infrastructure (Yemiru et al. 2010; Cordova et al. 2013). Similarly, those who live far away from the forest also derive more resources.

Around 70% of India's rural population, with the majority of them relying on agriculture or forest-based economies (Khan et al. 2018). Forest resources are used by over 350–400 million (40%) people (MoEF 2009), and their dependence is still high due to easy access, simple use and the lack of economically viable alternatives (Chhetri 2002). Minor forest provisions are thought to be less environmentally damaging than timber harvesting and other methods of forest sustainability (Shackleton and Pandey 2014). Furthermore, several ecosystem goods, such as *Sterculia urens* (karaya gum), *Santalum album* (chandan) and *Terminalia chebula* (baheda) have a monopoly in India (Yadav and Basera 2013). As a result, the commercialization of ecosystem provisions is seen as a very promising economic source, particularly for those who live on the outskirts of the forest. However, due to the lack of knowledge and opportunities, the process of marketization of ecosystem goods is primarily limited in local areas, mostly in the rural market (Senaratne et al. 2003). According to Mahapatra and Tewari (2005) in eastern India's deciduous forest, middlemen or local lenders were collecting ecosystem provisions from rural collectors at very low prices and selling them in urban marketplaces for significantly higher prices.

The number of studies based on economic assessment of biodiversity and ecosystem services is increasing around the world, there is still a lack of such studies in India and Vindhyan highlands. In Vindhyan highlands, the diversity of ecosystems and livelihood opportunities available to local communities are enormous. Few studies have been done on the forest provisioning ecosystem services in India (Joshi and Negi 2011; Jena 2020; Chhetri et al. 2021; Yadav et al. 2021). Despite this, the dry deciduous forests of Vindhyan highlands provide a variety of valuable services that are significant (Sharma et al. 2021; Patel et al. 2022) but mostly unexplored.

In the present study, we address how the collection of ecosystem provisions is related to the household structure of local people in Vindhyan highlands. We investigate whether certain family sizes gather more ecosystem products than others, such as fodder, fuelwood, oil seeds, wild edibles and medicinal plants.

Based on the above hypothesis, we propose three assumptions: i) to quantify various provisioning services (ecosystem goods) that the local people derive from the deciduous forests of Vindhyan highlands; ii) that larger households harvest more ecosystem provisions than smaller households; and iii) how socio-economic factors determine rural households' dependency on PES income in Vindhyan highlands.

Materials And Methods

Study area

The study area is the Dudhi block in Sonbhadra district of India (21° 29'–25° 11' N and 78° 15'–84° 15' E). It is a section of the Vindhyan highlands that is topographically a rocky plateau with a slightly sloping terrain and a valley at the bottom. The elevation ranges from 313 to 483 meters above sea level (Fig. 1). The climate of the area is tropical monsoon, with rainy seasons (late June-October), winter (November-February) and summer (April-mid June) throughout the year. The average annual temperature is 28°C, and the average annual rainfall is 1419.2 mm. The study site in Dudhi block is surrounded by Obra forest division in the north, Vindhyachal in the east, Chhattisgarh in the south and Madhya Pradesh in the west. The soil is red lateritic, sand-rich in texture and nutrient-poor. The area experiences nine months of dry weather in each annual cycle and remaining three months of humid weather. The Dudhi block was classified into five major categories viz., water bodies, built-up, bare land, dense forest and sparse vegetation (Fig. 2). The dense forest occupied the largest area (1065 km^2) followed by sparse vegetation included areas under agricultural cover and sparse forest patches (776 km^2), bare land with fallow land (395 km^2), water bodies (336 km^2) and built-up (111 km^2).

The forest in this area is tropical dry deciduous forest, therefore according to Champion and Seth (1968), the major forest types are: (i) Dry peninsular sal forest; *Shorea robusta* (Sal) grows in tiny patches alongside other tree species including *Boswellia serrata*, *Buchanania lanzan*, *Diospyrous melanoxylon*, *Anogeissus latifolia* and *Lagerstromia parviflora* in mixed stands. Other tall tree species such as *Elaeodendron glaucum*, *Adina cordifolia*, *Madhuca longifolia* and *Pterocarpus marsupium* are also found in modest numbers. *Woodfordia fruticosa* and *Hyptis suaveolens*, two of the most common shrubs are also present. (ii) Northern dry mixed deciduous forest; *Boswellia serrata*, which is primarily found on hilltops and *Acacia catechu*, which is mostly found on slopes, are the most common tree species. *Holarrhena antidysenterica* grows as an understory plant in the forest. (iii) Southern dry mixed deciduous forest; this type of forest may be situated at the southernmost reaches. *Anogeissus latifolia*, *Terminalia tomentosa*, *Hardwickia binnata*, *Chloroxylon swietenia* and *Lagerstromia parviflora* are among the plants that constitute the forest.

Data Collection

Forests of Vindhyan highlands provide essential PES for human well-being that often go overlooked due to the lack of quantifiable values. Fuelwood, fodder, wild edibles, medicines, leaves, oil seeds and resins are some of the most prominent PES extracted from the forests included in this study. The three study villages (namely Gardarva, Saudih and Rajkhar) were chosen based on their natural surroundings, indications of resource utilization and similarities in socio-economic and livelihood activities. Villages were surveyed from October 2017 to September 2019 in three consecutive years.

The primary data on the distribution of forest resources, ecosystem goods usage and economic benefits were acquired via structured household questionnaires, focus group meetings, in-depth interviews and information from community elders (Martin 2014). Individual questions were orally translated into the local language (Hindi) during the administration of questionnaire to respondents. Several components of the questionnaire covered general household socio-economic data, livelihood activities and the sale of ecosystem provisions. The income obtained from the sale of ecosystem provisions was reflective of cash income recorded by the household during the previous 12 months. The reliability of PES income data was enhanced by the fact that most ecosystem commodities are sold at different months of the year, when field activity is taking place. The collection of data required permission from the appropriate authorities and for this purpose, we first sought permission from the Gram Pradhans (village heads) and local authorities (Rural Panchayats) of selected villages.

The household survey included 225 households (66, 72, and 87 in Gardarva, Saudih and Rajkhar respectively), constituting a 10% sample intensity in each village for household interviews (Clarke 1986), which is higher than the 5% recommended by Boyd and Stach (1988). The household was the sampling unit in the household survey. The household sizes established during focus group discussions were used to stratify the sample families. The number of individual in the household was divided into three categories: small (1–4), medium (5–7) and large (> 8). In this study, we employed purposive sampling to identify knowledgeable people for key informant interviews. The village head and other elder community members served as key informants since they were aware about ecosystem commodities and able to provide information. We pre-tested the questionnaire in one of the study villages and made necessary changes. We met with the village head before performing the household interviews to brief them about the goals of our survey and to get their suggestions on where to find the households to interview.

The existing land use/land cover classification was determined using ESA's Sentinel-2A (MSI) satellite images obtained from the USGS Earth Explorer repository. The month of October 2018 was chosen to collect cloud-free data under the criterion of "less than 10% cloud cover." The image classification was performed in ENVI 5.1 through ANN supervised classification technique, whereas ArcGIS 10.3 was used for rest of the operations and map creation.

Valuation Method

In this study, each household was surveyed for information on the collection and sale of several ecosystem goods. Due to the seasonality of many ecosystem assets, valuing ecosystem goods is a

tedious exercise. As a result, our findings reflect seasonal variations in the quantity of these products collected from the forests. The monetary value of various commodities was calculated using the market price approach, as used by previous researchers (Singh 2002). During the field surveys, the monetary value of several ecosystem provisions was determined by a questionnaire survey and also validated through informal interactions with elderly residents in the area.

PES income is composed of many forest goods that are used for cash and subsistence, including wild edibles, fuelwood, fodder, medicinal plants, oil seeds and resins. Income derived from wild edibles, medicinal plants, oil seeds and resins were calculated by market prices or own-reported prices of respondents in local measure units multiplied by the reported annual amount collected. Annual income from fuelwood and fodder was calculated using sale quantities indicated by respondents were multiplied by market prices. However, to compute the quantities at village level, the total annual quantities of various ecosystem commodities collected by individual households and their monetary values were pooled.

Data analysis

Quantitative data was evaluated with the help of IBM SPSS software version 23 (IBM Corp. (2015) combined with Microsoft Excel version 10. The most common statistical approaches for analyzing quantitative data were descriptive and inferential statistical procedures (Giliba et al., 2011; Pallant, 2020). The socio-economic characteristics of rural communities were explained using descriptive statistics including mean values, standard error of the mean and percentages of observed attributes (Giliba et al., 2011). We examined how respondents perceived their family members' roles in gathering ecosystem provisions. For statistical analysis, one-way ANOVA was used to test the differences in PES quantity and income across the three household sizes, followed by Tukey test for pairwise comparisons. In order to determine the relationship between household characteristics and PES income, non-parametric Pearson correlations were used to investigate the causal relationship between a single dependent variable, i.e. PES income and the combined effects of two or more independent variables.

Results

Socio-economic setting of study area

In the villages of Gardarva, Saudih and Rajkhar, almost 24.24%, 36.11%, and 31.03% of households were in the small group, while 16.67%, 15.28%, and 16.10% were in the large category (Fig. 3). The distribution of household showed that males primarily composed 15.00%, 20.47% and 20.80%, while females composed 12.87%, 23.80% and 14.22% of small households. In large size of households, males comprised 26.50%, 26.98% and 24.80% and females made up 22.80%, 22.62%, and 29.29% in all three villages. Small households in Gardarva village had a lower illiteracy rate (39.13%) than large households (41.11%). However, the percentage of illiteracy is higher in small families (53.66% and 68.60%) than large families (38.95% and 49.50%) in Saudih and Rajkhar village respectively. The total literacy rate was

61.61% followed by 52.63% and 43.75% in Gardarva, Saudih and Rajkhar villages having completed primary, secondary or higher education.

In terms of household age composition, 22.30% of the sample population was aged 0–10 years, 21.49% in 11–20 years, 25.70% in 21–35 years, 22.71% in 36–50 years and 7.80% was aged above 51 years category for Gardarva. In Saudih village, 16.40% of the members were aged 0–10 years, 23.18% in 11–20 years, 26.32% in 21–35 years, 16.49% in 36–50 years and 17.61% were above 51 years. However, 25.23% of the population is aged 0–10 years, 19.45% in 11–20 years, 27.07% in 21–35 years, 10.27% in 36–50 years, and 17.98% above 51 years in Rajkhar village. Family size, education status and age all play a vital role in the planning and appropriate usage of the ecological services provided by forests. The majority of the households had animals. The total livestock holdings were around 233 in Gardarva, 213 in Saudih and 251 in Rajkhar village. The majority of animals graze in the proximity of forests, indicating that forests provide fodder and bedding material for livestock. Gardarva had the largest average landholding of 0.91 ha, followed by Saudih (0.83 ha) and Rajkhar (0.34 ha). Small households owned 0.86 ha, 0.69 ha and 0.16 ha of agricultural land respectively, whereas large households owned 1.10 ha in Gardarva and 0.95 ha in Saudih and Rajkhar villages.

Provisioning Ecosystem Services Derived From The Forests

Households in the study area obtained their subsistence from a variety of sources, although the primary source of subsistence income comes from the PES. The collection of number of PES varies by commodity for sale to traders or in local marketplaces. The substantial difference in ecosystem products gathered from the forests was caused mostly by variations in family size among villages. The total collection was estimated at 20,954.31 ± 874.99, 20,340.47 ± 663.36, 18,059.7 ± 896.83 kg $year^{-1}$ $village^{-1}$ by large households while small households collected 8588.43 ± 599.63, 7707.45 ± 268.3, 7690.4 ± 343.13 kg $year^{-1}$ $village^{-1}$. In spite of this, collection of leaves was also estimated at 2194.09 ± 106.06, 2170.90 ± 83.81, 1654.28 ± 91.67 sac $year^{-1}$ $village^{-1}$ for large families and 379.12 ± 28.30, 334.84 ± 19.41, 237.22 ± 10.25 sac $year^{-1}$ $village^{-1}$ for small families in Gardarva, Saudih and Rajkhar (Fig. 4). The total value of PES was quantified at 87,478.25 ± 7009.63, 69,449.16 ± 3256.91, and 54,799.85 ± 3192.38 INR $year^{-1}$ $village^{-1}$ by small size families whereas large families earned 2,72,598.35 ± 17466.04, 2,81,082.51 ± 17048.03 and 2,30,922.54 ± 13403.96 INR $year^{-1}$ $village^{-1}$ for all three villages which computes 5467.39, 2671.12 and 2029.62 per household per year for small size and 24,781.66, 25,552.95 and 16,494.46 per household per year for large size among the villages (Fig. 5).

Ntfps As A Source Of Provisioning Ecosystem Services

The study area is recognized to have an accumulation of various wildly growing plants that provide significant dietary and livelihood support to local residents. The local people often harvest ecosystem goods on a regular basis throughout the various months and seasons of the year. In each village, the

large size households collected the most leaves (2194.09 ± 106.06, 2170.90 ± 83.81, 1654.28 ± 91.67 sac $year^{-1}$ $family^{-1}$), while small size households collected the least leaves (379.12 ± 28.30, 334.84 ± 19.41, 237.22 ± 10.25 sac $year^{-1}$ $family^{-1}$) (Fig. 4a). The income generated from the sale of leaves were higher in large households (1,85,218.18 ± 14254.14, 1,96,327.27 ± 14202.54, 1,51,842.85 ± 10238.39 INR $year^{-1}$ $family^{-1}$) compared to small households (46,781.25 ± 4193.12, 32,640.76 ± 1977.19, 18,060.00 ± 1517.44 INR $year^{-1}$ $family^{-1}$) (Fig. 5a).

The collection from wild edibles was observed and documented to be the lowest in small size families (678.78 ± 60.21, 501.05 ± 19.66, 479.47 ± 13.99 kg $year^{-1}$ $family^{-1}$) and highest in large size families (4067.72 ± 249.01, 3972.27 ± 124.18, 3069.43 ± 219.22 kg $year^{-1}$ $family^{-1}$) in all three villages (Fig. 4b). The cost of wild edibles varies from small households (1639.47 ± 143.76, 1209.54 ± 47.87, 1161.28 ± 34.55 INR $year^{-1}$ $family^{-1}$) to large households (10,143.80 ± 192.77, 9,938.92 ± 346.04, 8,051.81 ± 378.08 INR $year^{-1}$ $family^{-1}$) (Fig. 5b).

The highest quantity of medicines were collected by large size households (2834.09 ± 82.07, 2712.72 ± 74.83, 1957 ± 150.40 kg $year^{-1}$ $family^{-1}$) both for selling and healthcare treatment, while small size households collected the lowest (321.03 ± 29.44, 247.97 ± 17.79, 214.32 ± 9 kg $year^{-1}$ $family^{-1}$) in Gardarva, Saudih and Rajkhar respectively (Fig. 4c). The most income extracted from the sale of medicine was high in large families (6928.88 ± 246.39, 6688.82 ± 155.45, 5098.21 ± 303.18 INR $year^{-1}$ $family^{-1}$) than small families (806.38 ± 75.30, 614.14 ± 53.13, 510.37 ± 30.33 INR $year^{-1}$ $family^{-1}$) (Fig. 5c). The majority of wild edibles and medicines are harvested for sale in local markets depending on their status in natural and adjacent forests as a source of income.

Oil seed extraction was observed and reported to vary from small (156.17 ± 16.79, 106 ± 8.42, 94.71 ± 5.96 kg $year^{-1}$ $family^{-1}$) to large size households (1364.31 ± 63.27, 1312.72 ± 52.97 kg $year^{-1}$ $family^{-1}$) in respective villages (Fig. 4f). The revenue from oil seeds also varies according small (776.64 ± 85.62, 471.26 ± 38.14, 423.56 ± 27.23 INR $year^{-1}$ $family^{-1}$) to large household size (5932.40 ± 291.85, 5725.45 ± 241.66, 4664.85 ± 227.78 INR $year^{-1}$ $family^{-1}$) (Fig. 5f). A statistical analysis of the gathering and income of leaves, wild edibles, medicines and oil seeds in all three villages reveals a significant difference ($p < 0.05$) between small, medium and large households. Overall, Gardarva has the highest PES across all categories followed by Saudih and Rajkhar village.

Fodder As A Provisioning Ecosystem Services

The fodder obtained from arable land is insufficient to meet the dietary requirements of cattle. As a result, the local population rely primarily on the forest-based fodder resource. In the study area, a wide range of tree species, forest floor phyto-mass and agricultural byproducts (including trees, shrubs, and herbs) are used as animal feed. Many grasses are favoured as fodder in forests, pastures and the farms.

In Gardarva, Saudih and Rajkhar villages, small households collected less fodder (5602 ± 280.64, 5292.61 ± 134.56, 5121.56 ± 134.28 kg $year^{-1}$ $family^{-1}$) than large ones (8528.80 ± 114.13, 8451.87 ± 103.65, 8299.10 ± 121.07 kg $year^{-1}$ $family^{-1}$) respectively (Fig. 4d). The cost of fodder also varies from small households (28,010.03 ± 1403.24, 26,463.07 ± 672.82, 25,607.81 ± 671.43 INR $year^{-1}$ $family^{-1}$) to large households (42,644.01 ± 570.68, 42,259.38 ± 518.72, 41,495.54 ± 605.37 INR $year^{-1}$ $family^{-1}$) (Fig. 5d). Statistical analysis of fodder collection and value reveals a significant difference ($p < 0.05$) between small, medium and large households in all three villages.

Fuelwood As A Provisioning Ecosystem Services

Fuelwood is the primary source of energy for India's rural population. Fuelwood is easily accessible and rural labour has a cheap opportunity cost. It is mostly collected from dried and fallen branches on the forest floor since it burns readily and emits less smoke. Fuelwood gathering was shown to differ across small, medium and large family size houses. The study reveals that small households had lower annual mean collection (1793.63 ± 207.25, 1530.26 ± 84.41, 1763.69 ± 178.55 kg $year^{-1}$ $family^{-1}$) whereas large families have the highest annual mean collection (4046.85 ± 355.96, 3797.99 ± 302.52, 3658.76 ± 331.16 kg $year^{-1}$ $family^{-1}$) in Gardarva, Saudih, and Rajkhar villages, respectively (Fig. 4e). The revenue obtained from the sale of fuelwood was lower in small households (8968.16 ± 1036.25, 7651.31 ± 422.08, 8818.46 ± 892.77 INR $year^{-1}$ $family^{-1}$) compared to large households (20,234.27 ± 1779.82, 18,889.95 ± 1512.63, 19,004.11 ± 1606.66 INR $year^{-1}$ $family^{-1}$) (Fig. 5e). A statistical analysis of fuelwood collection and value indicate a substantial difference ($p < 0.05$) between small, medium and large families. It is important to note that as the number of household members increases, so do the rates of fuelwood collection. Overall, fuelwood collection was maximum in Gardarva and minimum in Rajkhar village (see Fig. 4, 5).

Seasonality Of Collection

The seasonal availability of PES has a considerable impact on both revenue and market prospects. It has been noticed that the availability of various PES has varied collection times (Table 1). A variety of PES including: Oil seeds, wild edibles, resins, fuelwood, fodder, medicine and leaves were gathered in the study area by households (Fig. 6). Maximum PES harvesting days suggested a better market potential and economic worth. The locals were well aware of the seasonal available month of the year and the number of days required for collection. They travel an average of 10–15 kilometers every day from their residence, which varies depending on size of the family (small, medium and large). Medicines extracted from such plants as *A. racemosus*, *A. precatorious*, *A. paniculata*, *C. longus* and *O. turpethum* were largely harvested during the different months of the year followed by wild edibles such as *A. campestris, C. tora*, and *S. cumini* were collected during the rainy months of July to September. Oil-producing plants like *A. indica*, *H. suaveolens*, *M. longifolia*, *P. pinnata*, and *S. robusta* seeds (115 days) and resin-producing plants like *A. latifolia* and *B. serrata* (35 days) were highly seasonal and harvested during a short period

of time. Other items such as fuelwood, fodder and leaves (*B. vahlii*) were taken throughout the year. In the leaf category, *D. melanoxylon* fetching the maximum price of Rs. 680 per sac, while fuelwood and fodder are both valued at just Rs. 5 per kg. (Fig. 7).

Relationship Between Income And Socio-economic Characteristics

The relationship between household variables (household size, age, education, distance to forest and time spent) and income obtained from PES was investigated. The findings showed a strong relationship between several factors and the revenue from PES in Gardarva, Saudih and Rajkhar villages (Fig. 8). In Gardarva, the study revealed statistical evidence of relationship among the household size ($p < 0.01$), age groups (21–35, $p < 0.01$ to $p < 0.05$) and education ($p < 0.01$) were substantially and positively associated in all categories including oil seeds, wild edibles, resins, fuelwood, fodder, medicine and leaf. On the other hand, age groups 0–10 ($p < 0.01$) were significant with all PES except wild edibles, resins and fuelwood whereas, age groups 11–20 and 36–50 ($p < 0.05$) were significant with fodder and resins. The time spent was negatively correlated with PES income except fuelwood while, distance to forest ($p < 0.01$ to $p < 0.05$) was also negatively correlated with oil seeds, fuelwood and fodder respectively (Fig. 8a).

In Saudih village, association among the household size ($p < 0.01$), age groups (11–20 and 21–35, $p < 0.01$ to $p < 0.05$) and education ($p < 0.01$) were found to be positively correlated and significant, whereas distance to forests ($p < 0.01$) and time spent ($p < 0.01$) were found to be negatively correlated and significant with income from all categories of PES. However, fuelwood ($p < 0.01$) and fodder ($p < 0.05$) were positively linked and significant with age groups 0–10, while age groups 36–50 ($p < 0.01$) were significant with all PES except resins and leaves (Fig. 8b). In Rajkhar village, associations among household size ($p < 0.01$), all age groups and education ($p < 0.01$) were positively correlated and significant ($p < 0.01$ to $p < 0.05$) except above 51 which was significant only with resins and leaves. The time spent was negatively correlated and significant ($p < 0.01$) except for fuelwood and fodder. On the other hand, distance to forests was also negatively correlated for resins and leaves alone ($p < 0.01$) with revenue from PES in all categories (Fig. 8c).

Discussion

The average household size in the study area is 5.95 people, which is higher than the national average of 4.45 people for the country (Census of India 2011). The fact that large families have an economic impact due to the demand for labour force and belief in extended family structures which supports the rationale for large families. In the upper Kedarnath valley of the Garhwal Himalaya, Dhyani and Dhyani (2016) found that the average family size was 6 individuals/household. Hussain et al. (2017) found that the average household size in Van Gujjar villages around the Corbett Tiger Reserve in Uttarakhand, India, is 7.24 people per family.

According to an analysis of education levels in the three villages, a substantial number of family members only completed primary and secondary school, while illiteracy rates were high in Gardarva

village (56.25%). Higher levels of education are linked to a lower reliance on forests for livelihoods, as education opens up a wider range of job options, but illiteracy shows an over reliance on ecosystem products for subsistence owing to a lack of capacity to seek employment in the formal sector (Adhikari et al. 2004; Tugame et al. 2015). Livestock is a significant source of revenue in the studied villages. The average household has 2–3 animals, generally a cow and two oxen being the most common. These cattle provide a source of revenue to the poor in the form of milk, butter, curd and manure. On the other hand, the average land holding per household was assessed to be 0.66 hectares. Rising cattle-to-land ratios (8:1) have increased demand for lopped fodder from forests, as well as increased burden on available grazing areas (Dhyani et al. 2011). Considering the high extraction volumes per household per village, the rising human and animal population patterns of fuelwood and fodder consumption would become unsustainable in the near future.

Human societies are rely heavily on the provisioning services supplied by natural ecosystems in their surroundings. The study area is characterized by dry deciduous forests, with *S. robusta* (sal) and *M. longifolia* (mahua) as the dominant species, as well as other related species including wild edible plants, medicinal herbs, fuelwood and fodder species. The seasonal availability of ecosystem goods extracted from these species varies by month and collection period. The harvest of *D. melanoxylon* leaves takes place over a two-month period which is a lean season (May-June) for the villagers. Kumar and Saikia (2020) also describe collection of this leaves in Jharkhand. Wild edible species including *A. marmelos*, *A. campestris*, *B. lanzan* and *M. longifolia* were gathered for just a few months of the year. Schmidt et al. (2020) reported that some wild fruit species were gathered only during specific seasons, whereas others were collected throughout the year in Southern Sumatra, Indonesia.

Ecosystem goods play a critical role in the livelihood of rural communities in the study area. The current study also shows how communities depend on the direct contribution of natural resources. Ecosystem goods collection is the most significant activity of rural households to earn money by selling fuelwood, fruits of *M. longifolia*, leaves of *S. robusta* and *D. melanoxylon* and other PES. Although, locals are well aware of traditional knowledge and have extensive experience in collection of PES. The most often gathered ecosystem goods were fodder and fuelwood. People went to the forest on average every day or second day to harvest fodder and fuelwood. As a result, these ecosystem commodities provide useful additional household resources (Mariki 2016). The gathering and amount of fodder differed from village to village. The quantity of fodder collection was directly related to the number of livestock/households and the number of people of a household participating in gathering. The collection of fodder during the months of February-May was found to be lower than the gathering of green fodder months of August-September. This was owing to a lack of fodder in their village area as well as in forests due to a severe summer and leaf-fall from trees, which results in low-quality straw, crop residue and dry grasses, which also has an influence on the amount and quality of milk output.

Villagers harvested medicinal herbs and wild edibles considerably less frequently than fodder and fuelwood. This could be due to the fact that wild edibles and medicines are only available during specific seasons. Furthermore, therapeutic herbs may be preserved and kept for later use, unlike fuelwood and

fodder, which are required on a daily basis. Similar accounts have been also reported in other African countries (Lebmeister et al. 2018; Mushi et al. 2020) and Himalayan region (Maren et al. 2014; Chakraborty et al. 2018). The frequency of extraction varied depending on the size of household (small, medium and large) and the village level. Our findings demonstrate that as household size increased, fodder and fuelwood extraction also increased.

Some PES have significant potential to improve local livelihoods, but much of the revenue is collected by middlemen with better market access through multiple market channels (Obayelu et al. 2017; Arvola et al. 2019). Leaves are one of the most significant PES in the study region, and these are extracted and sold to the forest corporation in standard sacs, as well as other leaves species (Sal and mahuline) to local dealers in the marketplaces. As there are no restrictions on the gathering of leaves (Sal, tendu and mahuline), households receive the highest share of income from selling them. The income gained from the selling of leaves is similarly high in Odisha's Similipal forest (Jena 2019). Collectors sold some wild edibles directly to the market, such as *A. compestris* (mushrooms), *M. longifolia* (dried mahua fruits) and fuelwood, and they made a lot of profits from these products. On the other hand, provisioning services offer a tremendous potential for earning money if the locals perform some processing (Tiwari et al. 2010; Pangging et al. 2011). This practice is deficient due to illiteracy, insufficient physical and organizational facilities, absence of economic self-sufficiency and unavailability of teamwork. Many commodities are sold in the market as raw materials at very low rates, but they have the potential to earn 2–3 times more after processing. Local officials and the government should take measures to provide training in the processing of ecosystem commodities to the local population.

According to a correlation study between PES income and household socio-economic variables, household size and education are substantially linked with PES revenue in all categories (oil seeds, wild edibles, resins, fodder, fuelwood, medicines and leaves) in the investigated villages. These findings are consistent with those of previous research. For example, Kamanga et al. (2009) in Malawi, Tumusiine et al. (2011) and Tugame et al. (2015) in Uganda also found a positive relationship between family size and reliance on forest supplies for revenue production. This implies that households with large families are more reliant on ecosystem goods to meet their fundamental needs and sustain their livelihood (Bhandari and Jianhua 2017), and that they receive more income than households with smaller families (Balama et al. 2016). Furthermore, larger households tend to have more children who participate in simple forest activities like fuelwood collection, livestock herding and wild foods harvesting in order to supplement their income. Coulibaly-Lingani et al. (2009) asserted an opposite view that individuals from large families may have difficulty in accessing alternate sources of subsistence, and hence may be more inclined towards the use of forest provisions. Moreover, our findings demonstrated that educational attainment was an important variable that had a significant impact on household land use patterns, access to ecosystem commodities and population growth.

The age of household members played an important role in determining income-generating activities. PES income and forest dependency are both linked to the presence of children under the age of 10 in a family. This is to be expected, as child care necessitates more family time and that would reduce time

spent on the collection activities. This study was also supported by Beyene et al. (2020) of Ethiopia's Yavu coffee forest biosphere reserve. Our study revealed significant levels of association between fodder, fuelwood, wild foods, medicines, oil seeds and leaves. Younger and adult persons gathered ecosystem commodities more frequently than older ones. It could be because fodder and fuelwood are both heavy and easier to carry by younger and able-bodied people. Kalaba et al. (2013) and Cooms and Ban (2004) observed similar findings in northeastern Peru, stating that young men were more likely to engage in labor-intensive activities. Even wild edibles and medicinal plants were collected more frequently by younger and adult persons in all three villages, despite the fact that Ndagalasi et al. (2007) found that age is a major determinant in medicinal plant extraction frequency. In a study in Philippines, elder persons were more likely to acquire forest goods owing to their extensive knowledge of forest plants (Lacuna-Richman 2002).

The results indicate that distance from forests and time spent were found to be negatively related to PES income. This means that as distance from the forest increases, the income generated by households from the forest decreases. This corresponds to the report of Mamo et al. (2007) in Dendi district, Ethiopia. Extraction frequency of oil seeds, wild edibles, fodder and medicinal herbs reduced as distance from the forest increased. Close proximity to the forest allows households to extract more resources with less effort and time spent (Ndagalesi et al. 2007). Extraction is hampered by remoteness not only because it takes longer time but also because the chances of accessing ecosystem commodities are reduced. It is interesting to note that those who live far away from the forest are more likely to engage in prohibited harvesting than individuals who live close to the forest because forest guards may not be able to recognize them.

Conclusions

This study has shed light on the importance of PES to rural livelihoods in Vindhyan highlands. The sale of various PES contributes significantly to rural livelihood portfolios of all household sizes. The highest source of PES revenue was leaves followed by fodder and fuelwood in three villages. PES income is higher for large households than for medium and small households. The larger households with more family members were also found to collect more ecosystem provisions particularly leaves, for the purpose of selling. As a result, the contribution of income from the sale of various PES to household income was seen to vary significantly in this study.

Our findings show that deciduous forests of Vindhyan highlands can provide considerable PES to local communities. The findings also revealed that PES income is linked to household socio-economic characteristics. For example, among the five variables studied, household size, age, education, distance to forests and time spent were found to be important predictors in the use of various ecosystem provisions. More case studies across various forest ecosystems should be conducted to better understand how local socio-economic factors influence forest use and to guide the development of locally appropriate management practices. This study adds to the burgeoning literature on the effects of socio-economic factors for the collection and sale of forest provisions by presenting empirical evidence from the

Vindhyan highlands. This research could aid in better targeting local community engagement in the long-term management of PES collection. Capacity building, public awareness and local community participation are all necessary for sustainable forest management. In order to ensure sustainability, conservation practices should be implemented into forest resource management policies.

Declarations

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Author Contributions

AS performed the field work, conceptualized methodology, and prepared the draft of the article as well as formal analysis and writing. SKP helped in the field work, data analysis and prepared the early draft, and wrote the manuscript. RS reviewed and edited the English language and grammar. AKT prepared the location and land use/land cover map. GSS conceptualized and supervised the study and approved the final version of manuscript. All authors contributed to the article and approved the submitted version.

Ethical Approval

Not applicable.

Data availability statement

The data of this study are available from the corresponding author on reasonable request.

Conflict of interest

All authors declare that there is no conflict of interest.

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Table 1

Table 1 is available in the Supplementary Files section.

Figures

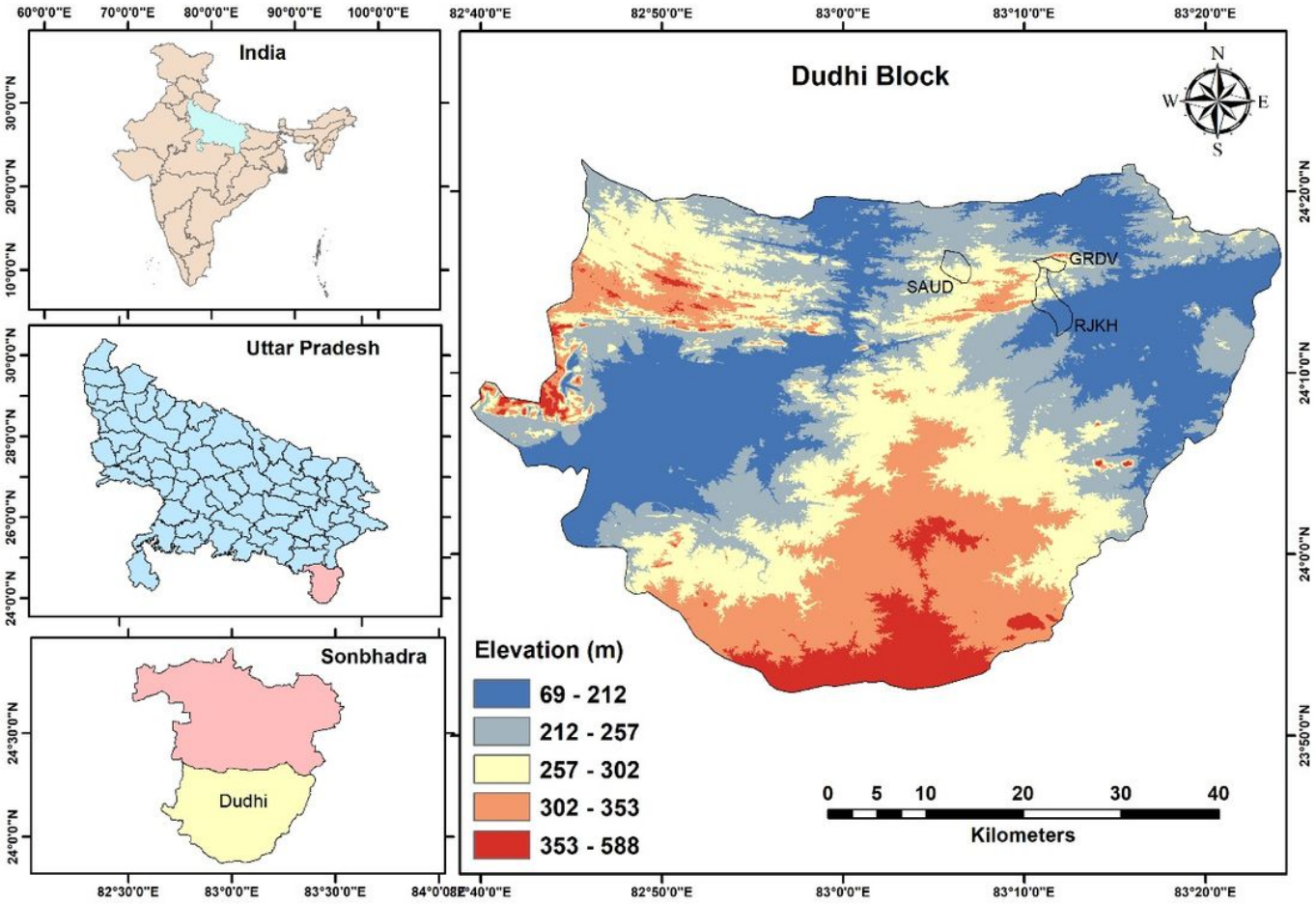

Figure 1

Geographical location of Dudhi block, Sonbhadra district showing three study villages (*GRDV* Gardarva, *SAUD* Saudih, *RJKH* Rajkhar) in Vindhyan highlands, India

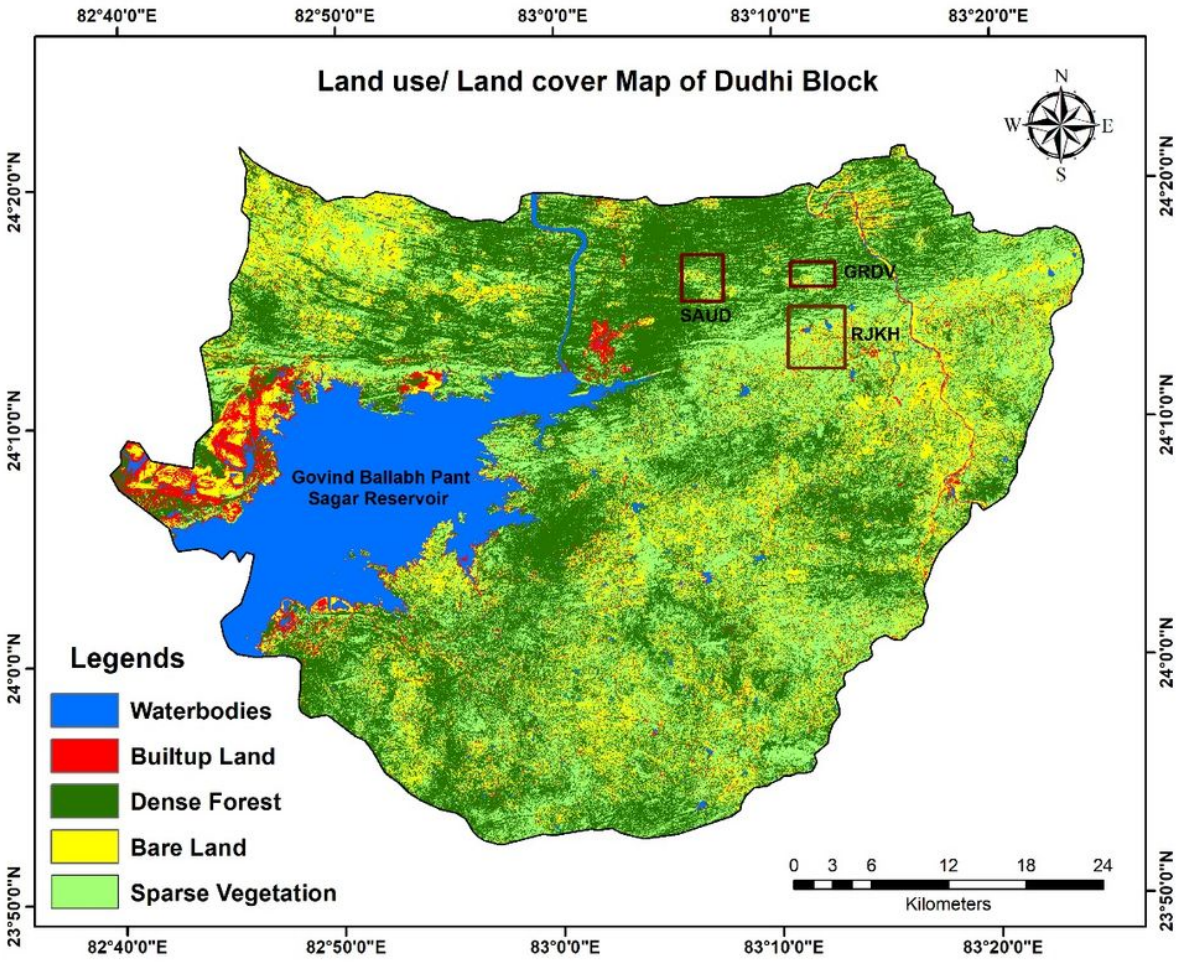

Figure 2

Land use/land cover map of Dudhi block of Sonbhadra District in Vindhyan highlands, India

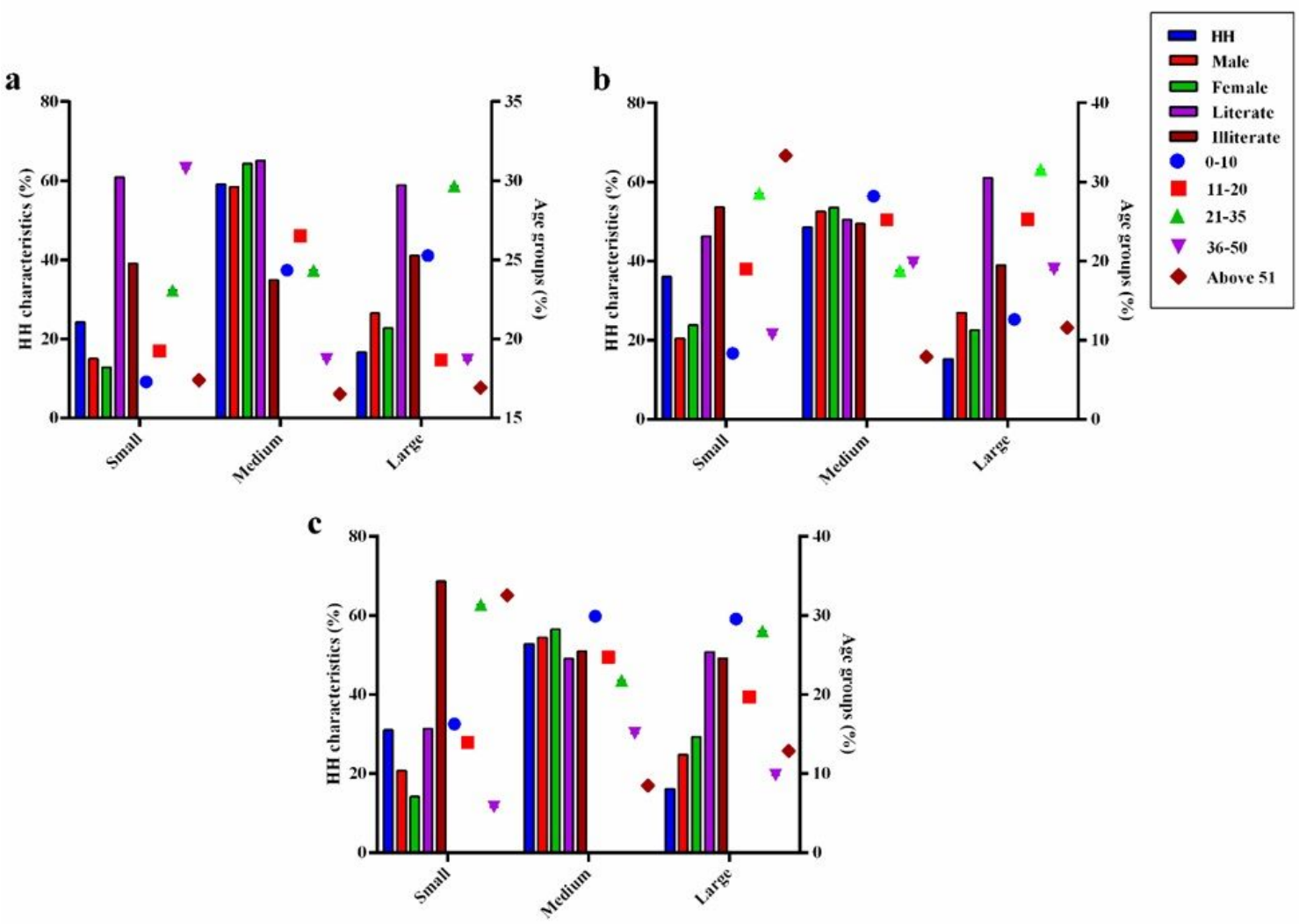

Figure 3

Socio-economic setting of study area in (a) Gardarva, (b) Saudih and (c) Rajkhar villages in Vindhyan highlands, India

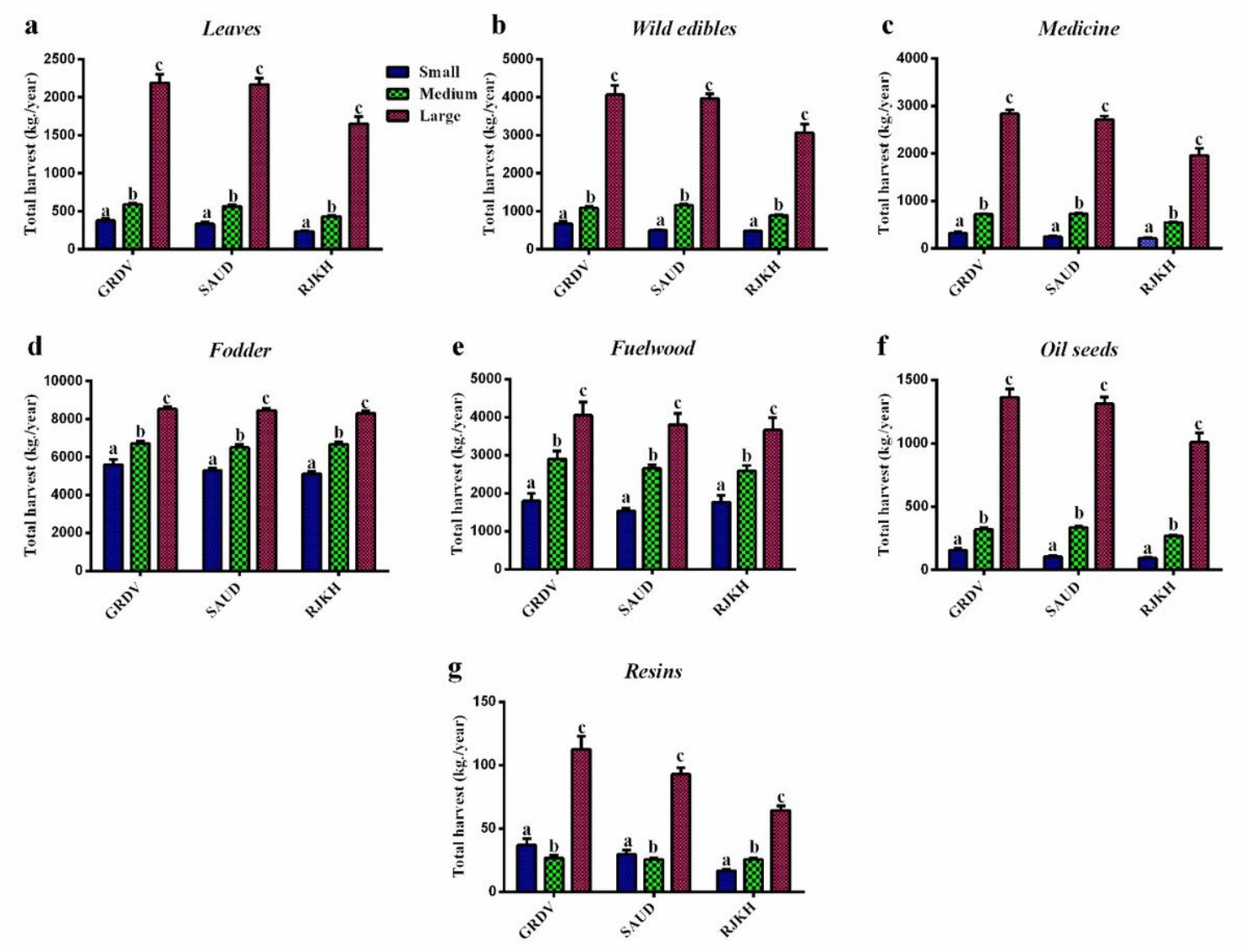

Figure 4

Mean annual collection (kg/year or sac/year/household) of provisioning ecosystem services from different forest products in Vindhyan highlands, India (The letters a, b and c are used to show the significant difference ($p < 0.05$) between/among the values according to the contrast test in the one-way ANOVA)

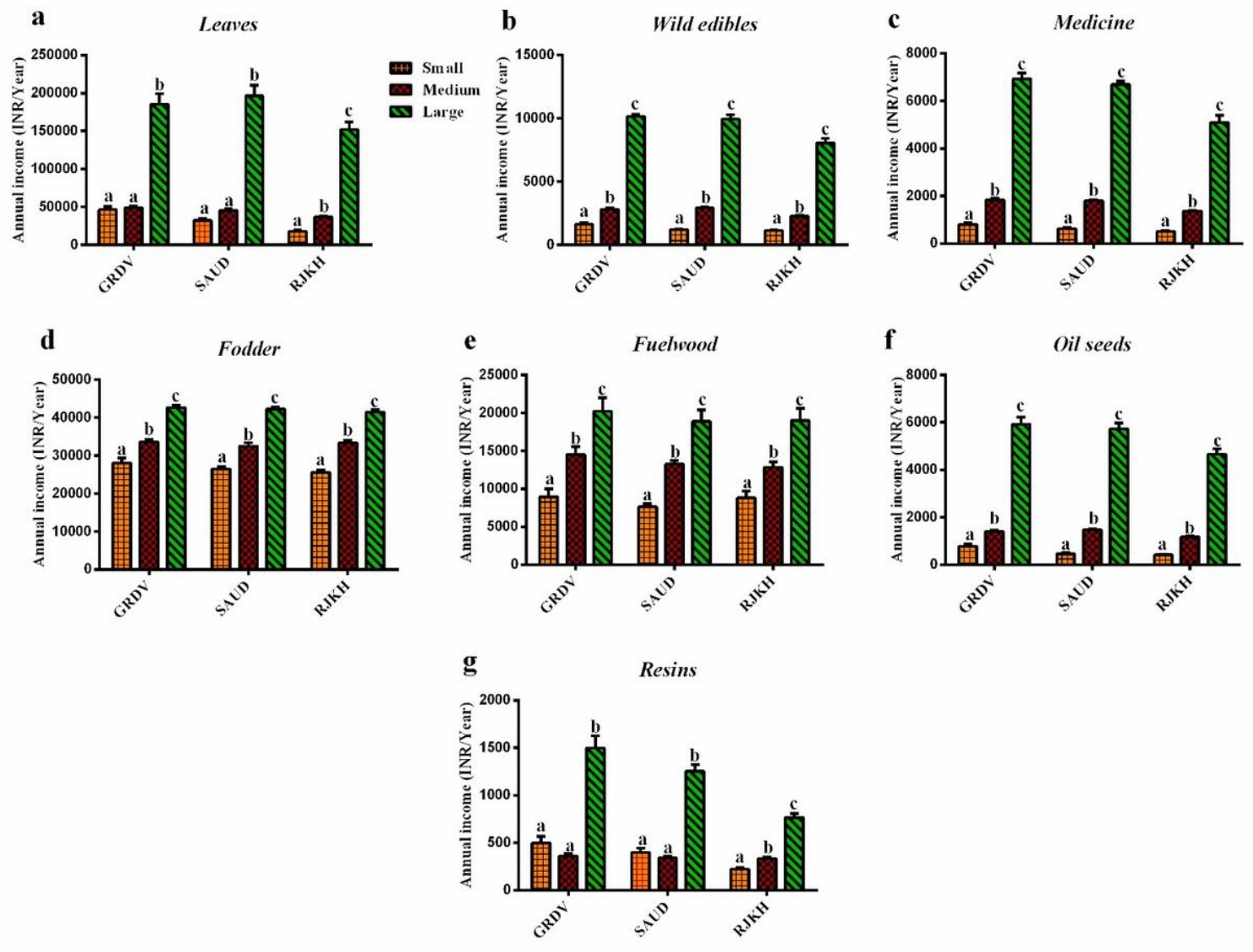

Figure 5

Mean annual income (INR/year) by household size in three villages of Vindhyan highlands, India ((The letters a, b and c are used to show the significant difference ($p < 0.05$) between/among the values according to the contrast test in the one-way ANOVA)

Figure 6

(a) and (b) Rural community members collected ecosystem provisions (Mushroom (*Agaricus campestris*) and Chironji (*Buchanania lanzan*) from forest around study sites (c) Local marketplaces for selling goods (d), (e) and (f) Medicinal herbs gathered from study sites in Vindhyan highlands, India

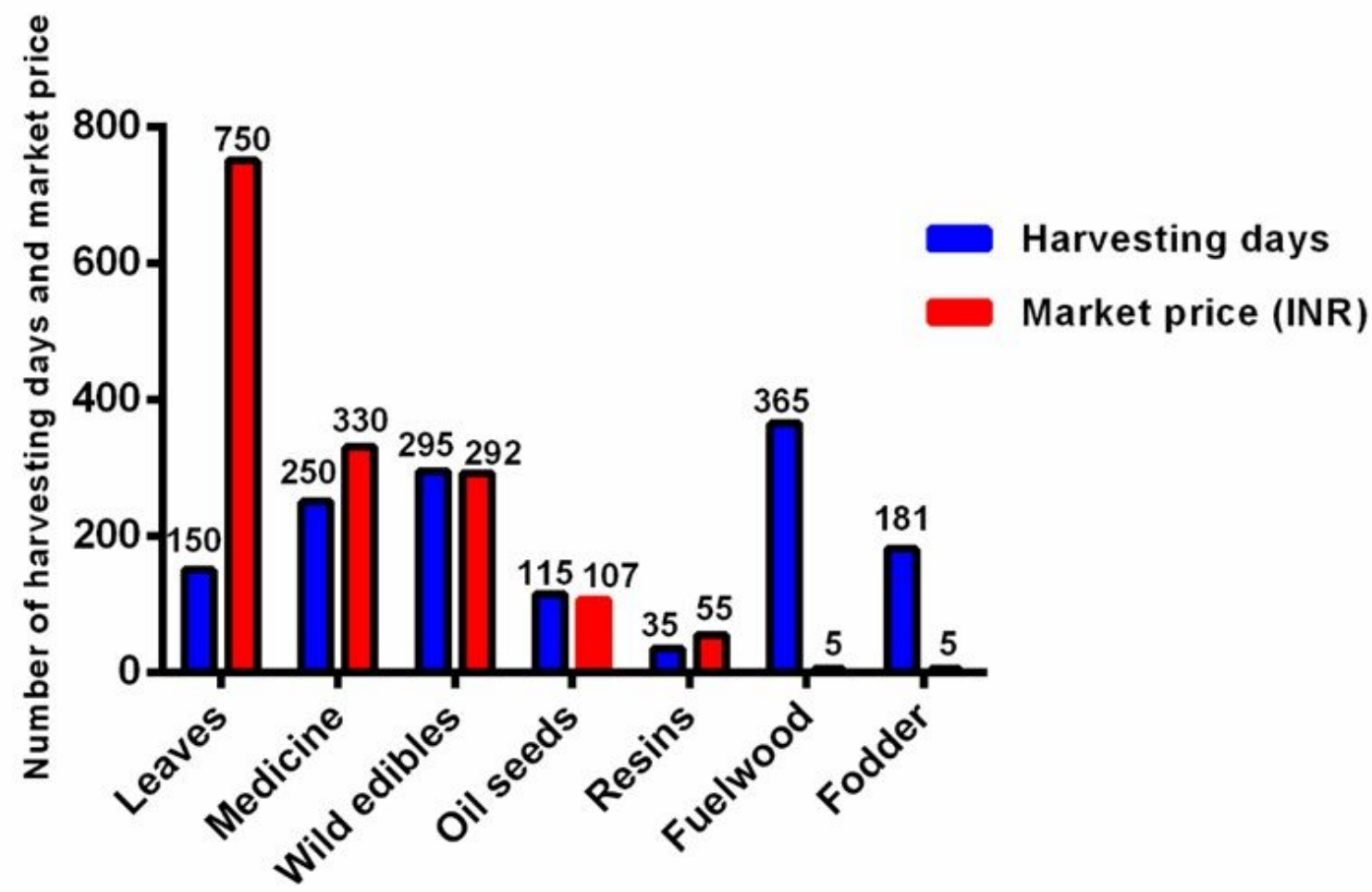

Figure 7

Provisioning ecosystem services collected from the forests in Vindhyan highlands, India

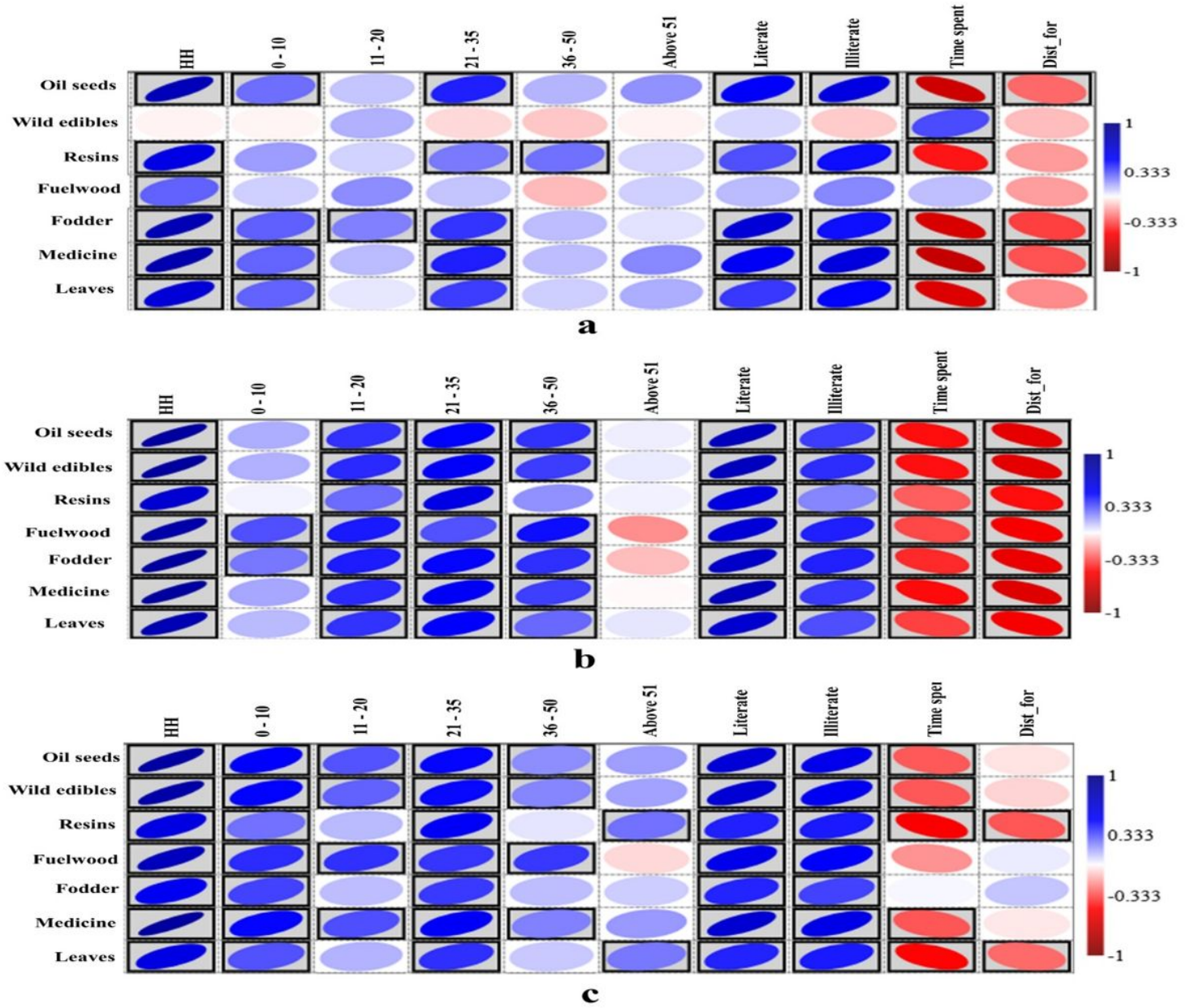

Figure 8

Relationship between income and household's socio-economic characteristics for (a) Gardarva (N=66), (b) Saudih (N=72) and (c) Rajkhar (N=87) villages in Vindhyan highlands, India

The correlation matrix shows a three-way representation of inter-parameter relation viz. shade or non-shade, shape of the circle and color code. Shaded boxes represents correlated nature ($p < 0.01$ or $p < 0.05$), either positive or negative. The more it is circular, the less correlated and the more narrowed oval it is, the more strongly correlated. If downwards to the right, it means negative and upwards to the right, it shows positive correlation. Violet and red shows highest and lowest correlation (+1 to -1) values and intermediate colors indicate moderate relation. This three algorithm based correlation plot shows clearly the relationship between income and household's socio-economic characteristics

Supplementary Files

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- Table.docx