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Productivity and Carbon Storage Potential of different Land Use Systems in Leh Region of Himalayan Cold Desert

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Abstract: Agroforestry is a sustainable land use system which has the potential to contribute to the improvement of rural livelihood and at the same time helps in fighting against global warming by sequestration of atmospheric carbon. Therefore in the present study, an attempt was made to estimate the total biomass production and carbon storage potential of seven different land use systems viz. agriculture, horticulture, agrisilviculture, agrihortisilviculture, silvipasture, hortisilvipasture and agrihorticulture in Leh region of Himalayan cold desert in the year 2017-2018. The hortisilvipasture land use system recorded maximum total biomass production (30.88 t ha^{-1}) and total carbon stock (15.44 t ha^{-1}) whereas, the minimum total biomass production (8.76 t ha^{-1}) and total carbon stock (4.38 t ha^{-1}) was in agriculture land use system.

Keywords: Biomass, Carbon, Cold desert, Himalayas and land use

Land is the most important natural resource which embodies soil, water and associated flora and fauna involving total ecosystem. The term 'land use' refers to the human activity or economic function associated with a specific piece of land whereas the 'land cover' relates to the type of feature present on the surface of the earth. The land use/land cover is the result of permanent adjustment between the constraining properties of land and the socio-economic attributes whereas the land utilization type defines the technical details about cultivation/form details. Information on land use or land cover allows a better understanding of the land utilization aspects like cropping patterns, fallow lands, forests, pasture lands, wastelands and surface water-bodies which are vital for development planning (Lillesand and Kiefer 2000). The Himalayas is a vast mountain system covering partly/fully 8 countries i.e. Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal and Pakistan. It consists of various kinds of land uses, like forest (Government forest, Village forest, and Municipal forest), cultivated and fallow land, non-cultivable land and alpine pastures. North western Himalayas is basically an agro-ecosystem, where 90 per cent of its total population lives in villages whose economy is dependent on agriculture, horticulture and animal husbandry. In India, cold desert comes under the trans Himalayan zone which is approximately 1,03,11,300 hectares of area (Gupta and Arora 2016). These arid areas are not benefited by the south east monsoon because they lie in the rain shadow area of the Himalayan mountain system. A cold desert ecosystem refers to an area where the climate has characteristics of great extremes of being hot and cold combined with excessive dryness. Temperature in these tracts normally ranges from -45°C during winters to +35°C in summers. In addition, scanty rainfall, massive snowfall, high wind velocity, sparse vegetation, high UV radiation, and extremely xeric conditions are the common features of this region (Devi and Thakur 2011). The soil of cold desert is generally grey and light, characterized by low fertility status coupled with poor water retention capacity and scanty plant cover. In absence of any substantial leaching of minerals from the soil, the bases are continuously added to the soil complex, thereby rendering the pH values on alkaline side (Tundup et al 2018). However, due to huge variations in the geology of the region, the nature and composition of the soil varies. Summers (June to September) the major growth period for the plants, is quite short and because of these plants require more time to establish themselves in such harsh areas (Tiwari and Kapoor 2013). Ladakh in erstwhile state of Jammu and Kashmir and Lahaul and Spiti in Himachal Pradesh form the cold desert. In India, major part of cold desert in the country is confined to Ladakh with approximately 82,665 sq. Km area and 37,555 sq. Km of this area is under the illegal occupation of Pakistan and China (Butola et al 2012). Hence area with India is 45,110 sq. Km, representing 87.40 per cent of total cold arid region. This region is enclosed by the Ladakh and Karakoram range in the north and Zanskar mountain and the Great Himalaya in the south. Land based economy of this region consists of agriculture and allied sectors. The region is ecologically fragile and subsistence agriculture is the backbone of local livelihoods. Agroforestry in this region has a potential to provide options for improvement in livelihood through simultaneous production of food, fodder and firewood (Salve and Bhardwaj 2020). Agroforestry is one of the important terrestrial carbon sequestration systems that help in mitigation of the impact of climate change (Tiwari 2000).

MATERIAL AND METHODS

The present study was carried out in two blocks i.e. Khaltsi and Saspol block of Leh district of erstwhile state of Jammu and Kashmir (now Union Territory of Ladakh). The region is enclosed by the Ladakh and Karakoram ranges in the north and Zanskar mountain and The Great Himalayas in the south. The average altitude of the region is 3200 m amsl. Precipitation is very low and mainly occurs in the form of snow in the winter months . The study sites were selected through multi-stage random sampling technique. Leh district consisted of 16 blocks and out of all the blocks, Khaltsi and Saspol block were selected for the study. In the first stage, two panchayats from each block were selected. In the second stage, from each panchayat, two villages were selected. In the 3rd stage, from each village, nine households were selected in such a way that three farmers were represented by small, medium and large category according to their land holding. Thus, from each block 36 households were selected and a total of 72 households were selected from both the blocks for the study. There were seven land use pattern (Table 3). The experiment was randomised block design with replication (villages).

Table 1. Locality factors of the study area

Latitude	34˚10" N
Longitude	77˚35" E
Altitude	2900-3500 m
Climate type	Dry temperate
Soil texture	Coarse and sandy

Experimental Methodology

Biomass production: The tree productivity refers to increase in tree biomass per unit area. Measurement of tree diameter and volume was made to estimate the standing biomass. For this, five sample plots of 30 × 10 m^2 were laid in each land use system. The tree species from different quadrates were recorded in the intercropping system and sole tree system.

Volume estimation of stem: The diameter of trees was measured for each existing land use systems in each quadrat for computation of standing volume of different tree species. The data were collected for trees from all the quadrats of different land use systems. The different volume equations were used to compute the volume of the different tree species (FSI, 1996). Above ground biomass (AGB): In order to estimate the tree biomass, the volume of individual trees in each sampling quadrat was multiplied with its specific gravity (SG) and stem biomass (SB) was derived. Later, the stem biomass was multiplied with the biomass expansion factor (BEF) to derive above ground biomass. BEF is the value to take into account the biomass of the other aboveground components of trees (leaves, twigs and branches).

$$AGB = SB \times BEF$$

Stem volume of different tree species were calculated from the volume equations and specific gravity of respective tree species were taken from literature.

$$SB = \text{volume} \times \text{specific gravity}$$

Where,

SB = Stem Biomass

BEF = Biomass Expansion Factor

Below ground biomass of trees (BGB): Below ground biomass of trees was calculated by multiplying above ground biomass (AGB) with root: shoot of tree species (IPCC 1996).

$$BGB = AGB \times \text{Root: Shoot}$$

Table 2. Multi-stage random sampling method for choosing the study sites

Block	Panchayat	Village	Farmer (9 farmers from each village according to their land holding)
Khaltsi	Khaltsi	i. Khaltsi ii. Skindiyang	• Three marginal farmer(<1 hectare) • Three small farmer (1-2 hectare) • Three medium farmer (2-5 hectare)
	Tingmosgang	i. Tingmosgang ii. Nurla	• Three marginal farmer(<1 hectare) • Three small farmer (1-2 hectare) • Three medium farmer (2-5 hectare)
Saspol	Saspol	i. Saspol ii. Saspochey	• Three marginal farmer(<1 hectare) • Three small farmer (1-2 hectare) • Three medium farmer (2-5 hectare)
	Gera	i. Gera ii. Alchi	• Three marginal farmer(<1 hectare) • Three small farmer (1-2 hectare) • Three medium farmer (2-5 hectare)

Herbs

Above ground biomass: A herb is a plant whose stem is tender and height is usually not more than one meter. For estimation of herb biomass, quadrats of 50×50 cm^2 size were laid out in the different land use systems in the study sites. All the herbs from quadrats were harvested and oven dried at 65±5°C to the constant weight.

Agriculture Crops: Above ground biomass: Crop biomass was estimated using 1×1 m^2 plots. All the crop plants within the border of quadrats were harvested and collected samples were weighed, sub sampled (separated into root and shoot) and oven dried at 65±5°C to a constant weight.

Below ground biomass of herbs and crops: Below ground biomass of crops and grasses (herbage) was determined by removing crops and grasses with roots carefully. Soil was separated by tapping and roots were washed and segregated species wise. Roots of each species were stored in paper bags and then were dried in oven at 65±5°C to a constant weight.

Carbon stock: Biomass of trees, herbage and crops was converted into biomass carbon by multiplying total biomass with a factor of 0.50 (IPCC 1996).

Carbon Stock = Total biomass × 0.50

RESULT AND DISCUSSION

The total biomass and carbon stock of different land use systems followed the order as hortisilvipasture > agrihortisilviculture > silvipasture > agrisilviculture > agrihorticulture > horticulture > agriculture. Hortisilvipasture land use system recorded maximum total biomass production (30.88 t ha^{-1}) and total carbon stock (15.44 t ha^{-1}) (Table 3). The minimum total biomass production (8.76 t ha^{-1}) and total carbon stock (4.38 t ha^{-1}) was in agriculture land use system. The above ground and below ground biomass in general followed the same trend as that of total biomass and total

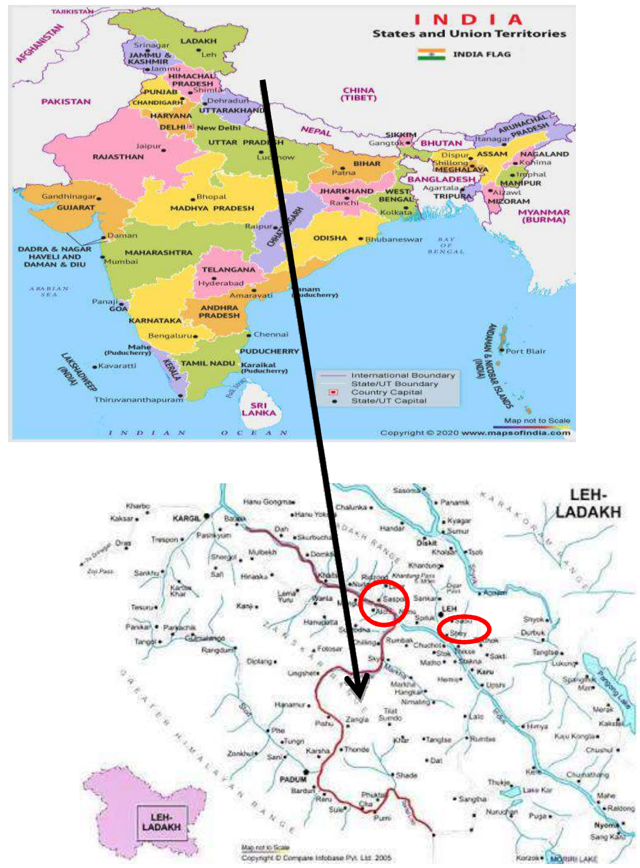

Fig. 1. Location map of the study area

Table 3. Above ground biomass, below ground biomass, total biomass and total carbon stock of various land use systems of the study area

Land use systems	Aboveground biomass (t ha^{-1})		Mean	Belowground biomass (t ha^{-1})		Mean	Total biomass (t ha^{-1})		Mean	Total carbon stock (t ha^{-1})		Mean
	Khaltsi Block	Saspol Block		Khaltsi Block	Saspol Block		Khaltsi Block	Saspol Block		Khaltsi Block	Saspol Block	
Agriculture	6.88	6.16	6.52	2.36	2.14	2.25	9.24	8.29	8.76	4.62	4.15	4.38
Horticulture	11.15	9.99	10.57	6.70	6.11	6.41	17.85	16.10	16.97	8.92	8.05	8.49
Agrisilviculture	17.72	16.50	17.11	6.28	5.79	6.03	23.10	22.29	23.14	11.10	11.15	11.57
Agrihortisilviculture	19.77	18.46	19.11	8.41	7.69	8.05	28.17	26.15	27.16	14.09	13.08	13.58
Silvipasture	17.44	16.39	16.91	9.62	9.41	9.51	27.06	25.79	26.43	13.53	12.90	13.21
Hortisilvipasture	20.73	19.17	19.95	11.22	10.65	10.93	31.95	29.81	30.88	15.98	14.91	15.44
Agrihorticulture	16.76	15.53	16.15	7.14	6.81	6.97	23.90	22.34	23.12	11.95	11.17	11.56
Mean	15.78	14.60		7.39	6.94		23.17	21.54		11.58	10.77	
C.D. (p=0.05)	System	0.78		System	0.47		System	0.80		System	0.40	
	Block	0.42		Block	0.25		Block	0.43		Block	0.21	
	(S X B)	NS		(S X B)	NS		(S X B)	NS		(S X B)	NS	

carbon stock of different land use systems. Further, it is evident that different land use systems had significant effect on biomass production and carbon stock. It is influenced by the age of the components (annual or perennial), type of crop, structure of system, nature and number of woody components etc. The higher biomass production in hortisilvipasture land use system can be because of the higher density of trees as compare to other land uses. The hortisilvipasture land use system consisted of fruit and fodder trees and grasses. Many workers have studied the biomass production and carbon stock of different land use systems and found similar trends. Montagini and Porras (1998) revealed that the mixed species have a greater capacity to produce high levels of biomass because of the difference in carbon fixing rates by species. Deshmukh (1998) reported that management practices also affect the biomass production of trees grown under different agroforestry systems. The higher biomass production in hortisilvipasture land use system can be because of the higher density of trees as compared to other land uses.

CONCLUSION

The total biomass and carbon stock accumulation was significantly variable under different land use systems and it can be concluded that for a cold desert like Ladakh, hortisilvipasture is the type of land use system which accumulates maximum biomass and stores maximum carbon is recommended for better land use management.

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