RESEARCH ARTICLE

FUELWOOD AND FODDER CONSUMPTION FROM AGROFORESTRY AT DIFFERENT ALTITUDINAL ZONES OF GARHWAL HIMALAYA

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Abstract: In Himalayan region, agroforestry is one of the strategies for adaptation to climate change through provision of direct and indirect impact on improving the livelihood of the farmers in the form of productive and protective benefits, respectively. The present study attempts to assess the contribution of agroforestry in fuelwood and fodder consumption at different altitudes of Garhwal Himalayan region. Multistage random sampling method was used for the selection of the agroforestry dominated villages during 2015 to 2017. Fuelwood and fodder consumption by households was estimated in regular interval for a period of 24 hrs using weight survey method. The results revealed that fuelwood consumption from agroforestry was 0.44, 0.63, 0.68 and 0.50 kg/capita/day while the consumption from other sources was estimated at 0.84, 0.90, 0.92 and 1.47 kg/capita/day at <800 m, 801-1200 m, 1201-1600 m and >1600 m altitude, respectively. Similarly, fodder consumption from agroforestry was estimated at 4.70, 5.35, 5.57 and 3.64 kg/ACU/day while the consumption from other sources was 7.16, 6.98, 7.02 and 10.05 kg/ACU/day at <800 m, 801-1200 m, 1201-1600 m and >1600 m altitudes, respectively. The estimated results of the study will be helpful in quantifying the contribution of agroforestry in fulfilling the requirements of fuelwood and fodder. Further the share of agroforestry might assist in framing the policies with respect to the agroforestry adoption as a mechanism for climate change adaptation through the means of protective and productive services as well as by reducing the anthropogenic pressure on forests at higher altitudes.

Keywords: Agroforestry, Biomass, Energy, Fodder, Fuelwood, Garhwal Himalaya

INTRODUCTION

Biomass is one of the principle component of domestic energy source in developing countries (Pandey, 2002). In India, it comprises 75% of the total energy consumption depending upon social and geographical conditions of the region (Khuman et al., 2011). In the Himalayan region, fuelwood is the most important livelihood resources besides the fodder for livestock (Ramakrishnan, 2005). Almost 90% of their energy demand is met from biomass (Sharma et al., 1999) derived from forest (Singh and Sundriyal, 2009), trees growing on homesteads, agricultural lands and common lands outside forests (Pandey, 2002).

Terraced based agriculture field for raising crops with trees is the permanent characteristic of hill farming system (Semwal and Maikhuri, 1996; Maikhuri et al., 1996; Bhatt and Todaria, 1999) alongwith livestock rearing for their basic daily needs (Bhatt, 2002). The rainfed hill agriculture is associated with forestry sector through agroforestry practices (Semwal and Maikhuri, 1996; Kumar et al., 2009) which is closely linked with domestic energy through providing energy in the form of non-conventional energy such as fuelwood and fodder from trees, crop residues, bio-sticks and cow dung (Ravindranath et al., 2005).

In the Garhwal Himalaya, rural households are mainly depend on the forest to meet their energy needs to sustain their livelihood due to remoteness, unemployment and low agricultural productivity (Bhatt and Sachan, 2004; Sharma et al., 2009; Singh and Sundriyal, 2009; Singh et al., 2010; Malik et al., 2014) and had the privileges to collect fuelwood and fodder in limited quantity from forested areas (Rawat et al., 2009). In recent decade the increased dependency of the growing population on finite resources has lead to severe depletion of natural resources especially forests (Duke, 1984; Tucker, 1987; Schickhoff, 1995; Ali and Benjamisen, 2004; Kumar et al., 2009; Malik et al., 2014). In this regard, the government of India (GOI) has initiated new environmental law to restricted biomass collection (Negi and Todaria, 1993; Rawat et al., 2009). Therefore the present study attempts to quantify the contribution of agroforestry to meet the domestic energy needs with the hypothesis that agroforestry contributes in fulfilling the fuelwood and fodder consumption requirements of rural households. The aim of the present study was to estimate the biomass consumption from agroforestry by rural households at different altitudinal zones of Garhwal Himalaya.

MATERIALS AND METHODS

Study area

The study area lies in Garhwal Himalaya between the coordinates 29˚26'-31˚28'N and 77˚49'-80˚06'E ranging from 250 to 7800 m amsl. To understand the altitudinal effect for the contribution of agroforestry for biomass consumption, the study area based on climatic conditions was classified into four altitudinal zones. The area is affected by tropical climate below 800 m, sub-tropical climate between

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801–1200 m, sub-temperate between 1201-1600 m and temperate climate above 1600 m (Bagwari and Todaria, 2011). Rainfed agriculture at small terrace is being practiced by the farmers (Rawat et al., 2018). The climate of the region is tropical to temperate, with the winter temperature ranging from 5˚C to 25˚C and from 18˚C and 30˚C during summer season having an annual precipitation of 1476 mm (IMD, 2017).

Data collection

Fuelwood and fodder consumption data was collected from 401 randomly surveyed agroforestry farmers in between 2015-2017 using the multistage random sampling. Two districts namely Pauri Garhwal and Rudraprayag representing the classified altitudinal zones were randomly selected in the first stage followed by selection of agroforestry dominated villages in second stage, and in the last stage, agroforestry practicing households was randomly selected as a primary sampling unit. The villagers depend on agroforestry and on other sources such as village forest, grassland and wasteland for fuelwood and fodder.

Estimation of fuelwood and fodder consumption

Fuelwood and fodder consumption estimation was done through, weight survey method. At first, a wood bundel and grass bundel was weighed and the sampled household was asked to make use of fuelwood and fodder only from the given bundles. Then the left over amount of fuelwood and fodder was deducted from the original weight after a period of 24 hours in order to get the actual per day consumption of each sampled household. For the estimation of fuelwood the procedure given by Mitchell (1979) was used. The following equation was used for fuelwood estimation:

$$Fu_{PCon} = \frac{TFu_{con}}{TH_m}$$

Where, Fu_{PCon} is fuelwood consumption per day by a member of household, TFu_{con} is total fuelwood consumption by a household and TH_m is the total number of members in a household.

Per day fodder consumption by an adult cattle unit (ACU) was estimated by converting the livestock into adult cattle unit and then dividing overall fodder consumption by total number of ACU. For estimation of fodder consumption following equation was used:

$$Fo_{con} = \frac{TFo_{con}}{T_{ACU}}$$

Where, Fo_{con} is per day fodder consumption by an ACU, TFo_{con} is total fodder consumption by a household, and T_{ACU} is total number of ACU in a household.

The ACU values was estimated as per the following details i.e., 1 buffalo = 1.50 ACU (GBPIEHD, 1980; Pandey, 2011a), 1 ox = 1.15 ACU, 1 cow = 1 ACU, young stock of buffalo/cow = 0.75 ACU, for sheep or goat = 0.15 ACU (Yang, 1971).

RESULTS AND DISCUSSION

Fuelwood consumption pattern

Fuelwood consumption from agroforestry and other sources were assessed at different altitudinal zones of Garhwal Himalaya. The statistical significant difference among the fuelwood consumption from different sources i.e., agroforestry and forests was assessed using paired t-test. The results of analysis show that fuelwood consumption from agroforestry and forests differs significantly in all the altitudes (Table 1).

The results of the study revealed that total fuelwood consumption was 1.29, 1.53, 1.61 and 1.98 kg/capita/day at <800 m, 801-1200 m, 1201-1600 m and >1600 m altitude, respectively. The result estimates showed that fuelwood consumption increased from lower altitude to higher altitude ranged from 1.29 to 1.98 kg/capita/day with the mean value of 1.60 kg/capita/day (Table 1). The lowest consumption was recorded at <800 m altitude because the people living in lower altitude are easily accessible to alternative commercial sources of cooking energy such as liquid petroleum gas (LPG) and kerosene as compared to higher altitude as well as temperature decreases with increasing altitude, hence the consumption of fuelwood increases with altitude.

The contribution of agroforestry was 0.44, 0.63, 0.68 and 0.50 kg/capita/day while the consumption from other sources was estimated to be 0.84, 0.90, 0.92 and 1.47 kg/capita/day at <800 m, 801-1200 m, 1201-1600 m and >1600 m altitude, respectively (Table 1). Fuelwood consumption from agroforestry was recorded to increase from lower to higher with maximum at 1201-1600 m altitude and lowest at the peak (i.e. above 1600 m) while the consumption from other sources increased with altitude because of easily availability of fuelwood from nearby forest and spend less time for collection of fuelwood as compared to lower altitudes.

The altitude influence the availability of commercial energy sources and the climatic conditions as temperature decreases with increasing altitude (Chettri et al., 2002; Sharma et al., 2009) hence people's dependency on wood for energy increases with increasing altitude particularly for space heating, boiling water for them as well as for their livestock and lighting purpose in addition to cooking (Bhatt and Sachan, 2004). The fuelwood consumption in the present study was consistent with the studies reported from Garhwal Himalaya (1.07 to 2.80 kg/capita/day) by Bhatt and Sachan (2004), 1.63 to 2.52 kg/capita/day by Kumar and Sharma (2009) and 1.53 to 2.91 kg/capita/day by Rawat et al. (2018). In other studies authors have reported that fuelwood consumption is greatly influenced by altitude which ranges from 1.61 to 3.24 kg/capita/day in Kedarnath Wildlife Sanctuary (Malik et al., 2014), 1.67 to 2.27 kg/capita/day in Rawanganga micro-watershed (Bagwari and Todaria, 2011), 1.77 to 3.0

kg/capita/day in Takoligad watershed (Dhanai et al., 2014). However, an average fuelwood consumption of 1.49 kg/capita/day has been recorded by Bhatt et al. (1994) for the rural and tribal communities of Western Himalaya.

The results of fuelwood consumption at household level was recorded 5.32, 5.66, 6.72 and 9.98 kg/household/day with an average value of 6.72 kg/household/day at <800 m, 801-1200 m, 1201-1600 m and >1600 m altitude, respectively. Fuelwood consumption from agroforestry at household level was estimated 1.86, 2.41, 2.60 and 2.54 kg/household/day with an average value of 2.35 kg/household/day and from other sources was 3.46, 3.20, 3.50 and 7.44 kg/household/day with an average value of 4.37 kg/household/day at <800 m, 801-1200 m, 1201-1600 m and >1600 m altitude, respectively (Table 1). Various researchers have reported that at household level fuelwood consumption mainly depends on the size of the family (Bhatt and Sachan, 2004; Kumar and Sharma, 2009; Sharma et al., 2009; Bagwari and Todaria, 2011; Malik et al., 2014) which was observed highest at the peak (i.e. >1600 m) in the present study followed by 801-1200 m, 1201-1600 m and least recorded at lower altitude (<800 m).

Table 1. Fuelwood consumption (Mean ± SD) from different sources at four altitudinal zones of Garhwal Himalaya

Source	Altitudinal zones				
	<800 m (n=101)	**801-1200 m (n=100)**	**1201-1600 m (n=104)**	**>1600 m (n=96)**	**Mean**
Fuelwood (kg/capita/day)					
Agroforestry	0.44 ± 0.15	0.63 ± 0.25	0.68 ± 0.25	0.50 ± 0.16	0.57 ± 0.23
Forest	0.84 ± 0.33	0.90 ± 0.36	0.92 ± 0.31	1.47 ± 0.32	1.03 ± 0.42
Total	1.29 ± 0.39	1.53 ± 0.44	1.61 ± 0.40	1.98 ± 0.35	1.60 ± 0.47
t-test (p-value)	-11.733 (<0.05)	-5.836 (<0.05)	-6.144 (<0.05)	-26.128 (<0.05)	-18.921 (<0.05)
Fuelwood (kg/household/day)					
Agroforestry	1.86 ± 0.68	2.41 ± 1.06	2.60 ± 0.98	2.54 ± 0.96	2.35 ± 0.97
Forest	3.46 ± 0.98	3.25 ± 0.95	3.50 ± 1.26	7.44 ± 2.00	4.37 ± 2.19
Total	5.32 ± 1.29	5.66 ± 1.51	6.72 ± 1.74	9.98 ± 2.51	6.72 ± 2.59
t-test (p-value)	-14.631 (<0.05)	-6.239 (<0.05)	-6.424 (<0.05)	-25.630 (<0.05)	-18.396 (<0.05)

n is the number of households

The results of the present study revealed that consumption of fuelwood per capita was inversely related to the number of individuals in the family in all the altitudes concluding that family size influences levels of per capita fuelwood consumption, that is, per capita consumption decreases as the family size increases. Linear regression analysis for altitude <800 shows that family size explained 57% (R^2 = 0.5698, n=101) of the fuelwood consumption and with an increase of one family member the daily per capita fuelwood consumption decreased by 0.18 kg. Regression analysis for altitude 801-1200 m shows that family size explained 56% (R^2 = 0.5622, n=100) of the fuelwood consumption and with an increase of one member in the family the daily per capita fuelwood consumption decreased by 0.21 kg. At altitude 1201-1600 m regression analysis shows that family size explained 52% (R^2 = 0.5219, n=104) of the fuelwood consumption and with an increase of one family member the daily per capita fuelwood consumption decreased by 0.18 kg. At altitude >1600 m linear regression analysis shows that family size explained 37% (R^2 = 0.3661, n=96) of the fuelwood consumption and with an increase of one family member the daily per capita fuelwood consumption decreased by 0.12 kg. Thus, the relationship between family size and fuelwood consumption showed a decreasing trend of fuelwood consumption with increased family size. A part from linear regression boxplot was also used to show the variation in the family wise consumption of fuelwood at different altitudes (Fig. 1, Fig. 2, Fig. 3 and Fig. 4).

Similar observations have also been reported by Mahato (2017) in a study of Garhwal Himalayas reporting that with increase in family size, per capita fuelwood consumption decreases. Asik and Masakazu (2017) in their study from Southern Bangladesh have also reported that the fuelwood consumption per capita decreases with the increase in the members of a family.

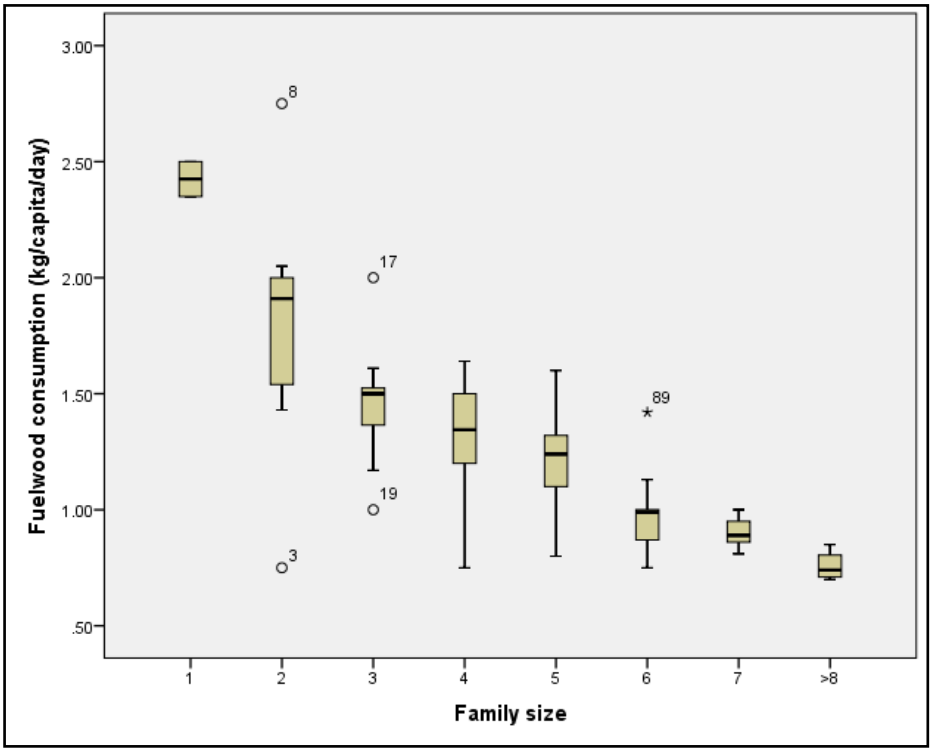

Fig. 2. Box plot showing variation in per capita fuelwood consumption among different family size at altitude <800 m

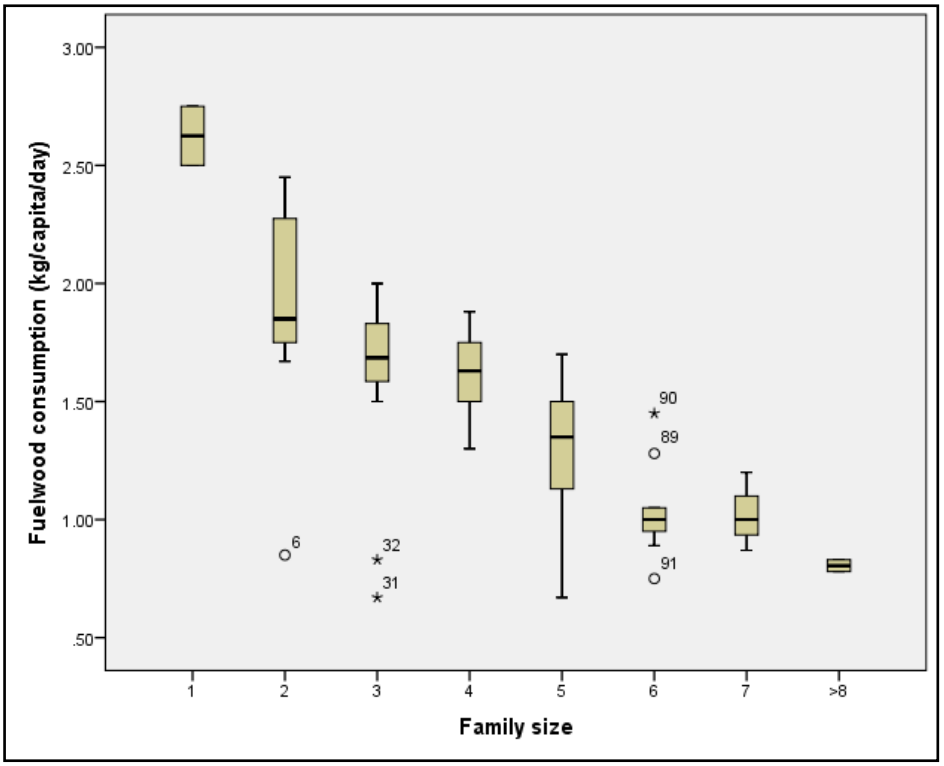

Fig. 3. Box plot showing variation in per capita fuelwood consumption among different family size at altitude 801-1200 m

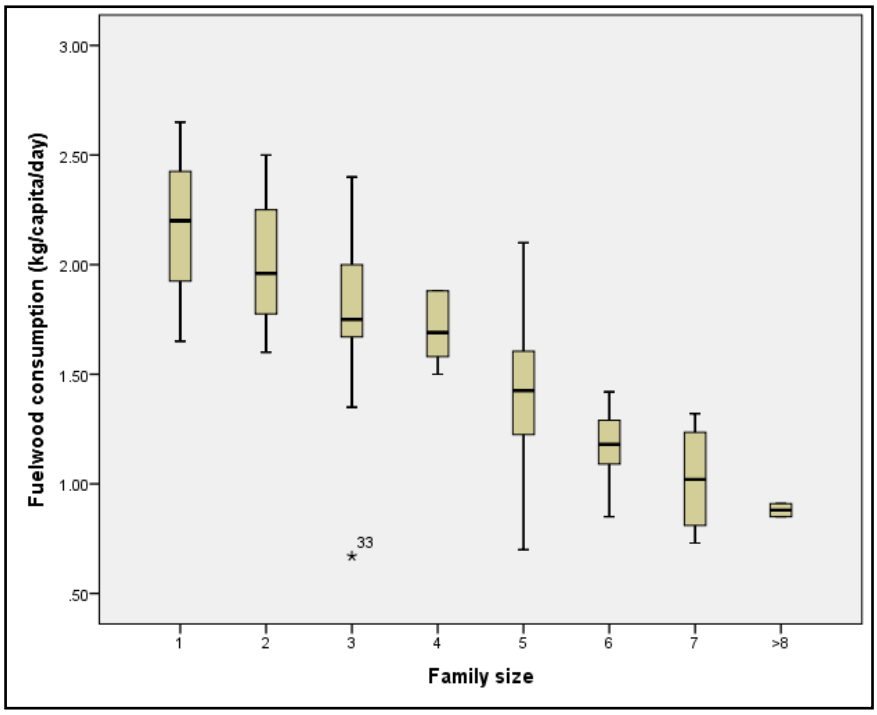

Fig. 4. Box plot showing variation in per capita fuelwood consumption among different family size at altitude 1201-1600 m

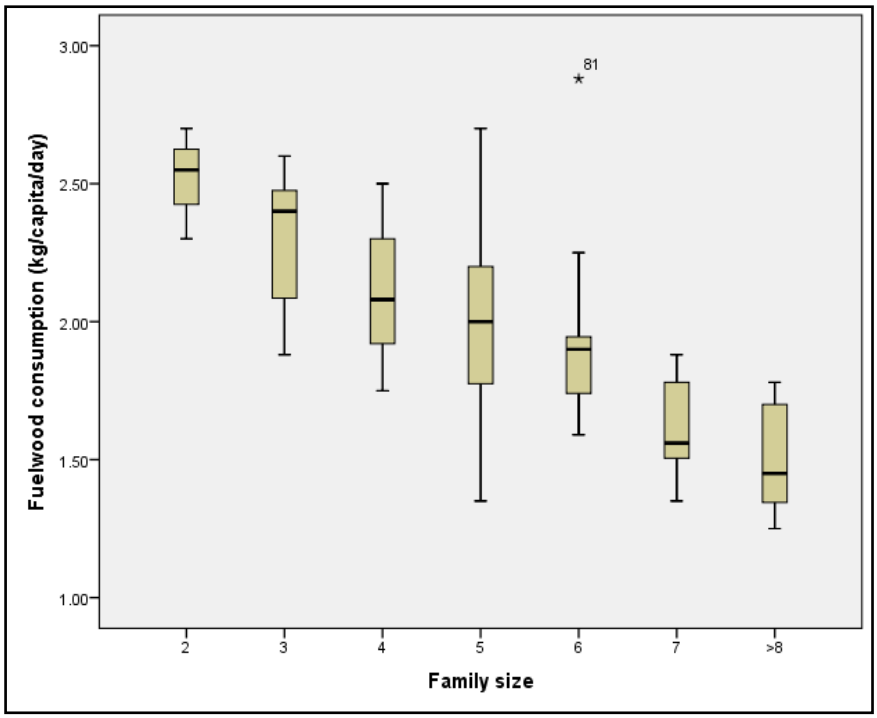

Fig. 5. Box plot showing variation in per capita per day fuelwood consumption among different family size at altitude >1600 m

Fodder consumption pattern

Livelihood of Himalayan people is depended on the terraced based agriculture and rearing livestock simultaneously for fulfilling their daily needs and income saving through the means of reducing expenditure on milk products as well as sometimes for income generation through selling milk and meat as pointed out by farmers during the survey. In the study area various sources of livestock feed were agroforestry and others sources such as forest, grassland and wasteland as pointed out by farmers and has also been reported by Bagwari and Todaria (2011). Therefore, fodder consumption per adult cattle unit (ACU) as well as at household level was

assessed to estimate agroforestry contribution at different altitudes.

Fodder consumption from different sources i.e., agroforestry and forests at different altitudes was statistical tested using paired t-test. The results of analysis show that fodder consumption from agroforestry and forests differs significantly in all the altitudes. The results of the study revealed that overall fodder consumption ranged from 11.86 to 13.69 kg/ACU/day with an average value of 12.60 kg/ACU/day. The estimates of fodder consumption from agroforestry was 4.70, 5.35, 5.57 and 3.64 kg/ACU/day while the consumption from other sources was 7.16, 6.98, 7.02 and 10.05 kg/ACU/day at <800 m, 801-1200 m, 1201-1600 m and >1600 m altitude, respectively (Table 2). The contribution of agroforestry in fodder consumption increased with altitude with maximum at 1201-1600 m altitude and afterwards decreases (i.e., above 1600 m). The contribution of agroforestry was lowest at peak because of less adoption and number of trees at agroforestry fields while consumption from other source was directly dependent on the availability of more number of trees on agroforestry farm at 1201-1600 m followed by 801-1200 m altitude.

In various studies from different altitudinal zones of Garhwal Himalaya similar estimates have also been reported for fodder consumption ranging in between 16.65 and 21.77 kg/animal/day (Dhanai et al., 2014) and 15.48 to 15.78 kg/ACU/day (Rawat et al., 2018). Similarly, Pandey (2011b) has also reported that fodder consumed ranges from 9.85 to 14.70 kg/ACU/day, with an average of 13 kg/ACU/day in the lower Himalaya region. The estimates of fodder consumption in the present study are inconsistent with the findings of Bagwari and Todaria (2011). Increased stall feeding by surveyed farmers may be the reason for variation in fodder consumption at high altitude because of the implementation of new government policy for limited livestock grazing in forest to enhance the regeneration.

The overall fodder consumption at household level was reported that 32.99, 33.51, 36.47 and 45.00 kg/household/day with an average value of 36.90 kg/household/day at <800 m, 801-1200 m, 1201-1600 m and >1600 m altitude, respectively. Contribution of agroforestry for fodder consumption at household level was 12.75, 14.72, 16.73 and 12.19 kg/household/day while from other sources was 20.23, 18.79, 19.74 and 32.82 kg/household/day at <800 m, 801-1200 m, 1201-1600 m and >1600 m altitude, respectively (Table 2). The number of adult cattle unit (ACU) varies among different altitude and is influencing the fodder consumption at household level.

Table 2. Fodder consumption (Mean ± SD) from different sources at four altitudinal zones of Garhwal Himalaya

Source	Altitudinal zone				
	<800 m (n=101)	**801-1200 m (n=100)**	**1201-1600 m (n=104)**	**>1600 m (n=96)**	**Mean**
Fodder (kg/ACU/day)					
Agroforestry	4.70 ± 1.63	5.35 ± 2.06	5.57 ± 1.87	3.64 ± 1.29	4.83 ± 1.89
Forest	7.16 ± 1.70	6.98 ± 2.55	7.02 ± 2.60	10.05 ± 2.67	7.77 ± 2.72
Total	11.86 ± 2.33	12.33 ± 4.04	12.59 ± 3.79	13.69 ± 2.98	12.60 ± 3.42
t-test (p-value)	-10.369 (<0.05)	-7.155 (<0.05)	-5.954 (<0.05)	-21.348 (<0.05)	-18.327 (<0.05)
Fodder (kg/household/day)					
Agroforestry	12.75 ± 5.80	14.72 ± 6.74	16.73 ± 9.75	12.19 ± 6.37	14.14 ± 7.55
Forest	20.23 ± 10.17	18.79 ± 7.20	19.74 ± 8.15	32.82 ± 13.35	22.76 ± 11.41
Total	32.99 ± 14.05	33.51 ± 12.54	36.47 ± 15.69	45.00 ±17.82	36.90 ± 15.80
t-test (p-value)	-8.584 (<0.05)	-6.653 (<0.05)	-3.494 (<0.05)	-18.457 (<0.05)	-15.430 (<0.05)

n is the number of households

In the present study results of linear regression analysis shows that per capita fodder consumption in a household was inversely related to the number of total ACU in the family at all the altitudes concluding that number of ACU influences fodder consumption in a household. Fig. 5 shows total ACU explained 71% (R^2=0.7121, n=101) of the fodder consumption and with an increase of one ACU the daily fodder consumption per ACU decrease by 0.83 kg. Fig. 6 shows total adult cattle unit explained 84%

(R^2 = 0.8425, n=100) of the fodder consumption and with an increase of one ACU the daily fodder consumption per ACU decrease by 1.86 kg. Fig. 7 shows total ACU explained 78% (R^2 = 0.7784, n=104) of the fodder consumption and with an increase of one ACU daily per ACU fodder consumption decrease by 1.24 kg. Fig. 8 shows total adult cattle unit explained 66% (R^2 = 0.6574, n=96) of the fodder consumption and with an increase of one ACU the daily per ACU fodder consumption decrease by 1.05 kg.

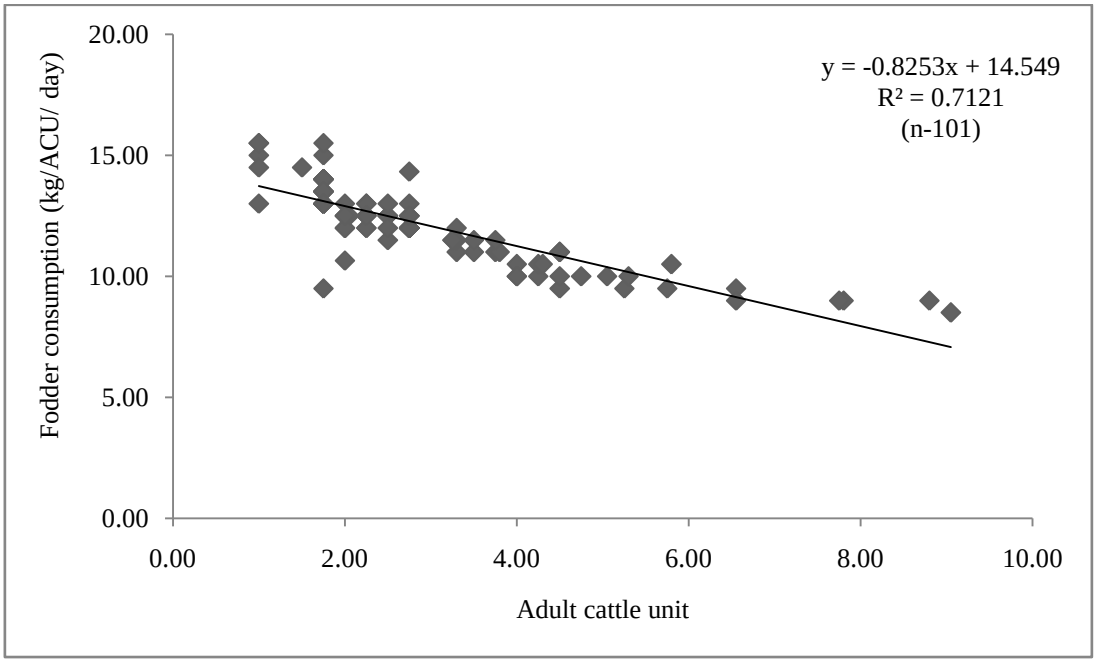

Fig. 5. Relationship between fodder consumption and total ACU per household at <800 m altitude

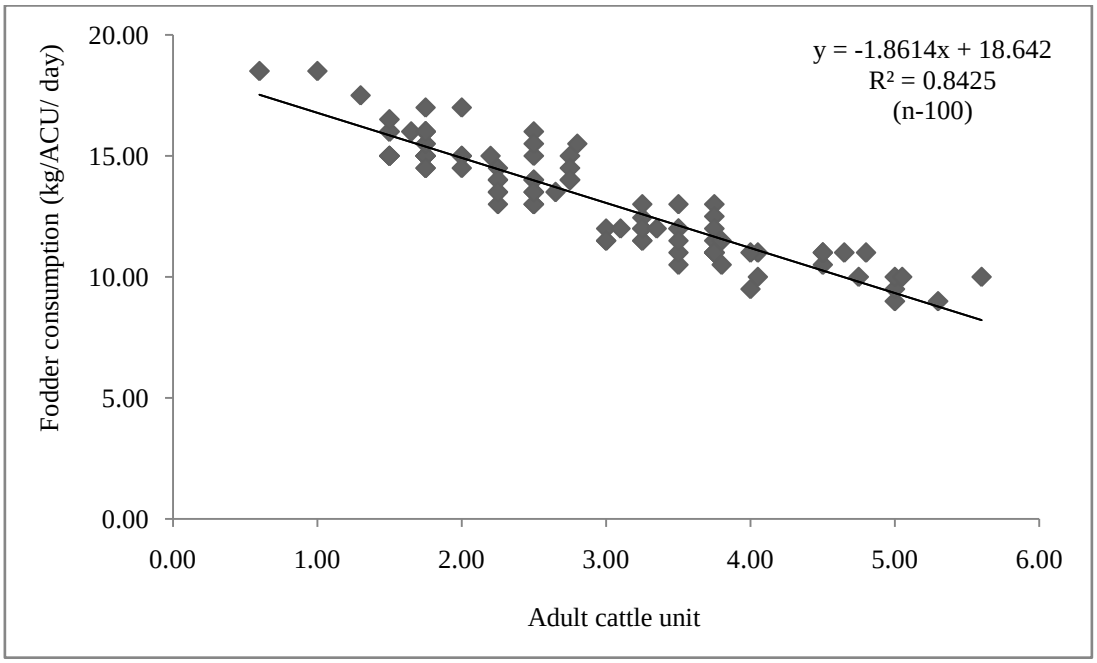

Fig. 6. Relationship between fodder consumption and total ACU per household at 801-1200 m altitude

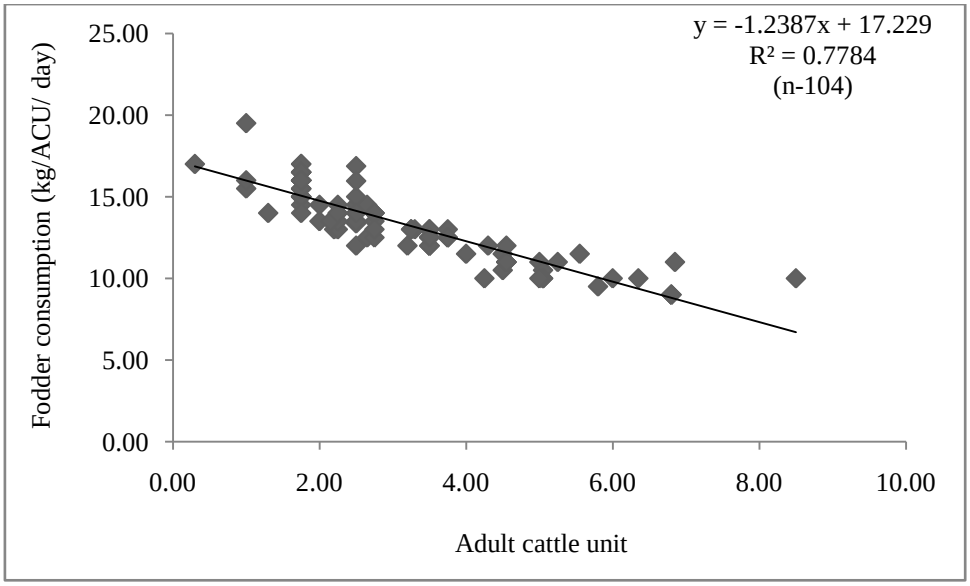

Fig. 7. Relationship between fodder consumption and total ACU per household at 1201-1600 m altitude

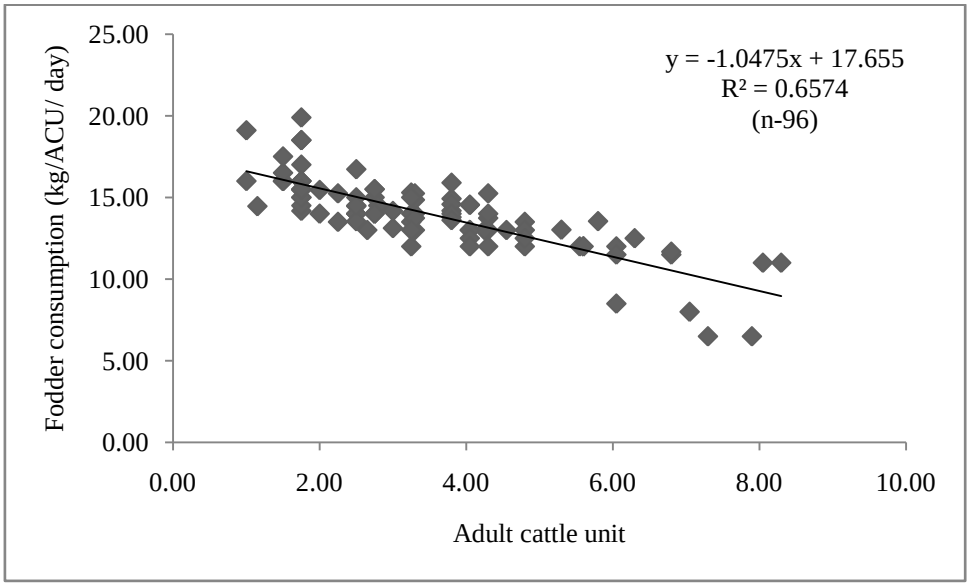

Fig. 8. Relationship between fodder consumption and total ACU per household at >1600 m altitude

CONCLUSION

Agroforestry practices help in reducing the gap between demand and supply of fuelwood and fodder as well as pressure on natural forests, and can be an effective approach in achieving the objectives of the National Forest Policy (1988) in India.

This study produced comprehensive information on the use of farm trees for meeting energy needs among smallholders in the Garhwal Himalayan region, India. The estimated results revealed that contribution of agroforestry for fuelwood and fodder was observed maximum in 1201-1600m altitude while minimum was at altitude >1600 m. Therefore the results suggest more adoption of agroforestry practices must be encouraged at higher altitude to fulfill the requirement of fuelwood and fodder in addition to other services such as fruit, timber, fiber, bio-sticks etc. The estimates of the study will also be helpful in identifying the role of agroforestry in forest management and minimizing the anthropogenic pressure. This can be achieved through government initiatives such as providing suitable planting material at a low cost to support livelihoods which will consequently assist in climate change mitigation and adaptation.

Need of effective communication with rural smallholders on the multifunctional values of agroforestry adoption and a better understanding of the importance of planting suitable tree species for multipurpose uses and their integration into farming systems in the mountainous region is of great importance in order to enhance agroforestry practices.

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