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Biomass productivity of different horticulture based agroforestry systems in North-Western Himalayas

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Abstract
The study was carried out to know about the biomass productivity of different horticulture based agroforestry systems in five altitudinal zones of North-Western Himalayas. Above ground, below ground as well as total biomass productivity of each zone with respect to the farmer's category was calculated and also the data related to the crops in different agroforestry systems types was also recorded accordingly. The result showed that the medium farmer's category is having high biomass production as compared to other farmer's category which may be due to better management practices.

Keywords: Biomass productivity, agroforestry systems, North-Western Himalayas

Introduction

Agroforestry is a land use system that integrates trees, crops and animals in a way that is scientifically sound, ecologically desirable, practically feasible and socially acceptable to the farmers (Nair, 1979) [14]. Agroforestry has established itself as one of the most promising land management system, helping in the expeditious enhancement of productivity per unit area, on sustainable basis and has high potential for simultaneously satisfying three important objectives, *viz*., protecting and stabilizing the ecosystems, producing a high level of output of economic goods, improving income and basic materials to rural population (Rao *et al*., 2018) [13]. Agroforestry systems have the potential to combine agricultural production, the supply of woody biomass and the provision of numerous environmental services such as carbon storage, conservation of biodiversity and soil protection. Above ground woody biomass plays a decisive role in considering the economic value of the agroforestry as well as the carbon storage. Numerous agroforestry systems both natural as well as manmade have been developed in different agro-climatic regions of the country, which have been found highly productive and ecofriendly. In fact the agroforestry momentum is getting a good response in India. Most agroforestry system aim to increase the production and productivity of farming systems, reduce the agricultural inputs and thus production costs, diversify production by the use of trees or other woody perennials to produce food, fodder, lumber, building materials and fuel wood etc. An increase in production, productivity and product diversity through agroforestry can help to improve the health and nutrition of the rural poor. A characteristic feature of mountains is their vertical zonation and their differences in environment variables along the elevations gradients the contribute to altering biological diversity of mountains along elevation, which offer enough options for geophysical and biological research, conservations and ecosystem services (Becker *et al*., 2007) [11]. North western Himalaya is basically an agroecosystem, where 90 per cent of its total population lives in villages, whose economy is dependent on agriculture, horticulture and animal husbandry (Atul *et al*., 1994) [12]. The incorporation of tree or shrubs on farms or pastures can increase the amount of biomass compared to the monoculture field of crop plants or pasture. In addition to above ground biomass, agroforestry systems can also store below ground biomass.

Materials and Methods

Study Area: The study was carried out in 20 panchayats of Shimla district of Himachal Pradesh that lies between 30°45" to 31°40" N latitude and 77 °0" to 78 °19" E longitude. The altitude of the district ranges between 300-6000 m amsl. The climate of the district varies from sub-tropical in low hills and valleys to sub-humid in the mid hills and temperate in high hills. Precipitation is in the form of rainfall (average annual 1000 mm), snowfall (in upper ridges) and hailstorm in some pockets of the study area. Average minimum and maximum temperature of the district lies between -4 °C to 31 °C, respectively.

Biological yield of agriculture crops: The biomass production in cultivated land was determined by taking random samples of Kharif and Rabi crops on the farmer's field by making a quadrates of size 1m x 1m. Total harvest method was carried out by digging out the crop plant along with the root falling within the quadrate. The soil was gently removed by tapping. Roots and shoot of crops were segregated and stored in different paper bags. All crop samples were washed to remove the soil and oven dried The biomass production in cultivated land was determined by taking random samples of Kharif and Rabi crops on the farmer's field by making a quadrates of size 1m x 1m. Total harvest method was carried out by digging out the crop plant along with the root falling within the quadrate. The soil was gently removed by tapping. Roots and shoot of crops were segregated and stored in different paper bags. All crop samples were washed to remove the soil and oven dried at 70 °C till a constant weight was achieved. The dried samples of root and shoot of each crop species were weighed to determine above ground and below ground biomass of each species.

Biological yield of trees: The estimation of above ground tree biomass was done by non-destructive method using local volume equation developed by (FSI, 1996). For the biomass study, the trees falling in the plot (30×10 m^2) were enumerated. The diameter at breast height (dbh) was measured with the help of tree calliper and height was measured with Ravi's multimeter (Chaturvedi and Khanna, 2013) [8]. The above ground biomass was calculated by multiplying stem wood volume with wood density and biomass expansion factor (BEF). Total above ground biomass of trees was calculated by using the formula given by (Deb *et. al.*, 2015) [9].

Total above ground biomass=Stem wood volume ×Wood Density ×BEF

Below ground Trees Biomass: Belowground biomass of a particular tree species was calculated by multiplying its above ground biomass with the root-shoot ratio. In unavailability of the root-shoot ratio, simple default value of 25 per cent (for hard wood species) and 21 per cent (for soft wood species) to the total above ground biomass recommended by (IPCC, 2006) [7] was considered. The sum of aboveground and belowground biomass was taken as total biomass of tree.

Below ground biomass = Above ground biomass × Root: Shoot

Results and Discussion

It is clear from the Table 1, that highest above ground, below ground as well as total biomass was observed in AH under marginal farmer's category whereas, lowest above ground, below ground as well as total biomass was observed in PHS under small farmer's category. The results are in conformity with Nair *et al*., 2009 [6].

Table 1: Above ground, below ground and total biomass production (t/ha) in identified AFS in Altitudinal Zone-I

AFS	AGB			BGB			TB		
	Marginal	Small	Medium	Marginal	Small	Medium	Marginal	Small	Medium
AH	16.07	13.43	10.69	4.87	3.53	3.77	20.94	16.96	14.45
PHS	-	6.26	8.05	-	1.76	2.48	-	8.02	10.53

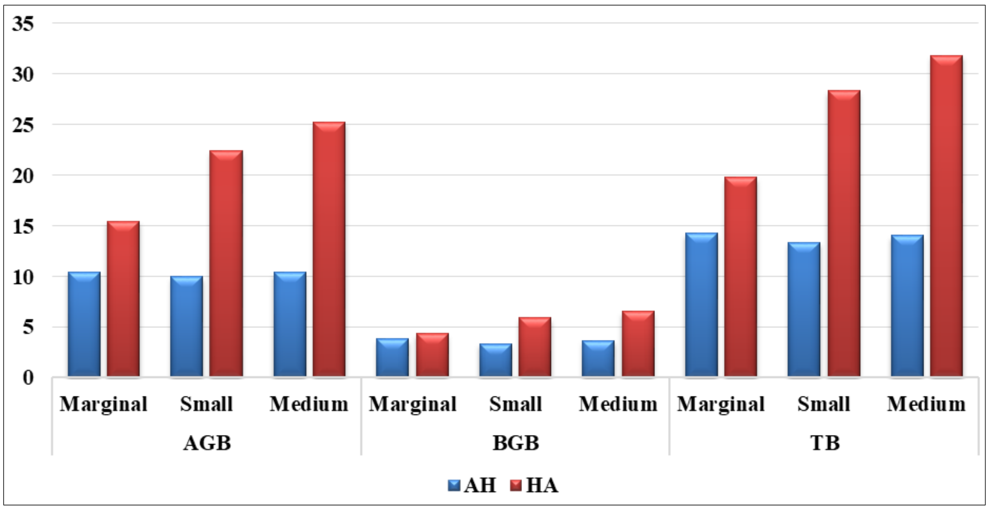

Fig 1

Table 2: Above ground, below ground and total biomass production (t/ha) in identified AFS in Altitudinal Zone-II

AFS	AGB			BGB			TB		
	Marginal	Small	Medium	Marginal	Small	Medium	Marginal	Small	Medium
AH	10.15	9.61	9.68	3.09	2.68	3.22	13.24	12.29	12.90
PHS	-	-	3.15	-	-	1.09	-	-	4.23

Table 2, indicated that highest above ground biomass as well as total biomass was observed in AH under marginal farmer's category whereas, lowest was observed in PHS under medium farmer's category. However, below ground biomass was found to be highest in AH under medium farmer's category and lowest was observed in PHS under same farmer's category. These results are in conformity with the findings of Minj, 2008.

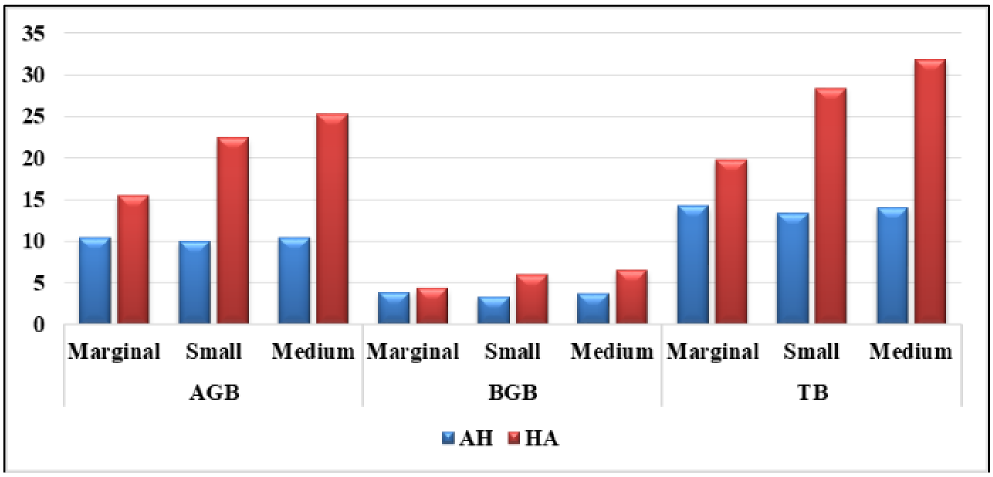

Fig 2

Table 3: Above ground, below ground and total biomass production (t/ha) in identified AFS in Altitudinal Zone-III

AFS	AGB			BGB			TB		
	Marginal	Small	Medium	Marginal	Small	Medium	Marginal	Small	Medium
AH	11.64	10.69	9.58	3.69	3.44	3.25	15.32	14.13	12.83
HA	14.17	15.30	15.27	7.10	4.11	3.99	21.27	19.41	19.26
PHS	4.30	-	3.52	1.74	-	1.16	6.04	-	4.68
HP	-	13.77	18.94	-	3.61	4.78	-	17.38	23.72

Perusal to the data presented in Table 3, it is clear that highest above ground biomass was observed in HP under medium farmer's category and lowest was observed in PHS under same farmer's category. However, below ground biomass was found to be maximum in HA under marginal farmer's category and lowest was observed in PHS under medium farmer's category. The total biomass was observed highest in HP under medium farmer's category and lowest was observed in PHS under same farmer's category. Same findings were observed by (Albercht and Kandji, 2003; Luedeling *et al.*, 2011).

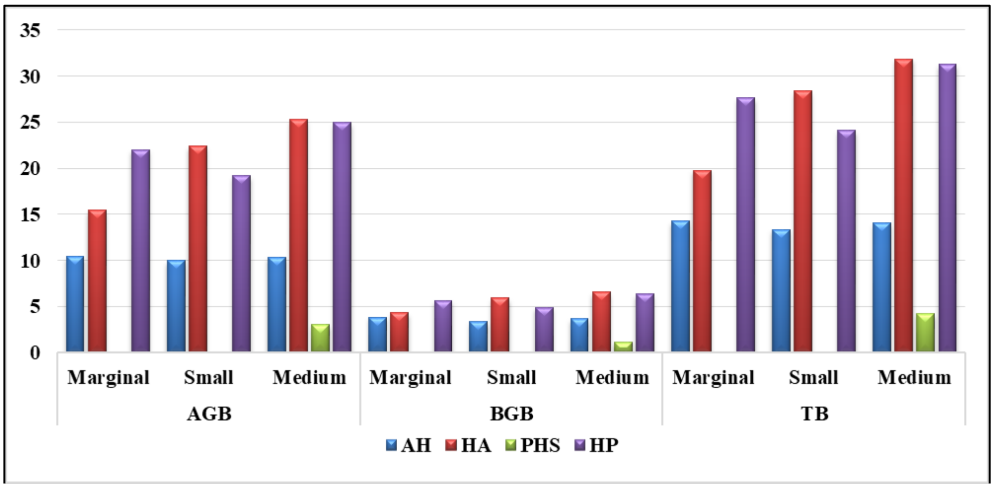

Fig 3

Table 4: Above ground, below ground and total biomass production (t/ha) in identified AFS in Altitudinal Zone-IV

AFS	AGB			BGB			TB		
	Marginal	Small	Medium	Marginal	Small	Medium	Marginal	Small	Medium
AH	12.76	10.71	10.91	4.40	3.60	3.74	17.16	14.30	14.65
HA	17.23	22.83	26.42	4.72	6.01	6.84	21.95	28.84	33.26
PHS	-	-	3.19	-	-	1.11	-	-	4.30
HP	22.51	19.86	21.23	5.76	5.12	5.39	28.27	24.98	26.62

Table 4, indicated that highest above ground biomass was observed in HA under medium farmer's category and lowest was observed in PHS under same farmer's category. However, below ground as well as total biomass was observed highest in HA under medium farmer's category and lowest was observed in PHS under same farmer's category. These values are much closer to the findings of Sharma *et al.* (2008).

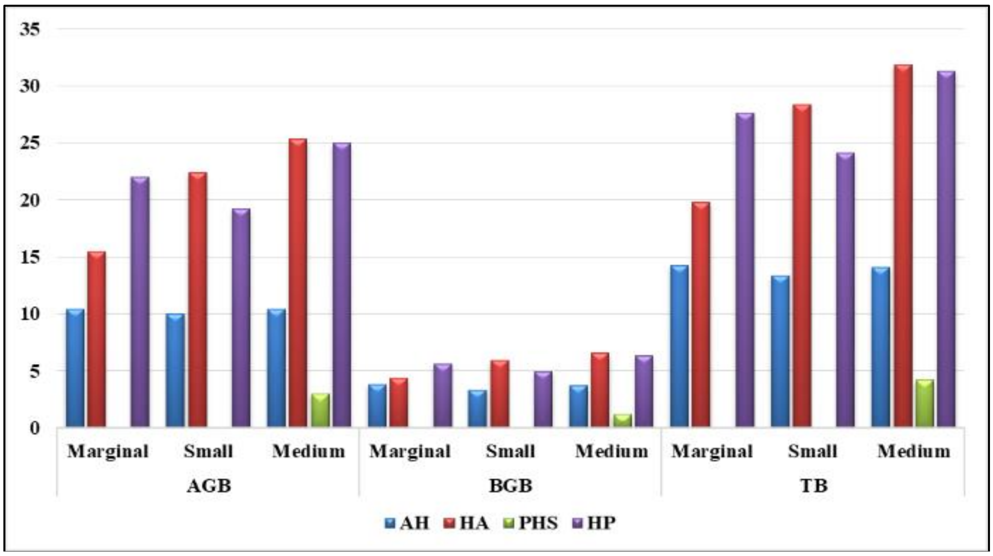

Fig 4

Table 5: Above ground, below ground and total biomass production (t/ha) in identified AFS in Altitudinal Zone-V

AFS	AGB			BGB			TB		
	Marginal	Small	Medium	Marginal	Small	Medium	Marginal	Small	Medium
AH	10.43	10.00	10.38	3.84	3.35	3.69	14.27	13.35	14.07
HA	15.45	22.42	25.29	4.34	5.94	6.56	19.79	28.36	31.85
PHS	-	-	3.01	-	-	1.18	-	-	4.19
HP	22.01	19.19	24.97	5.63	4.93	6.33	27.64	24.11	31.30

It is clear from the table that highest above ground, below ground as well as total biomass was observed in HA under medium farmer's category and lowest was observed in PHS under same farmer's category. The results of the present study are supported by the findings of Rajput *et al.* (2017) [2].

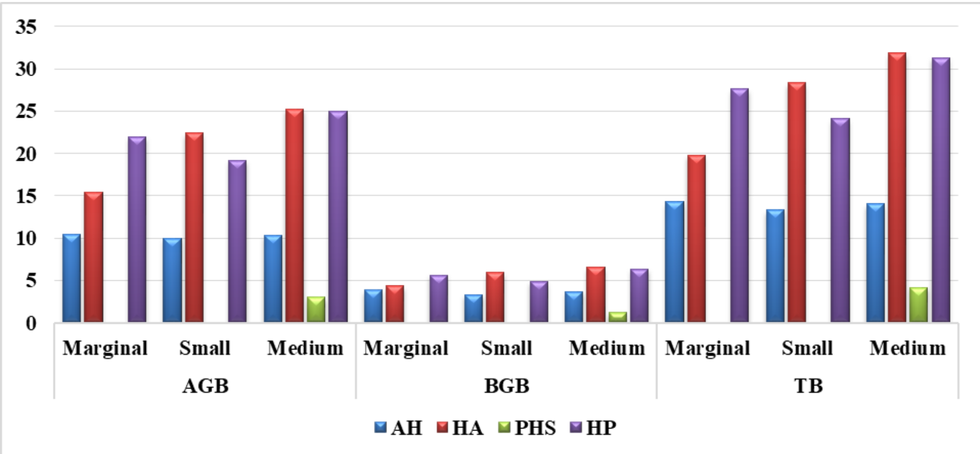

Fig 5

Conclusion: From present studies it can be concluded that in altitudinal zone-I, AH system was found to be best for above ground, below ground as well as total biomass production under marginal farmer's category. In zone-II, above ground and total biomass was recorded highest in AH system under marginal farmer's category and below ground biomass was recorded highest in same agroforestry system under medium farmer's category. In zone-III, both above ground and total biomass production was highest in HP under medium farmer's category and in case of below ground biomass it was found to be produced maximum in HA under marginal farmer's category. In zone-IV as well as in zone-V, above ground, below ground and total biomass production was recorded highest in HA under medium farmer's category.

Table 6: Crop composition in altitudinal Zone-I

AFS type	Annual crops	Tree species
AH	Maize, Colocasia, Sesame, Turmeric, Chilli, Wheat, Barley, Potato, Onion, Mustard	*Mangifera indica, Psidium guajava, Citrus limon*
PHS	-	*Psidium guajava, Leucaena leucocephala, Mangifera indica, Citrus aurantifolia, Punica granatum Grewia optiva, Morus alba Citrus limon, Toona ciliate*

Table 7: Crop composition in altitudinal Zone-II

AFS type	Annual crops	Tree species
AH	Maize, Colocasia French Bean Cabbage, Wheat, Barley, Tomato, Garlic	*Juglans regia, Prunus persica, Prunus domestica, Citrus limon*
PHS	-	*Bauhinia variegata, Quercus glauca, Ficus palmata,, Prunus persica, Prunus domestica, Citrus pseudolimon, Malus domestica, Prunus armeniaca, Pyrus communis*

Table 8: Crop composition in altitudinal Zone-III

AFS type	Annual crops	Tree species
AH	Colocasia, Maize, Cabbage, Kidney Bean, Barley, Pea, Potato	*Malus domestica, Pyrus communis, Prunus armeniaca, Prunus domestica, Prunus persica*
PHS	-	*Malus domestica, Pyrus communis, Prunus armeniaca, Prunus domestica, Quercus leucotrichophora, Pinus wallichiana, Ficus palmata, Salix alba*
HA	French Bean, Kidney Bean, Colocasia, Barley, Pea, Potato	*Malus domestica, Pyrus communis, Prunus armeniaca, Prunus domestica, Prunus persica, Juglans regia*
HP	-	*Malus domestica, Pyrus communis, Prunus armeniaca, Prunus domestica, Prunus persica*

Table 9: Crop composition in altitudinal Zone-IV

AFS type	Annual crops	Tree species
AH	Colocasia, Maize, Cabbage, Kidney Bean, French Bean, Barley, Pea, Coriander	*Malus domestica, Pyrus communis, Prunus armeniaca, Prunus domestica, Prunus persica*
PHS	-	*Malus domestica, Pyrus communis, Prunus armeniaca, Prunus domestica, Quercus dilatata, Cedrus deodara, Salix alba Rhododendron arboretum*
HA	French Bean, Maize, Kidney Bean, Colocasia, Barley, Pea, Potato, Corinader	*Malus domestica, Pyrus communis, Prunus armeniaca, Prunus domestica, Juglans regia*
HP	-	*Malus domestica, Pyrus communis, Prunus armeniaca, Prunus domestica,*

Table 10: Crop composition in altitudinal Zone-V

AFS type	Annual crops	Tree species
AH	Colocasia, Maize, Kidney Bean, French Bean, Barley, Pea, Potato, Coriander	*Malus domestica, Pyrus communis, Prunus armeniaca, Prunus domestica*
PHS	-	*Malus domestica, Pyrus communis, Prunus armeniaca, Prunus domestica, Quercus semicarpifolia, Cedrus deodara, Salix alba Picea smithiana, Abies pindrow*
HA	Colocasia, Maize, Kidney Bean, French Bean, Barley, Pea, Potato, Coriander	*Malus domestica, Pyrus communis, Prunus armeniaca, Prunus domestica, Prunus persica*
HP	-	*Malus domestica, Pyrus communis, Prunus persica, Prunus domestica, Prunus armeniaca*

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