



## **Bio-economic potential of pastoralsilviculture land use system in north-western Himalayas**

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### **Abstract**

The present investigation was carried out to quantify carbon stock and economic potential of the pastoralsilviculture system along altitudinal gradient in Indian north-western Himalayas during 2019-2021. The area was divided into four altitudinal ranges as per agro-ecological classification of the state viz., altitudinal ranges viz., zone-I (<1000 m amsl), zone-II (1000-1500 m amsl), zone-III (1500- 2500 m amsl) and zone-IV (> 2500 m amsl). Further, farmers practicing pastoralsilviculture system were divided into three farmer categories viz. marginal (less than 1 ha land area), small (1-2 ha land area) and semi-medium (2-4 ha land area) as per Government of Himachal Pradesh standards. The results revealed that the total biological productivity (aboveground+belowground) of the pastoralsilviculture system ranged between 24.90-43.24 Mg ha<sup>-1</sup>, showing an increasing trend along altitude with zone-III having maximum total biomass production. The bio-economic potential of the pastoralsilviculture system was not found to be significantly affected by the farmer category. Soil carbon density was maximum (31.65 Mg ha<sup>-1</sup>) at zone-I which was significantly at par with soil carbon density at zone-III (30.86 Mg ha<sup>-1</sup>). Total carbon stock potential, comprising vegetation carbon and soil carbon, of the system was recorded maximum (52.48 Mg ha<sup>-1</sup>) for Zone-III, while minimum (42.58 Mg ha<sup>-1</sup>) for zone-IV. Economic potential of the pastoralsilviculture system in terms of output:input ratio was found maximum (3.73) in zone-III which was significantly at par with output:input ratio in zone-II (3.62) and minimum was recorded in zone-IV (3.05).

### **Introduction**

Tree, crop and livestock are the three basis components of agroforestry. Rearing of livestock is an integral part of the rural livelihood in the western Himalayan region that helps in maintaining the sustainability of the farming system. Livestock being an inseparable component of agroforestry is not only helpful in maintaining sustainability of the system but also is an enterprise itself. Livestock to a certain extent depends for fodder on the common property resources which play an important role in providing round the year fodder to livestock through grazing (Pathania and Dev 2011). In the Himalayan region, there is a dynamic relationship between the livestock and common property resources such as forests, water resources and grazing land. The 1.5 million hectare of grasslands constituting around 33 per cent of the land utilization of Himachal Pradesh is suffering from low productivity (GoHP 2020) mainly attributed to the lack of management, overgrazing and weed infestations. This ultimately

affects the productivity of the livestock mainly dependent on these natural resources because of dearth of nutritious green fodder along with dry fodder and concentrates (NITI 2018) and widening gap between the demand and supply of the green fodder. Further, under the climate change scenario the low biological productivity of the grasslands also pose challenges to adapt and mitigate the adverse climatic conditions. Integrating grasses with the tree component may address the challenge of biological productivity, dearth of quality fodder along with sustainable land management. Pasture-based land use systems may be the solution to the problems faced by livestock sector and can help in mitigation of the challenges posed by the climate change. Keeping in view the importance of pastures the present study was carried out for determining the bio-economic potential of the pastoralsilviculture system along altitudinal gradient in western Himalayan region.

## Methods

The present study was conducted during 2020-2021 at Nauni, Solan (HP), India in Chamba district of Himachal Pradesh located in North-Western Himalayas. The study area was divided into four altitudinal zones representing the four agro-climatic zones found in the state Himachal Pradesh viz., zone-I (<1000 m amsl) (Z1), zone-II (1000-1500 m amsl) (Z2), zone-III (1500-2500 m amsl) (Z3) and zone-IV (>2500 m amsl) (Z4). The pastoralsilviculture system being practiced by the three farmers categories viz., marginal (<1 ha) (F1), small (1-2 ha) (F2) and medium (2-4 ha) (F3), in the study area were identified for the assessment of their bio-economic potential. For herbage and shrubs, destructive method of sampling was adopted by making the plots of standard size 1×1 m<sup>2</sup> and 5×5 m<sup>2</sup> respectively, while, for trees non-destructive method based on the regional volume equations (FSI 1996) was used with sampling in 0.1 ha plot. The method of aboveground biomass (AGB) estimation of trees was as follow:

$$\text{Stem biomass (Mg ha}^{-1}\text{)} = \text{VOB} \times \text{WD}$$

Where, VOB = volume over bark (from volume equations)

WD = volume weighted average wood density

The AGB of a tree was calculated by formula:

$$\text{AGB (Mg ha}^{-1}\text{)} = \text{Stem biomass (Mg ha}^{-1}\text{)} \times \text{BEF}$$

Where, BEF = biomass expansion factor

Belowground biomass (BGB) of a tree was calculated by multiplying its aboveground with a standard factor of 0.26 (Cairns et al. 1997). Biomass carbon stock was calculated by multiplying the biomass with the standard factor of 0.5 given by IPCC (IPCC 2003). Soil organic carbon (SOC) stock was calculated using formula given below:

$$\text{SOC (Mg ha}^{-1}\text{)} = \text{Soil bulk density (gcm}^{-3}\text{)} \times \text{soil depth (cm)} \times \text{OC (\%)} \times 100$$

Where, C: soil organic carbon density

OC: soil organic carbon percent expressed in decimal fraction

Aggregation of vegetation carbon stock along with SOC depicted the total carbon stock (TCS) potential of the system. The economic potential of the system was assessed by dividing outputs obtained from the system with inputs to manage the system and is expressed as output:input ratio (O:I). Inputs include cost per unit area for the establishment and maintenance of system components, labour, land rent and plant protection, while, outputs include the market value per unit area of the various products harvested from the pastoralsilviculture system such as grass, green fodder, fuelwood, small timber and fruit. The data on various parameters were subjected to two way ANOVA using SPSS software for analysis.

## Results

### *Biological productivity of the pastoralsilviculture system*

The results revealed that the AGB, BGB and total biomass (TB) were significantly affected by the altitudinal zones (Table 1) and interaction of altitude with farmer category (Table 2). However, no significant effect of the farmer category (Table 1) was found on biological productivity of the system. In case of altitudinal zones, AGB ranged between 19.79-34.72 Mg ha<sup>-1</sup> with maximum biomass recorded at Z3 and minimum at Z1. BGB ranged between 5.11-8.52 Mg ha<sup>-1</sup> with trend similar to that followed in AGB. TB, being combination of AGB and BGB, also followed the same trend and ranged between 24.90-43.24 Mg ha<sup>-1</sup>. In case of interaction, AGB (37.34 Mg ha<sup>-1</sup>), BGB (9.33 Mg ha<sup>-1</sup>) and TB (46.66 Mg ha<sup>-1</sup>) were recorded maximum for the combination Z3F1, while, minimum AGB (15.76 Mg ha<sup>-1</sup>), BGB (4.05 Mg ha<sup>-1</sup>) and TB (19.81 Mg ha<sup>-1</sup>) were recorded for Z1F1.

### *Carbon stock potential of the pastoralsilviculture system*

In case of SOC, altitudinal zones and interaction between the factors have shown significant variation with farmer category not having any significant contribution towards SOC (Table 1 and Table 2). Maximum SOC was recorded at Z1 (31.65 Mg ha<sup>-1</sup>) which was significantly at par with SOC at Z3 while, minimum SOC was recorded at Z4 (22.20 Mg ha<sup>-1</sup>). In case of interaction, SOC was recorded maximum for Z1F2 (34.41 Mg ha<sup>-1</sup>) significantly at par with Z1F3 and Z3F1 while, minimum was recorded for Z4F2 (19.91 Mg ha<sup>-1</sup>) significantly at par with Z4F3. The higher soil organic carbon may be because of the lesser dependence on biomass as fuel, better decomposition as well as management of the system which results in the production of more biomass and its incorporation in the soil. The TCS of the system was found to be significantly affected by altitudinal zones, while, farmer category didn't affected TCS significantly. Z3 resulted in maximum (52.48 Mg ha<sup>-1</sup>) storage of the carbon stock in pastoralsilviculture system, while, Z4 was found to have least (42.58 Mg ha<sup>-1</sup>) carbon storage in the pastoralsilviculture system which was significantly at par with carbon stock at Z1 and Z2. Considering interaction, TCS was recorded maximum (55.09 Mg ha<sup>-1</sup>) for the Z3F1, while, minimum (38.51 Mg ha<sup>-1</sup>) was recorded for Z1F1.

### *Economic potential of the system*

Considering economic potential of the pastoralsilviculture system, only altitudinal zone was found to have significant effect on the O:I. The O:I of the system varied between 3.05-3.73 with maximum O:I recorded at Z3 which was significantly at par with O:I in Z2 while, minimum ratio was recorded in Z4 which was at par with Z1.

Table 1: Bio-economics of different farmer categories practicing pastoralsilviculture along altitude

Parameters	AGB (Mg ha <sup>-1</sup> )	BGB (Mg ha <sup>-1</sup> )	TB (Mg ha <sup>-1</sup> )	SOC (Mg ha <sup>-1</sup> )	TCS (Mg ha <sup>-1</sup> )	O:I
Z1	19.79	5.11	24.90	31.65	44.10	3.24
Z2	24.26	5.81	30.07	27.87	42.91	3.62
Z3	34.72	8.52	43.24	30.86	52.48	3.73
Z4	32.36	8.41	40.77	22.20	42.58	3.05
LSD (p<0.05)	3.00	0.76	3.76	2.13	2.92	0.22
F1	29.05	7.30	36.35	28.17	46.34	3.42
F2	28.23	7.01	35.24	27.82	45.44	3.33
F3	26.07	6.58	32.64	28.44	44.76	3.48
LSD (p<0.05)	NS	NS	NS	NS	NS	NS

Table 2: Interaction effect of altitude and farmer's category on bio-economic potential of pastoralsilviculture

Parameters	AGB (Mg ha <sup>-1</sup> )	BGB (Mg ha <sup>-1</sup> )	TB (Mg ha <sup>-1</sup> )	SOC (Mg ha <sup>-1</sup> )	TCS (Mg ha <sup>-1</sup> )	O:I
Z1F1	15.76	4.05	19.81	28.61	38.51	3.24
Z1F2	22.21	5.44	27.64	34.41	48.23	3.12
Z1F3	21.40	5.84	27.23	31.93	45.54	3.37
Z2F1	29.14	6.99	36.12	28.49	46.55	3.93
Z2F2	21.64	5.18	26.82	26.79	40.20	3.45
Z2F3	22.02	5.25	27.26	28.33	41.96	3.49
Z3F1	37.34	9.33	46.66	31.76	55.09	3.49
Z3F2	37.21	9.13	46.34	30.17	53.35	3.80
Z3F3	29.62	7.10	36.72	30.63	48.99	3.89
Z4F1	33.97	8.83	42.80	23.82	45.22	3.04
Z4F2	31.87	8.29	40.16	19.91	39.99	2.96
Z4F3	31.24	8.12	39.36	22.85	42.53	3.17
LSD (P<0.05)	5.20	1.32	6.52	3.68	5.06	NS

## Discussion

Biomass production may be the result of physiographical features, compositional differences, age, density of trees, interaction, farmer preferences, needs as well as ecological conditions as reported by Gupta et al. 2017 and Kumar et al. 2021, along altitude in Himalayan region. At Z3, the perennial components were dominated by the mature tree species having higher biomass production such as *Cedrus deodara*, *Pinus wallichiana*, *Salix spp* etc. which may be the reason for the increased biomass production. Marginal farmers being subjected to the dearth of the land availability make intensive use of the available resources in order to fulfill various needs, which may result in the higher biological productivity under the influence of intensive land management as can be predicted from higher biomass production in Z3F1. Carbon stock of the system is the aggregation of the carbon stored in the biomass as well as in the soil. The biomass carbon is just the fraction of the biological productivity of the system so it is obvious that it will show variations similar to that recorded for the biomass production of the system. Reduced soil carbon stock along altitude may be because of intensive utilization of the litter as well as biomass (Goswami et al. 2017) for fulfilling the fodder and fuel requirements. Further, decrease in temperature along altitude may reduce the rate of decomposition which under the influence of steep slopes may cause movement of the organic matter to the lower regions. Although soil carbon stock was higher at lower elevations yet the broad contribution of the biomass to total carbon stock of the system resulted in maximum carbon stock at Z3. The higher carbon stock at Z3F1 may be the cumulative effect of the farming intensity with the composition as well as density of the perennials in the system as reported by Singh et al. 2018; Adhikari et al. 2020. Pasture based systems are remunerative from the perspective of marginal lands where farmers may get multiple products along with the prevention of land from degradation. However, higher economic potential of the pasture based land use systems can be availed by incorporating agriculture and horticulture components as reported by Tiwari et al. 2021.

Thus, it can be concluded that pastoralsilviculture is the prominent pasture-based land use system in the study area having highest bio-economic potential at zone-III. The system can serve as an important land management option to reclaim the degraded land areas as well as a viable option for the mitigation and adaptation to climate change.

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