



Economic valuation of fuelwood consumption in Dehradun of Uttarakhand

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Abstract

Agroforestry system has been known to provide a wide range of ecosystem services. The objective of the present work was to study the farmers practicing agroforestry, consumption pattern of provisioning services (fuel wood) and its valuation. The study was carried out in 39 villages (526 respondents) of Dehradun with a structured questionnaire method. The values of fuelwood ecosystem services were estimated based on regional market price of it. Fuel wood consumption revealed distinct pattern with altitudinal gradients, with highest consumption 0.866 kg/capita/day at higher altitude (1600-2100 m asl), followed by 0.608/capita/day at middle altitude (1100-1600m asl) and 0.474 kg/capita/day at lower altitude (600-1100m asl). The per capita value of fuel wood ranges between ₹. 1039.16/year to ₹. 1897.38/year through the altitude gradient. The village wise consumption ranges from 11.57 tons/year (in Lohari village) to 261.83 tons/year (in village Kalsi) The average benefits are estimated to be 0.57 Million INR in the lower altitude category, 0.50 million INR in the mid altitude category, and 0.49 Million INR in the higher altitude category.

Keywords: distribution, *Momordica cymbalaria*, plant protection, pollinator ecology, scope for exploitation, topography

Introduction

Agroforestry the intentional growing of trees and crops in interacting combinations, gained prominence in the late 1970s when the international scientific community recognized its potential in the tropics and recognized it as a science-seeking practice (Nair, 1979) ^[21]. Agroforestry systems provide economic and environmental benefits (Idol *et al.*, 2011) ^[12]. Agroforestry, as a land use system, can help achieve at least nine of the 17 SDGs: no poverty, zero hunger, good health and well-being, gender equality, clean water and sanitation, affordable and clean energy, responsible consumption and production, climate change, and life on land (Network, 2018).

Ecosystem services, commonly defined as the benefits that people derive in various ways from the functioning of ecosystems, could be put in jeopardy by human activities at all scales, from local to global. Ecosystem services are promoted as a benefit to value the underlying "natural capital," which is closely associated with economic valuations. The societal costs of natural ecosystem loss are estimated to be astronomical, necessitating a realignment of economic priorities to achieve progress in human well-being under the umbrella of sustainable development (Barbier, 2009) ^[2].

The concept of ecosystem services (ES) has emerged as an essential model for linking the functioning of ecosystems to human well-being (Millennium Ecosystem Assessment (MEA), 2005). These advantages can be direct or indirect, tangible or intangible, and available locally or on a larger scale. Nonetheless, various definitions of ecosystem services can be given based on the scale and perspective (Daily, 1997) ^[6]. A critical goal of the MEA is to analyse and quantify the importance of ecosystems to human well-being as much as possible to make better decisions about the long-term use and management of ecosystem services.

Groot *et al.* (2010) ^[7] categorized ecosystem services into four categories: 1) provisioning services which refer to the processes that combine and change organic and inorganic

substances into goods that humans can directly use through primary and secondary production; 2) regulating services which are the ability of natural ecosystems to regulate essential ecological processes and life support systems via biogeochemical cycles and other biosphere processes, i.e. clean air, water, soil, nutrient regulation, disturbance prevention, biological control, and pollination; 3) cultural services, which benefit human mental health and recreation; and 4) supporting services: refer to the importance of ecosystems in providing habitat for various stages in the life cycles of wild plants and animals, which maintains biological and genetic diversity and evolutionary processes. Economic evaluation is an analytical decision-making tool for weighing the advantages and disadvantages of various scenarios. It can help decision-makers choose between alternatives or preferred combinations of possible interventions by providing helpful information (Barbier *et al.*, 1997). Economic valuation enables the measurement and comparison of ecosystem benefits and can be a powerful tool in assisting and improving their wise use and management (Barbier *et al.*, 1997). It attempts to quantify the goods and services provided by environmental resources regardless of market prices. Today's most pressing issue for developing countries is promoting agricultural practices that provide essential goods and services while conserving natural capital (Lette *et al.*, 2002) ^[17].

Recognizing the economic value of environmental services and disservices generated by alternative agricultural practices is critical for developing appropriate policies and strategies that promote sustainable land use (Rasul, 2009) ^[26]. Failure to recognize the use and non-use value of various land-use systems' environmental services, such as soil conservation, carbon sequestration, and biodiversity conservation, frequently encourages implementing policies that lack incentives for sustainable agricultural practices (Barbier, 2007) ^[1]. The valuation of ecosystem services is gaining traction among various social sectors to provide more concrete data on the value and importance of

biodiversity and ecosystems to populations (de Groot *et al.*, 2010) [7]. Economic value quantification can and frequently does provide helpful information for public decisions, especially when the values' limitations and strengths are acknowledged (Barbier, 2009) [2]. An economic valuation can improve decision-makers understanding of the actual costs and benefits of environmental resources, increasing the efficiency and effectiveness of decisions about their protection (de Groot *et al.* 2010) [7]. This paper has the following objectives: (1) to assess the altitude-wise consumption of fuelwood in the study area; (2) to assess the economic value of the provisioning service inform of fuelwood from agroforestry.

Study area

The study area was the Kalsi and Chakrata Tehsils of Dehradun district of Uttarakhand. (Figure 1) which lie between coordinates longitude 77.744° E - 78.086° E and latitude 30.508° N - 30.866° N. The total area of Kalsi tehsil is 267 km², and Chakrata has 454 km². Kalsi and Chakrata

Tehsil has a population of 47329 and 49607, respectively (Census, 2011) [5]. The Chakrata and Kalsi tehsils have total 109 and 168 villages with a literacy rate of 53.74% and 58.96%, respectively.

The study area generally has a temperate climate; however, most of the area is under hilly terrain, and significant height differences cause temperature swings ranging from tropical to extreme cold. Summers are more pleasant in the hilly terrains, with an average annual rainfall is 1780 mm. From June to September, the study area receives most of its rain and snowfall chances between December and February. The tropical region of the district is below 300 m a.m.s.l (meter above mean sea level). At the same time, sub-tropical areas between 300-1100 m a.m.s.l. have broad leaf deciduous forest, shrubs, pine forest, and bushes. The temperate area expands between 1100-1800 m a.m.s.l. has mixed forest of *Quercus* sps, and *Myrica* sps; cold regions of the district is between 1800-2800 m a.m.s.l. has coniferous forest and deodar forest; high altitude alpine area falls between 2800-3071 m a.m.s.l.

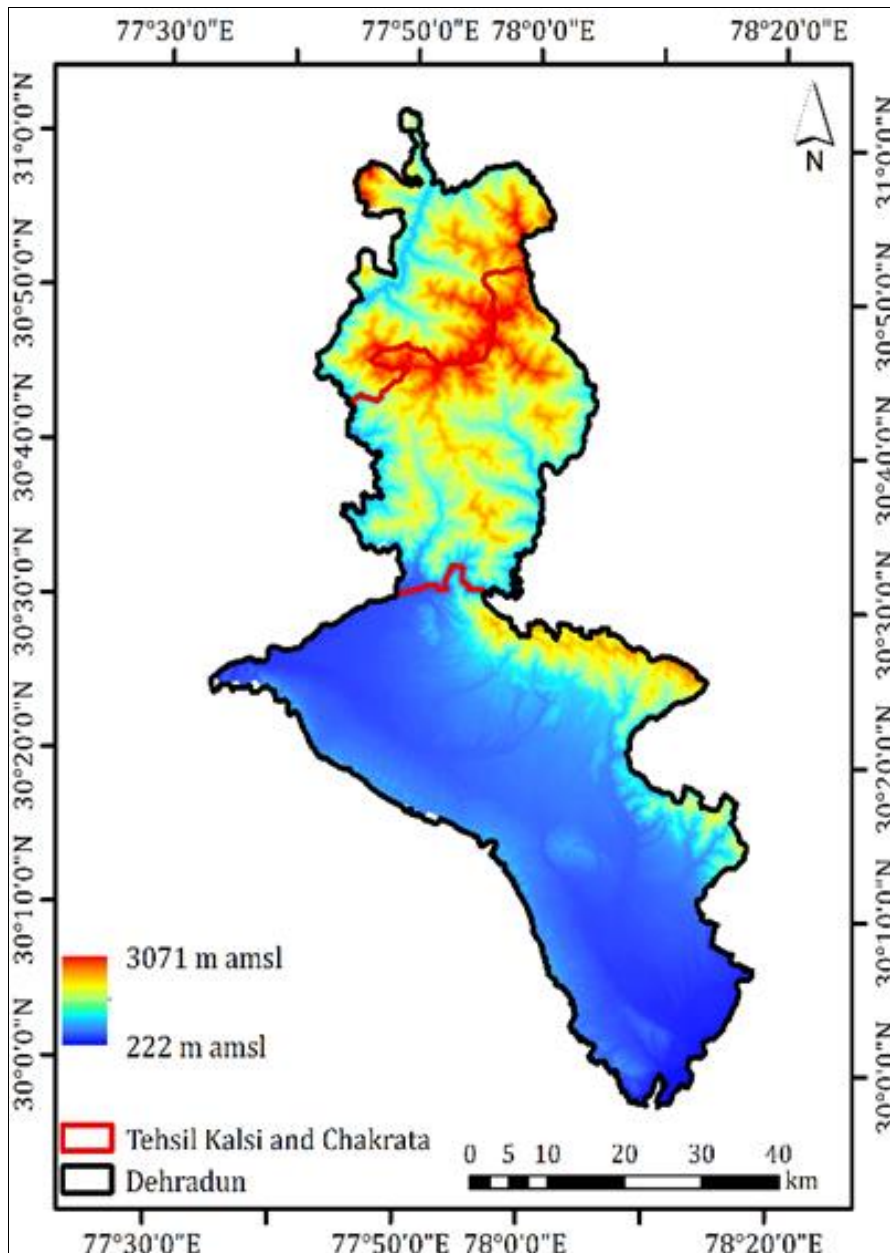


Fig 1: Study area map of the district Dehradun

Methodology

Following participatory rural appraisal method, primary data was collected from the villages (Barikh *et al.*, 2012) [3]. Agriculture was the main occupation of the study area, with villagers managing trees in their agriculture fields for their daily needs, such as fodder, timber, minor forest products, and fuelwood. Between altitudes of 600-1100 m a.m.s.l., 1100-1600 m a.m.s.l., and 1600-2100 m a.m.s.l., fuelwood consumption was analysed. The collected data analysed the per capita and village-wise fuelwood consumption (Mitchell, 1979). The per day fuelwood consumption for cooking was estimated based on the amount used by the family for cooking, heating, and other purposes. Fuel wood consumption was calculated per capita as per Gupta *et al.* 1997 and for the village by multiplying per capita consumption by the total population of the village (Equation 1).

$$\text{Fuel wood consumption (per capita)} = \frac{\text{Quantity of fuel wood consumed (HH)}}{\text{No. of individuals at HH}}$$

Equation 1

$$\text{Fuel wood consumption (village)} = \text{Individual consumption} * \text{Village population}$$

Equation 2

The population of the villages visited in this study is listed in Table 1. The village with the highest population was Kalsi, with 1546, and the village with the lowest population in village Lohari 65 (Census, 2011) [5]. The village population was listed in this study as the population plays an essential role in the total value of the fuelwood price consumed by the village.

Various economic valuation methodologies (market price method, hedonic pricing method, replacement cost method etc) has been adopted in the valuation of the monetary values of the ecosystem services. In this study the economic value of provisioning services (fuel wood) was estimated based on the market price method. The market price method determines the value of an ecosystem service by using the prices of goods and services bought and sold in commercial markets. Changes in the quantity or quality of a good or service are valued using this method. The market price method employs current market prices for goods and services traded in markets, such as timber or commercially sold fish. The market price represents the value of an additional unit of that good or service (King & Mazzotta, 2000).

Table 1: Village wise population; consumption per-capita/day, kg/capita/year and tonnes/village/year; price value of the consumed fuelwood per capita/year and village/year

S.N.	Altitude	Sites	Population	Household	kg/Per capita/day	kg/capita/year	Tonnes/village/year	Price per-capita/year (INR)	Price village /Year (in Million INR)
1	600-1100	KOTI	805	153	0.384	140.16	112.82	840.96	0.68
2		TIMARA	372	32	0.512	186.88	69.51	1121.28	0.42
3		SARADI	651	97	0.448	163.52	106.45	981.12	0.64
4		KALSI	1546	273	0.464	169.36	261.83	1016.16	1.57
5		LOHARI	65	11	0.488	178.12	11.57	1068.72	0.07
6		KENOTA	121	13	0.52	189.8	22.96	1138.8	0.14
7		ASTA	177	17	0.432	157.68	27.90	946.08	0.17
8		KHARI	139	20	0.51	186.15	25.87	1116.9	0.16
9		MAGHAM	614	76	0.504	183.96	112.95	1103.76	0.68
10		MALAITHA	961	108	0.512	186.88	179.59	1121.28	1.08
11		LAKHA MANDAL	1044	185	0.48	175.2	182.90	1051.2	1.10
12		SAHIYA	197	31	0.44	160.6	31.63	963.6	0.19
13	1100-1600	KHARAYA	238	27	0.639	233.235	55.50	1399.41	0.33
14		SURYO	518	58	0.666	243.09	125.92	1458.54	0.76
15		JHUTAYA	89	14	0.54	197.1	17.54	1182.6	0.11
16		KANBUA	364	41	0.531	193.815	70.54	1162.89	0.42
17		UDAPATTA	1038	134	0.648	236.52	245.50	1419.12	1.47
18		SAMALTA DADAULI	874	128	0.54	197.1	172.26	1182.6	1.03
20		KITRAULI	203	29	0.657	239.805	48.68	1438.83	0.29
21		DAUDHA	535	34	0.585	213.525	114.23	1281.15	0.69
22		SAILJA	323	35	0.576	210.24	67.90	1261.44	0.41
23		DAKRENA	191	19	0.621	226.665	43.29	1359.99	0.26
24		THANTA	305	32	0.64	233.6	71.24	1401.6	0.43
25		BISAU	69	9	0.652	237.98	16.42	1427.88	0.10
26	GUTHAR	206	28	0.612	223.38	46.01	1340.28	0.28	
27	1600-2100	PATA	107	12	0.747	272.655	29.17	1635.93	0.18
28		DAMATA	256	22	0.99	361.35	92.50	2168.1	0.56
29		BHODA	66	8	0.936	341.64	22.54	2049.84	0.14
30		GADOUL	96	12	0.909	331.785	31.85	1990.71	0.19
31		LATAU	158	16	0.792	289.08	45.67	1734.48	0.27
32		RATAR	119	15	0.981	358.065	42.60	2148.39	0.26
33		MATHYAU	231	24	0.765	279.225	64.50	1675.35	0.39
34		NAYARA	420	44	0.918	335.07	140.72	2010.42	0.84

35		SIJLA	179	17	0.702	256.23	45.86	1537.38	0.28
36		SUJAU	314	37	0.783	285.795	89.73	1714.77	0.54
37		KOTUWA	331	26	0.94	343.1	113.56	2058.6	0.68
38		KOTA	666	80	0.954	348.21	231.90	2089.26	1.39
39		BIJNAU	410	55	0.846	308.79	126.60	1852.74	0.76

Result

Villagers in the study area have been using many species like *Celtis australis*, *Quercus leucotrichophora*, *Grewia oppositifolia* *Melia azedarach*, *Pinus roxburghii*, *Myrica esculenta*, *Prunus sarmentosa* *Ficus palmata*, *F. auriculata*, *F. glomerata*, *Bauhinia variegata*, *Boehmeria rugulosa*, *Lyonia valifolia* *Terminalia bellerica*, *Alnusne palansis* *Toona ciliata*, *Woodfordia fruticosa*, *Rhus parviflora* as fuelwood to meet cooking and heating needs. In the study area, villagers typically collected fuelwood from adjacent traditional agroforestry fields and forests. Most of the fuelwood collection is typically from the forest.

Valuation of fuelwood consumption (kg/capita/year)

The fuelwood consumption was also calculated from the agroforestry field in the Kalsi and the Chakrata region, shown in Table 1. In-case of per-capita fuelwood consumption ranges from 0.384 - 0.52 kg/capita/day in the lower altitudes (600-1100 m a.m.s.l.). Per capita village wise fuelwood consumption was highest in the village of Kenota is 189.80 kg/capita/year at lower altitudes (600-1100 m a.s.l.) and lowest per capita is in the village of Koti at 140.16 kg/capita/year. In case of consumption village/year is highest in Kalsi, where it is 261.83 tonnes/village/year, and the lowest in Lohari, where it is 11.58 tonnes/village/year. The economic value of the fuelwood provisioning services is highest in the village Kenota at ₹ 1138.8 per-capita/day and ₹ 840.96 per-capita/day in Koti. Kalsi has the highest economic value of fuelwood consumption of 1.57 Million INR/village/year and the lowest in the 0.069 Million INR /village/year Lohari villages.

Fuelwood consumption in the mid ranges (1100-1600 m a.m.s.l.) ranges from 0.53-0.66 kg/capita/day. In-case of per-capita fuelwood consumption was highest in this category is in the village of Suryo (243.09 kg/capita/year) and lowest is in villages Kanbua is 193.82 kg/capita/year. In case of village year wise, consumption is highest in

Udapalta, where it is 245.51 tonnes/village/year, and the lowest in Bisau, where it is 16.42 tonnes/village/year. The economic value of the fuelwood provisioning services is highest in the village Suryo is ₹ 1458.54 per-capita/day and ₹ 1162.89 per-capita/day in village Kanbua. Year wise economic value for village is highest in Udapalta 1.47 Million INR /village/year and lowest in the in the 0.098 Million INR /village/year in village Bisau village. Village wise details is provided in Table 1

Fuelwood consumption in the higher altitude (1600-2100 m a.m.s.l.) ranges from 0.70-0.99 kg/capita/day. In-case of per-capita fuelwood consumption was highest in village Damata is 361.35 kg/capita/year and lowest is in villages Silja is 256.23 kg/capita /year. In case of village year wise, consumption is highest in Kota, where it is 231.91 tonnes/village/year, and the lowest in Bhoda, where it is 22.548 tonnes/village/year. The economic value of the fuelwood provisioning services is highest in the village Damata which is ₹ 2168.10 per-capita/day and lowest is ₹ 1537.38 per-capita/day in village Sijla. Year wise economic value for village is highest in Kota 1.39 Million INR /village/year and lowest in the in the 0.135 Million INR /village/year in village Bhoda village. Village wise details is provided in Table 1

The daily average consumption of fuel wood varies across altitude gradients between villages (Fig. 2). For example, the fuel requirement from agroforestry was 0.866 kg/capita/day at higher altitude (1600-2100 m a.m.s.l.), followed by 0.608 kg/capita/day at mid altitude (1100-1100 m a.m.s.l.), and 0.474 kg/capita/day at lower elevations (600-1100 m a.m.s.l.). Fuelwood consumption was found to be higher in the lower altitude (600-1100 m a.m.s.l) 95.49 tonnes/village/year followed by 1100-1600 m a m s l having 84.23 tonnes/village/year and 82.26 tonnes/village/year in the higher altitude (1600-2100 m a.m.s.l).

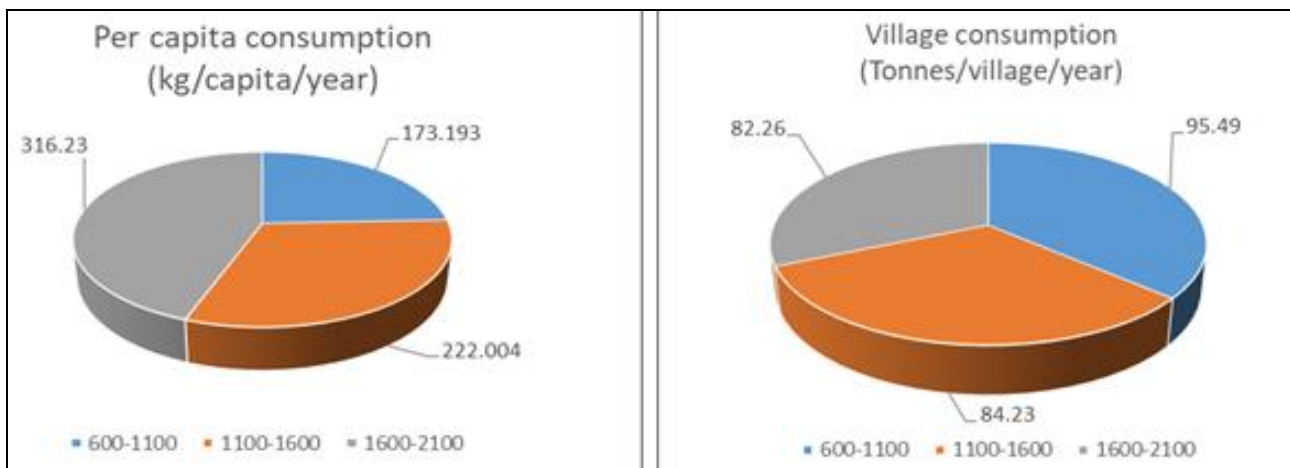


Fig 2: Altitude wise average per-capita and average village consumption of fuel wood in Dehradun district

Discussion

Fuelwood is essential for providing services from agroforestry systems. It is regarded as an important energy source in the Himalayan regions, where the majority of villagers collect fuelwood from a variety of sources such as forests, agroforestry, pasture land, and community land. The current study concentrated on villagers collecting fuelwood from agroforestry at various elevations. In the lower altitudes, fuelwood consumption ranged from 600-1100 m a.m.s.l., 1100-1600 m a.m.s.l. in the middle altitudes, and 1600-2100 m a.m.s.l. in the upper altitudes. Many researchers (Maikhuri, (1991) ^[18], Bhatt and Sachan (2004) ^[4], Dhanai, (2014) ^[8] have studied fuelwood consumption in various parts of the world, and the country and Garhwal Himalayan region reported consumption values compared to the current study's altitude. In this study it was found that average per capita fuelwood consumption was found to be higher 316.23 kg/capita/year in the higher altitude (1600-2100 m a.m.s.l.) as compared to mid altitude (1100-1600 m a.m.s.l.) has 222.004 kg/capita/year and 173.193 kg/capita/year in lower altitude (600-1100 m a.m.s.l.). Kumar and Kumar (2015) got similar results their study on the consumption of fuelwood from the agroforestry in the Takoli Gad watershed of Tehri Garhwal Himalaya. Tahir and Vishwanath (2015) got similar results in Shagarb and Kilo 26 site in Eastern Sudan. Bhatt and Sachan (2004) ^[4] studied fuel wood consumption in Garhwal Himalaya and reported consumption ranging 390.55-1022.00 kg/capita/year. Altitudinal variation in consumption of fuel is reported by many researchers (Parmar and Negi, 2019; Dhanai, *et al.* 2014) ^[8]. Several researchers (Rawat, 2016; Kumar and Kumar, 2015; Rajwar and Kumar, 2011; Kumar and Sharma, 2009; Bhatt and Sachan, 2004) ^[4] found that while the majority of the demand for fuel wood is met by nearby forests, only 20-30% of the fuel wood requirement is met by nearby agroforestry fields. Participants in the area stated that agroforestry supplies of fuel wood met some of their demands of domestic fuel wood requirements. Many respondents prefer nearby agroforestry fields for small amount of fuel wood requirement as well. Jaiswal, (2013) also found that the major fuel wood demands are fulfilled by local peoples from nearby forest area and some of their fuel wood demands are met from agricultural fields, pasture and open fallow lands. Mishra, (2008) estimated fuelwood use in rural Orissa. Result in this study and from different researches showed that fuel wood consumption varies between sites and also along the altitudinal gradient. Higher consumption of fuel at higher altitude may be due to colder condition in the area.

The accurate economic valuation of ecosystem services is difficult due to use and non-use ecosystem services provided by the agroforestry system. There's uncertainty involved in the estimation of non-use ecosystem services. Among the various environmental valuation methodologies, the direct market valuation technique was chosen for this study (deGroot *et al.*, 2002). It is possible that using different techniques (such as contingent valuation or benefit transfer) will yield different results. Because market prices exist for the provisioning service (fuelwood) in this study, using direct market value ensures the best value estimate (OECD, 2001). Singh *et al* 2021 in their study used market price for the estimation of monthly value of the fuelwood. In their result they found ₹. 322.19 per capita/year for fuelwood price. Ullah *et al* (2021) estimated the fuelwood

prices in the Basho Valley, Baltistan, Pakistan using the local market price, which was found to 393101 PKR per-capita/month. Tahir and Vishwanath (2015) in their estimation of total economic value of agroforestry systems in Eastern Sudan found value of agroforestry to be 1.33 Million US\$ per household/annum using specific market value. Franzel (2004) in their agroforestry practice analysis used 1997 market prices for the financial analysis of the agroforestry practice in Zambia.

Conclusion

Agroforestry systems, both traditional and farm plantation, provide important provisioning services to local communities in a given area. Agroforestry systems provide food, fuel wood, fibre, feed, fodder, medicines, and other direct consumable services. These agroforestry products benefit villager livelihoods while also benefiting the environment by reducing local reliance on nearby forestry. According to this finding, the highest per capita consumption was found to be 0.866 kg/capita/day in the upper altitude, followed by 0.608 kg/capita/day in the mid altitude, and 0.474 kg/capita/day on these levels. The average economic benefits were discovered to be higher in areas where total fuel consumption was higher due to population density. The average benefits in the lower altitude category are estimated to be 0.57 Million INR, followed by 0.50 Million INR in the mid altitude and 0.49 Million INR in the higher altitude. When the total value of all direct and indirect use ecosystem services is monetarized, its market value rises. However, a detailed quantitative and qualitative study of all ecosystem services provided by the agroforestry system would be required for better planning and development of appropriately designed conservation policies that contribute significantly to the well-being of regional people while also improving the area's environmental health.

Declarations

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Conflict of Interest

The authors declare that they have no conflict of interests.

Author's Contribution

The writing portion was contributed by (Deepak Kumar Mishra); Editing done by (Ujjwal Kumar, Kusum Arunahcalam); Authors share first author equally.

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