Carbon sequestration potential of pasture-based systems along an altitudinal gradient in the north-western Himalayas

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Abstract: The present investigation was carried out in the Chamba district of Himachal Pradesh (India) to identify the pasture-based land use systems being practiced by farmers and to find out their carbon sequestration potential along different altitudes. For carrying out the study, the area was divided into four 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), according to agro-ecological zones in the state. Results revealed that the pasture-based systems practiced by the farmers in the altitudinal zone-I and zone-II were silvo-pasture and pastoral-silviculture, while, at altitudinal zone-III and zone-IV, the pasture-based systems being practiced were pastoral-silviculture and horti-pastoral depending upon the composition of the components. The aboveground biomass was found ranging between 27.78- 38.18 Mg ha^{-1} among different pasture-based land use systems with maximum aboveground biomass under silvo-pasture system and minimum under pastoral-silviculture. Along altitudinal gradient, aboveground biomass was found to have been increased with values varying between 29.09- 34.12 Mg ha^{-1}. Belowground biomass ranged between 6.93- 9.80 Mg ha^{-1} in different systems under consideration and generally showed increasing trend with increasing altitude. Overall biological productivity was found to be highest under silvo-pasture system followed by horti-pastoral and pastoral-silviculture system. Being biologically most productive, silvo-pasture system stored maximum carbon stock and ultimately sequestered more carbon as compared to the other systems. The estimated vegetation carbon sequestration potential of the pasture-based systems was 63.71- 88.06 Mg ha^{-1}, while, along altitude the carbon sequestration potential varied from 67.14- 78.62 Mg ha^{-1} showing increasing trend with altitude.

Introduction

Changing climatic conditions are becoming more evident during the last decade that demands the direct as well as indirect concerns of the society. Rearing of livestock is an important and integral part of the rural livelihood in the western Himalayan region that helps in maintaining the sustainability of the farming system. 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. Himachal Pradesh is having abundant grasslands to an extent of 1.5 million hectare constituting around 33 per cent of the land utilization but is suffering from low productivity (GoHP 2020). 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. 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 carbon sequestration potential of the pasture based land use systems along altitudinal gradient in western Himalayan region.

Material and 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), zone-II (1000-1500 m amsl), zone-III (1500-2500 m amsl) and zone-IV (>2500 m amsl). The pasture-based systems being practiced by the farmers in the study area were identified for the assessment of the carbon sequestration potential. For herbage and shrubs, destructive method of sampling was adopted by making the plots of standard size 50×50 cm and 5×5 m 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 estimation of trees was as follow:

Stem biomass (Mg ha^{-1}) = VOB x WD

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

WD = volume weighted average wood density

The aboveground biomass of a tree was calculated by formula:

Aboveground biomass (Mg ha^{-1}) = Stem biomass (Mg ha^{-1}) x BEF

Where, BEF = biomass expansion factor

Belowground biomass 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). Carbon sequestration was calculated by multiplying the vegetation carbon stock with the factor 3.67 (Rizvi et al. 2019). The data were subjected to two way ANOVA using SPSS software for analysis.

Results and Discussion

Identification of pasture based systems

In the study area, three pasture-based land use systems were identified viz., silvo-pasture (SP) pastoral-silviculture (PS) and horti-pastoral (HP). The system types were termed on the basis of major functional unit in combination identified through the specific functional contribution of the component to the system, for example, in silvo-pasture system, trees were primary component, while, grasses were secondary and vice-versa for pastoral-silviculture. However, in horti-pastoral system, fruit trees were primary component with grasses being secondary. Among all the pasture-based systems, pastoral-silviculture was the most prominent system which was found prevalent in all the altitudinal zones in the study area, while, silvo-pasture was found to be practiced by farmers in zone-I and zone-II and horti-pastoral system being practiced in zone-III and zone-IV. The tree composition found in different pasture-based systems in altitudinal zone-I were *Toona ciliata, Bauhinia variegata, Albizia chinensis, Ficus palmata, Celtis australis, Pinus roxburghii, Melia composita, Broussonetia papyrifera, Grewia optiva, Pyrus pashia, Butea monosperma* and *Erythrina suberosa* with grasses such as *Chrysopogon montanus, Heteropogon contortus, Panicum maximum, Cymbopogo martini, Chloris gayana, Setaria spp, Saccharum spontanum Cynodon dactylon, Pennisetum spp* and *Desmostachya bipinnata.* In zone-II, trees present were *Toona ciliata, Ficus palmata, Bauhinia variegata, Albizia chinensis, Pistacia integerrima, Ficus roxburghii, Leucaena leucocephala, Pyrus pashia, Broussonetia papyrifera, Olea cuspitata, Pinus roxburghii, Prunus paddus, Celtis australis* and *Erythrina suberosa* and grasses present were *Setaria spp, Apluda mutica, Desmostachya bipinnata, Paspalum dilatatum, Cymbopogo martini, Chloris gayana, Chrysopogon montanus, Heteropogon contortus, Imperata cylindrica, Pennisetum spp, Saccharum spontanum* and *Sorghum bicolor.* Forest tree species present in zone-III were *Salix tetrasperma, Celtis australis, Cedrus deodara, Robinia pseudoacacia, Morus serrata, Ulmus wallichiana, Populus ciliata, Aesculus indica, Quercus dilatata, Pinus wallichiana* and *Picea smithiana* with fruit trees such as *Malus domestica, Pyrus communis* and *Juglans regia,* and grasses viz., *Chrysopogon montanus, Heteropogon contortus, Themeda anathera, Apluda mutica, Pennisetum orientale, Arundinella nepalensis, Agrostis spp, Sorghum bicolor, Setaria spp, Bromus inermis, Andropogon nardus, Chloris spp, Ischaemum aristatum* and *Cynodon dactylon.* In zone-IV, forest trees present were *Salix alba, Cedrus deodara, Populus ciliata, Ulmus wallichiana, Celtis australis, Populus ciliata, Aesculus indica, Crataegus songarica* and *Pinus gerardiana* and fruit trees were *Malus domestica, Pyrus communis, Corylus jacquemontii* and *Juglans regia.* Grasses present in zone-IV were *Setaria spp, Saccharum spontanum, Pennisetum orientale, Bromus inermis, Arundinella nepalensis, Poa annua, Dactylis glomerata, Arundo donex, Chrysopogon spp, Digitaria spp, Agrostis spp* and *Piptathrum spp.* Similar pasture-based systems prevalent along altitudinal gradient in Himachal Pradesh were also reported (Kumari *et al.* 2008; Chisanga *et al.* 2013; Gupta *et al.* 2017; Singh *et al.* 2019; Sharma *et al.* 2021). The composition of the systems varies from place to place owing to the ecological conditions, economic considerations, edaphic factors, topographical features, needs and preferences of the farming communities.

Biological productivity of the pasture based systems

The results revealed that aboveground biomass was maximum under silvo-pasture system (38.18 Mg ha^{-1}), while, minimum (27.78 Mg ha^{-1}) under pastoral-silviculture system. The above ground biomass under horti-pastoral system was recorded equal to 31.83 Mg ha^{-1} (Table 1). The increased aboveground biomass under silvo-pasture system may be ascribed to the higher tree density, presence of mature trees, tree component contributing more towards biomass production as well as management practices (Gupta et al. 2017; Singh et al. 2019). The aboveground biomass was generally found to have increased along altitude as is evident from the data in table 1 similar to the findings of Gupta *et al.* (2017). Compositional differences, nature of the species, farmer preferences, needs as well as ecological conditions may be the possible causes for biomass variation with altitude. Among interaction maximum (38.40 Mg ha^{-1}) aboveground biomass was recorded for silvo-pasture system in zone-I, while, minimum (19.79 Mg ha^{-1}) for pastoral-silviculture in zone-I.

Table 1: Aboveground biomass (Mg ha^{-1}) under pasture based systems along altitudinal gradient

Agroforestry System (AFS)	Altitudinal Zone (Z) Aboveground biomass				Mean	Altitudinal Zone (Z) Belowground biomass				Mean
	Zone I	Zone II	Zone III	Zone IV		Zone I	Zone II	Zone III	Zone IV	
Silvo-pasture	38.40	37.97	-	-	**38.18^{a}**	9.88	9.73	-	-	**9.80^{a}**
Pastoral-silviculture	19.79	24.26	34.72	32.36	**27.78^{b}**	5.11	5.81	8.52	8.30	**6.93^{b}**
Horti-pastoral	-	-	27.77	35.89	**31.83^{c}**	-	-	6.95	9.14	**8.04^{c}**
Mean	**29.09^{a}**	**31.12^{a}**	**31.24^{a}**	**34.12^{b}**		**7.49^{a}**	**7.77^{a}**	**7.73^{a}**	**8.72^{b}**	
LSD	AFS×Z: 3.31					AFS×Z: 0.91				

For each parameter mean values in respective row and column followed by different alphabet are statistically different at p<0.05

Belowground biomass also followed the trend similar to aboveground biomass with maximum belowground biomass for silvo-pasture system (9.80 Mg ha^{-1}) followed by horti-pastoral system (8.04 Mg ha^{-1}) and pastoral-silviculture system (6.93 Mg ha^{-1}) as is evident from table 1. Dominance of tree component and improved soil properties may be the factor for increased belowground biomass in silvo-pasture and horti-pastoral system. Belowground biomass along with the altitudinal zone followed the order zone I< zone III< zone II< zone IV. Total biomass production (aggregation of aboveground and belowground biomass) under different pasture-based systems was found in order silvo-pasture (47.99 Mg ha^{-1})> horti-pastoral (39.87 Mg ha^{-1})> pastoral-silviculture (34.72 Mg ha^{-1}). Rajput *et al.* (2017) also reported higher biomass production under silvo-pasture system as compared to other agroforestry systems attributed to age of trees, nature of trees, tree density and biomass production was reported to have increased along altitude which may be attributed to the less biotic interference and inaccessibility of the landscapes. Interaction results, between agroforestry system and altitudinal zone, revealed maximum (9.88 Mg ha^{-1}) belowground biomass under silvo-pasture in zone-I and minimum (5.11 Mg ha^{-1}) under pastoral-silviculture in zone-I.

Table 2: Carbon sequestration potential (Mg ha^{-1}) of pasture based systems along altitudinal gradient

Agroforestry System (AFS)	Altitudinal Zone (Z)				Mean
	Zone I	Zone II	Zone III	Zone IV	
Silvo-pasture	88.60	87.53	-	-	**88.06^{a}**
Pastoral-silviculture	45.68	55.18	79.35	74.62	**63.71^{b}**
Horti-pastoral	-	-	63.70	82.62	**73.16^{c}**
Mean	**67.14^{a}**	**71.36^{a}**	**71.53^{a}**	**78.62^{b}**	
LSD	AFS×Z: 7.73				

Mean values in respective row and column followed by different alphabet are statistically different at p<0.05

Among all the systems silvo-pasture system was found to have highest vegetation carbon sequestration potential (88.06 Mg ha^{-1}) as depicted in table 2. Carbon sequestration potential was found to have increased with increase in altitude ranging between from 67.14 to 78.62 Mg ha^{-1}. Among interaction, maximum (88.60 Mg ha^{-1}) carbon sequestration was recorded under silvo-pasture system in zone-I, while, minimum (45.68 Mg ha^{-1}) under pastoral-silviculture in zone-I. Similar findings were reported by Rajput *et al.* (2017) and attributed to structural and functional composition, age, density and management. Land use systems comprised of perennial component result in continuous accumulation of the biomass carbon as compared to system comprised of annual component which results in higher biomass production but their continuous removal results into lower sequestration of the carbon. Horticulture based system also have higher carbon sequestration potential because they are intensively managed resulting in greater accumulation of the biomass carbon with low removal in the form of pruned material and harvested fruits.

Conclusion

Silvo-pasture, pastoral-silviculture and horti-pastoral were the prominent pasture-based system in the area with silvo-pasture system having highest carbon sequestration potential. Further, horti-pasture system seems productive as well as protective system from economic point of view and carbon stock potential.

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