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Policy implications of utilizing indigenous tree species as agroforestry systems in Himalayan states of India: Case study of Uttarakhand

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ABSTRACT

Energy supply from the biomass of indigenous tree species in agroforestry systems continues to be an area of great interest among researchers world over to generate fundamental data and innovative ideas for developing appropriate policies, guidelines and legislation. Among the land use systems, agroforestry is recognized as superior land management system having potential to deliver sustainable biomass and energy supply in rural landscape. Present study highlights a comparison of seasonal biomass consumption pattern in terms of fodder and fuelwood energy supply across different village clusters along an altitudinal gradient. The average fuelwood consumption ranged between 242 ± 22 to 373 ± 23 kg/capita/year and fodder consumption ranged between 154 ± 17 to 463 ± 14 kg/unit/year. However, the energy value of fuelwood and fodder consumption ranged between 2160 ± 242 to 7317 ± 234 MJ/kg. The study demonstrated that the fuelwood and fodder consumption was significantly greater ($p < 0.05$) in winter (lean period) as compared to that in summer and monsoon seasons. The results of this study are valuable to policy planners to improve the current policies for sustainable biomass energy supply in the Himalayan context through utilization of indigenous tree species in agroforestry systems.

1. Introduction

Biomass use is a major source of domestic energy in the Himalayan region a pattern similar in many developing countries. In addition, its constant exploitation without substantial policy guidelines for re-vegetation and sustainable management practices have been identified as the most important causes of natural resource decline (Bhatt et al., 2004). Biomass of tree species accounts for approximately 14% of total energy used worldwide and it is the largest energy source for about 70% of the global population in developing countries (Gunhan et al., 2005). Energy demand and supply in Himalayan regions is complex due to the spatio-temporal variations in availability, difficult topographical conditions of the region, and accessibility of resources (Rijal, 1999). The indigenous agroforestry systems in the Himalayan region are an integral part of the society and environment as they constitute an interlinked system comprised of agriculture, livestock and forests. Management of agroforestry systems provides viable options for rural energy supply through simultaneous production of food, fodder and fuelwood. It plays an important role in reducing vulnerability, increasing resilience of farming systems and buffering the capacity of rural households against climatic variability (NRCAF, 2013). Agroforestry on degraded lands contributes to improving soil fertility, organic carbon content, reducing the anthropogenic pressure on existing forest resources and also in enhancing the sink potential of CO_2 (Semwal et al., 2013). Therefore, it has been considered as the most sustainable and promising land management system, providing expeditious enhancement of tree and biomass productivity per unit land. Agroforestry represents as ecologically and socio-culturally valuable vegetation across the Himalayan region and elsewhere in the world where other forms of land use are not advisable and or possible (Ramakrishnan, 2007).

Recently, agroforestry is receiving great attention in most of the developing countries because of its potential for high biomass production as a source of domestic energy (Thangata et al., 2012). In the Himalayan region of India, local communities maintain indigenous tree species in agroforestry systems especially on the edges of rainfed terraced agriculture fields without any external inputs or manpower (Rawat et al., 2011). The farmers have an integrated system of crops, trees, and livestock for meeting acute shortages of fuelwood and fodder biomass (Maikhuri et al., 1996). However, farmers with small land holdings are unable to follow such an integrated farming system due to

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constant pressure of changes brought about by socio-cultural, demographic, economic and technological advancement. Depleting forest resources due to anthropocentric biased developmental programme limits the availability of fuelwood whereas, commercial sources such as liquefied petroleum gas (LPG) and kerosene oil fail to meet the adequate domestic energy demands due to logistic and economic constraints of the rural communities in the Himalayan Mountains (Rijal, 1999). Therefore, reducing inefficient use of fuelwood and fodder biomass and encouraging conservative use of alternative bioresources in meeting the energy demand ensures ecological and social sustainability. Since the scientific information on indigenous agroforestry systems has been disproportionately minor in view of the perception that they are less productive, these systems are often overlooked in policies for socio-economic development despite their significant contribution in food and nutritional security to a large section of the society. Therefore, in the present study we analyze and quantify the seasonal variations in fuelwood availability, and fodder consumption as basis for developing appropriate strategies for policy implications with respect to agroforestry systems in the Himalayan region.

2. Materials and methods

2.1. Study area and climate

Uttarakhand (28°43′ and 31°28′ N latitude and 77°49′ and 81°03′ E longitude) is a Himalayan state located in the northwest part of India. The state spreads over an area of 53,483 sq km with predominance of mountains. The total population of the state is around 10.1 million out of which 69.4% is rural (Census, 2011). The present study was carried out in three different village clusters i.e., Dagar, Jakhand, and Saknidhar (five villages in each cluster) of Tehri district, located in the western part of the state, an area that exhibits tropical to temperate climate with distinct characteristics of specific vegetation types (Fig. 1). The study villages are located between an elevation range of 800–1800 m above sea level (m asl), with agriculture and animal husbandry as the major occupation of the population.

2.1.1. Climate of the study area

The year consists of three seasons *viz.*, summer season (March–June), monsoon season (July–October), and winter season (November–February). The average temperature is highest in the month of May and June (23–39 °C) and lowest in the month of January (3–18 °C). About 60% of total annual rainfall is received during June to September.

2.1.2. Human and livestock population

The population of the studied village clusters is 5586 in 980 households, and the average family size is 5.7. Total livestock population of the studied village clusters is 2173 of which 28.2% are buffaloes, 23.6% cows, 13.9% bullocks, 31.7% goats, and 2.6% are mules and horses.

2.1.3. Land cover and land use

The studied agroforestry landscape could be divided into four land use types based on distribution of the plant species *viz.*, agriculture land (44%), grassland (29%), barren land (20%) and kitchen garden (7%). In the Western Himalayan region, indigenous agroforestry systems are often characterized by cultivation of food crops in small sloppy terraces of agriculture farm every year and scattered fodder tree species growing on the bunds of these farms.

2.2. Methodology

2.2.1. Baseline survey

Participatory Rural Appraisal approach was followed for the field study (Reed, 2008; Chambers, 2009; Phondani et al., 2016a). To understand the characteristics changes in indigenous agroforestry systems, the study area was divided into three ecological zones along an elevational gradients *viz.,* 800–1100, 1200–1400 and 1500–1800 m above sea level. Five representative villages in each cluster were selected at different ecological zones for comprehensive analysis of seasonal fuelwood and fodder consumption patterns for domestic energy supply. To carry out the appraisal, a team of researchers traveled through the region and administered the appraisal through questionnaire and or verbally, depending on the situation of each household. More than 40% of households from each village were identified for detail data collection. Through participatory approaches and questionnaire survey, information about various aspects from the village clusters such as altitude, population, family size, source of income, dependency of local people on agroforestry, agriculture pattern, land holding, livestock holding, bioenergy resources, source and requirements of fodder and fuelwood, infrastructure development, socio-economic status and education level were collected during the year 2015–2017.

2.2.2. Prioritization of indigenous tree species in agroforestry systems

Indigenous tree species used for different purposes were identified and prioritized based on their characteristics features and multiple use value with the help of questionnaire survey, existing literature survey, personal interviews, and consultations with local informants (Phondani et al., 2016b). During the surveys, attempts were made to collect all possible information about the multiple use value of indigenous tree species were prioritized in agroforestry systems. The criteria for ranking of selected tree species were given consideration based on preference of local people used for different purposes i.e., fodder, fuelwood, timber, fiber, food and medicine. The respondents (n = 150), who were generally the heads of households, were approached and face-to-face interviews were conducted with them in local dialects.

2.2.3. Assessment of fuelwood consumption and energy value

Local people involved in fuelwood collection were questioned about the frequency and quantity of fuelwood collected in each season and the number of bundles harvested and approximate weight of each bundle was also estimated. The net quantity of fuelwood consumption in the studied village clusters was estimated over a period of 24 h by using the weight survey method (Mitchell, 1979). Quantification of fuelwood for various purposes, i.e., cooking, lighting, space-heating and also for other miscellaneous purposes (human dead body cremation, weed residue burning in agriculture field, sharpening of agriculture tools by blacksmith) was evaluated in different seasons (i.e., winter, summer and monsoon) in the year (Maikhuri et al., 1996). For quantification of the fuelwood consumption in the study area, initially a wood lot (bundle) was weighed and left in the kitchen of the each sample household and the household was requested to burn wood only from the sample bundle. After 24 h, the household was visited again and the actual fuelwood consumption was calculated. The difference in weight of the fuelwood was considered as the amount used per day and the fuelwood consumption pattern was calculated on seasonal basis. The estimation of energy value of fuelwood consumption was calculated (Mitchell, 1979) using the energy value of 1 kg oven dry weight fuelwood as 16.8 MJ/kg.

2.2.4. Assessment of fodder consumption and energy value

Data on fodder consumption pattern and mode of utilization of each plant species was collected through direct observation on a household basis (Rawat et al., 2011). The fodder harvesting patterns such as the preference, availability and milk enhancing quality of fodder species were studied in the selected villages. Species, genera, and family of all fodder plants were identified by experts at the Department of Botany, H.N.B. Garhwal Central University, Srinagar Garhwal, Uttarakhand, India and authenticated with the help of regional flora (Gaur, 1999). Before collecting the actual data, the questionnaires used for survey