Bulletin of Environment, Pharmacology and Life Sciences
Bull. Env. Pharmacol. Life Sci., Vol 8 [Suppl.1] November 2019 : S26-S31

Online ISSN 2277-1808
Journal's URL:http://www.bepls.com
CODEN: BEPLAD
Global Impact Factor 0.876
Universal Impact Factor 0.9804
NAAS Rating 4.95

ORIGINAL ARTICLE **OPEN ACCESS**

Carbon Stock and Sequestration Potential of Different Sized Agroecosystems in Kumaun Himalaya

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ABSTRACT

The present study was conducted within agroecosystems of Kumaun Himalaya in Uttarakhand state to assess the vegetation -´48.02˝E Longitudinal gradient. On the basis of land holding sizes the agroecosystems were divided into three size classes viz. small (0.1- 0.26 ha), medium (0.16- 0.3 ha) and large (0.2- 0.4 ha). E. coracana, P. sativum, S. tuberosum, Brassica spp., T. aestivum and Z. mays were the main cultivated crops whereas J. regia, M. domestica, P. persica and P. domestica were the main tree components in these agroecosystems. Highest herb layer carbon stock was reported during rainy season (5920.47 g m^{-2}) followed by summer (5691.64 g m^{-2}) and winter season (381.32 g m^{-2}) while among agroecosystems sizes the pattern depicted as medium> small> large, which showed that the medium and small sized agroecosystems were more beneficial in terms of carbon storage potential. The tree layer carbon stock was highest in large sized agroecosystems (59.45 t ha^{-1}) and it was largely contributed by bole, branch and root components of tree. Carbon sequestration potential of trees showed the trend as small (1.51 t C ha^{-1} yr^{-1})> medium (0.92 t C ha^{-1} yr^{-1})> large (0.69 t C ha^{-1} yr^{-1}). Present study revealed that the young aged trees in small sized agroecosystems supported high carbon sequestration than the larger sized agroecosystems with old aged trees. In terms of carbon storage and sequestration potential the smaller sizes of agroecosystems are easier to manage than larger one, thus beneficial in a long run for Himalayan Community.

Keywords: *Himalayan agroecosystems, size variations, carbon stock and sequestration potential*

Received 21.09.2019 Revised 20.10.2019 Accepted 11.11.2019

INTRODUCTION

Agroecosystems are simply defined as an artificial ecosystem or an altered natural ecosystems managed by human to produce food, feed and raw material for the sustenance of human life. These are the ecosystems in which humans have deliberately magnetized selective crops and livestock composition replacing to the natural flora and fauna of the site up to an extent [1]. In the Himalayan region village acts as an ecosystem, function as an independent unit of economic activity and is comprised of agroecosystem, livestock, forest ecosystem and market support. The agroecosystem is largely dependent on the other systems of the village and has forward and backward linkages with livestock, forest and the market [2, 3]. Traditional crop–livestock mixed farming is the basis of livelihood of local communities and backbone of rural economy [4, 5]. Being different from other natural ecosystems, agroecosystems are typical economic-natural-social composite human-centered ecosystems and are always under anthropogenic disturbance and management. Removal of carbon (C) from atmosphere and storing it in the terrestrial vegetation is one of climate change mitigation options, which compensate the greenhouse gas (GHG) emission. Agricultural lands are a major sink of carbon and could absorb large quantities of C if trees are included with crops and judiciously managed together [6, 7]. It is well proven that agricultural and forestry practices can partially mitigate increasing CO_2 concentration by sequestering carbon. Similarly, alternative agricultural practices, where biomass crops are cultivated can impact CO_2 levels not only by sequestering C, but also by replacing fossil fuel with the biomass produced [8]. In this regard the present study was conducted within agroecosystems of Kumaun Himalaya to assess the carbon stock and sequestration potential of herb and tree layer biomass in different sized agroecosystems.

MATERIAL AND METHODS

The study area was located within the altitudinal range of 2000-2200 m above mean sea level and at a latitude 29º23´39.31˝N and longitude 79º39´48.02˝E. The climate in the study area can be divided in to three seasons summer (March to June), rainy season (Half June to October) and winter (November to February). The main climatic seasons are severe cold in winter, feasible climatic conditions in summer, and heavy downpour in the rainy season. This site was rainfed and relies on natural springs and the farms were relatively smaller in size and located at steeply slopes. Wheat, maize, finger millet and various cash crops like potato, cabbage, cauliflower and pea were dominating crops while apple, pear and peach tree species were common in this study area.

Carbon stock for trees and herbs was calculated following Magnussen and Reed [9] as:

$$C = B \times 0.475$$

Where, C is the carbon stock and B is oven dry biomass. The estimation of biomass was carried out by using the volumetric and allometric equations already developed for some trees and interspecies. Biomass of the crop or herbs was estimated by using 1×1 m^2 quadrates. Crop in the quadrats were uprooted from the ground during peak biomass and weighed. Herb samples were taken to laboratory and were oven dried at 80°C to a constant temperature. Dry weight was measured using electronic pan balance.

RESULTS AND DISCUSSION

Rainy season

The total carbon stocked by herb layer in the small sized AGEs was 6371.15 gm^{-2}, of which 50.37 % was contributed by aboveground parts and 49.63 % was contributed by belowground parts. Among all the species, maximum carbon stock was recorded for *Solanum tuberosum* (3255.05 g m^{-2}) whereas; minimum carbon stock was reported for *Galinsoga parviflora* (1.95 g m^{-2}).In the medium sized AGEs, the total carbon stock of herbs was 5594.52 g m^{-2},which was the sum total of aboveground (2346.54 g m^{-2}) and belowground parts(3247.98 g m^{-2}). In this systems *S. tuberosum* contributed maximum carbon stock3412.90 g m^{-2} and minimum carbon stock was contributed by *F. vesca* (0.59 g m^{-2}).The total carbon stock in the herb layer was 5795.75 g m^{-2} in the large sized AGEs**,** of which aboveground parts shared 47.76 % whereas 52.24 % was shared by belowground parts. Among these AGEs the *S. tuberosum* (3191.99 g m^{-2}) was depicted maximum and *Anagallis arvensis* (1.69 g m^{-2}) was recorded with minimum carbon stock (Table 1).

Table 1. Carbon stock (g m^{-2}) for herbaceous vegetation (Cultivated and Wild) in different sized agroecosystems

Herb species	Rainy			Winter			Summer			Mean
	AG	BG	TCS	AG	BG	TCS	AG	BG	TCS	
Small sized AGE										
Cultivated										
*Brassica oleracea var. capitata*L.	1434.98	22.98	1457.95	-	-	-	1121.95	14.17	1136.12	864.69
Eleusine coracana(L.) Gaertn.	167.97	32.58	200.55	-	-	-	-	-	-	66.85
*Phaseolous lunatus*L.	8.91	0.8	9.71	-	-	-	-	-	-	3.24
*Pisum sativum*L.	-	-	-	-	-	-	536.48	3.3	539.78	179.93
*Solanum tuberosum*L.	303.08	2951.97	3255.05	-	-	-	407.69	2832.08	3239.77	2164.94
*Triticum aestivum*L.	-	-	-	332.75	62.97	395.72	-	-	-	131.91
*Zea mays*L.	1288.68	151	1439.68	-	-	-	782.33	210.24	992.56	810.75
Wild										
*Anagallis arvensis*L.	2.15	1.08	3.23	-	-	-	-	-	-	1.08
*Galinsoga parviflora*Cav.	1.3	0.64	1.95	-	-	-	7.89	4.33	12.22	4.72
*Oxalis corniculata*L.	-	-	-	-	-	-	0.67	0.02	0.69	0.23
*Stellaria media*L.	-	-	-	-	-	-	8.71	0.89	9.6	3.2
*Urtica dioca*L.	1.78	1.26	3.03	-	-	-	-	-	-	1.01
Total	**3208.85**	**3162.31**	**6371.15**	**332.75**	**62.97**	**395.72**	**2865.72**	**3065.03**	**5930.74**	**4232.55**
Medium sized AGE										
Cultivated										
Amaranthus caudatus L.	1.11	0.59	1.7	-	-	-	-	-	-	0.57
*Brassica oleracea var. capitata*L.	1522.8	9.93	1532.73	-	-	-	1335.7	11.92	1347.62	960.12
Eleusin coracana(L.) Gaertn.	-	-	-	-	-	-	138.07	19.05	157.13	52.38
*Phaseolous lunatus*L.	31.25	1.49	32.74	-	-	-				10.91

*Pisum sativum*L.				-	-	-	410.97	4.24	415.2	138.4
*Solanum tuberosum*L.	310.96	3101.94	3412.9	-	-	-	428.29	3272.75	3701.04	2371.31
*Tagetus erecta*L.	9.65	2.52	12.16	-	-	-	-	--	-	4.05
*Triticum aestivum*L.	-	-	-	334.88	62.3	397.18	-	-	-	132.39
*Zea mays*L.	451.25	127.21	578.46	-	-	-	798	266	1064	547.49
Wild										
*Anagallis arvensis*L.	1.37	0.12	1.48	-	-	-	-	-	-	0.49
*Cannabis sativa*L.	12.73	2.05	14.78	-	-	-	-	-	-	4.93
Cynodon dactyon(L.) Pers.	1.57	0.35	1.93	-	-	-	-	-	-	0.64
*Fragaria vesca*L.	0.49	0.1	0.59	-	-	-	-	-	-	0.2
*Galinsoga parviflora*Cav.	2.5	0.32	2.82	-	-	-	6.96	0.61	7.57	3.46
*Oxalis corniculata*L.	0.86	1.36	2.23	-	-	-	0.42	0.03	0.45	0.89
*Stellaria media*L.	-	-	-	-	-	-	12.83	1.05	13.88	4.63
Total	**2346.54**	**3247.98**	**5594.52**	**334.88**	**62.3**	**397.18**	**3131.24**	**3575.65**	**6706.89**	**4232.86**
Large sized AGE										
Cultivated										
*Brassica oleracea var. capitata*L.	1283.45	11.47	1294.92	-	-	-	-	-	-	431.64
*Pisum sativum*L.	-	-	-	-	-	-	354.54	2.83	357.37	119.12
*Solanum tuberosum*L.	298.42	2893.57	3191.99	-	-	-	353.34	2593.5	2946.84	2046.28
*Tagetes erecta*L.	8.11	1.4	9.51	-	-	-	-	-	-	3.17
*Triticum aestivum*L.	-	-	-	292.83	58.24	351.07	-	-	-	117.02
*Zea mays*L.	1171.01	120.27	1291.28	-	-	-	896.09	217.88	1113.97	801.75
Wild										
*Amaranthus caudatus*L.	5.54	0.82	6.36	-	-	-	-	-	-	2.12
*Anagallis arvensis*L.	1.54	0.15	1.69	-	-	-	-	-	-	0.56
*Galinsoga parviflora*Cav.	-	-	-	-	-	-	8.12	0.47	8.59	2.86
*Oxalis corniculata*L.	-	-	-	-	-	-	0.37	0.04	0.4	0.13
*Stellaria media*L.	-	-	-	-	-	-	9.41	0.72	10.13	3.38
Total	**2768.07**	**3027.68**	**5795.75**	**292.83**	**58.24**	**351.07**	**1621.87**	**2815.44**	**4437.3**	**3528.03**

AG- aboveground carbon stock; BG- belowground carbon stock; TCS- total carbon stock

Winter season

In the small sized AGEs, the total carbon stock was recorded 395.72 g m^{-2} forsingle herb species (*Triticum aestivum*), of which 84.09 % was contributed by above ground parts and 15.91 % was contributed by belowground parts.Medium sized AGEs stored the total carbon stock as 397.18 g m^{-2} for single herb species (*T. aestivum*), of which 334.88 g m^{-2} was contributed by above ground parts and 62.3 g m^{-2} was contributed by belowground parts. The total carbon stock in the herb layer was 351.07 g m^{-2} in the large sized AGEs**,** of which aboveground parts shared 83.41 % whereas 16.59 % was shared by belowground parts (Table 1).

Summer season

During summers the small sized AGEs contained 5930.74 g C m^{-2} through theherb layer, of which 48.32 % was contributed by aboveground parts and 51.68 % was contributed by belowground parts. Among all the species, maximumcarbon stock was recorded for *Solanum tuberosum* (3239.77 g m^{-2}) whereas minimumcarbon stock was reported for *O. corniculata* (0.69 g m^{-2}).In the medium sized AGEs, the total carbon stock of herbs was 6706.89 g m^{-2} and in these systems *S. tuberosum* contributed maximum carbon stock 3701.04 g m^{-2} andminimum carbon stock was contributed by *O. corniculata* (0.45 g m^{-2}).The total carbon stock in the herb layer was 4437.3 g m^{-2} for the large sized AGEs**,** of which aboveground parts shared 1621.87 g m^{-2} whereas 2815.44 g m^{-2} was shared by belowground parts. Among these AGEs the *S. tuberosum* (2946.84 g m^{-2})was depicted maximum and *O. corniculata* (0.40 g m^{-2}) was recorded with minimum carbon stock (Table 1).

Herb layer carbon stock depicted significant relation with AGEs sizes as it slightly increased towards small sized AGEs while with seasons there was no significant pattern observed (Figure 1). Biomass transfer such as crop harvest, residuals remove, and application of dung, manure and other land management practices in AGEs at various intensities results in either build-up or depletion of SOC stock.

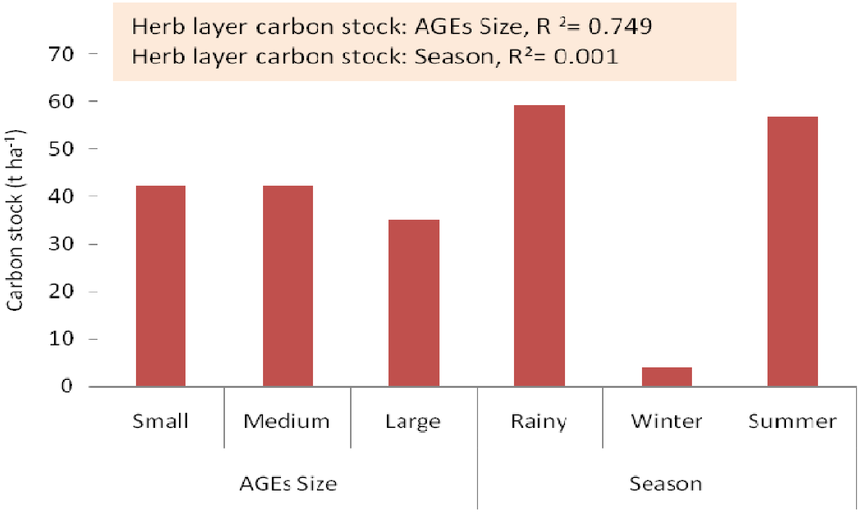

Figure 1. Herb layer carbon stock as affected by AGE sizes and seasons.

Tree layer Carbon stock and sequestration

Small sized AGEs were observed with 36.07 t C ha^{-1} through trees, of which 28.85 t C ha^{-1} was accumulated by aboveground parts and 7.21 t C ha^{-1} by belowground parts. In the medium sized AGEs, total estimated tree layer carbon stock was 15.55 t C ha^{-1}, which was the sum total of aboveground (12.44 t C ha^{-1}) and belowground parts (3.11 t C ha^{-1}). Large sized AGEs stored 59.45 t C ha^{-1} through trees which was contributed by aboveground parts (47.56 t C ha^{-1}) and belowground parts (11.89 t C ha^{-1}). *P. domestica* was the dominant tree species and contributed 57.31 t C ha^{-1} followed by *M. domestica* (2.15 t C ha^{-1}) (Table 2).A range of tree layer carbon storage capacity between 31.14 and189.77 t C ha-1 was reported by Parihaar [10] among different agroforestry systems in Kumaun Himalaya.

In the small sized AGEs tree species (*J. regia* and *M. domestica*) sequestered 1.52 t C ha^{-1} yr^{-1}. In the medium sized AGEs carbon sequestration rate was 0.93 t C ha^{-1} yr^{-1}, of which the aboveground parts shared 0.74 t C ha^{-1} yr^{-1} and 0.19 t C ha^{-1} yr^{-1} was shared by the belowground parts. The carbon sequestration was 0.69 t C ha^{-1} yr^{-1} in large sized AGEs (Figure 1). The incorporation of trees or shrubs on farms or pastures can increase the amount of C sequestered compared to a monoculture field of crop or pasture [11, 12, 13].The flora and plant composition are among one of the important factors affecting SOC stock of an area [14]. Present study revealed that the AGE sizes significant affected the carbon sequestration potential (Figure 2) of trees (R^2= 0.939) and the pattern was reported as small(1.51 t C ha^{-1} yr^{-1}) >medium (0.92 t C ha^{-1} yr^{-1}) >large (0.69 t C ha^{-1} yr^{-1}). Six et al.,[15]and Dhyani et al.[16] have stated that the carbon sequestration potential of trees varies with species composition, canopy structure and age of plant.

Table 2. Component wise carbon stock (t C ha^{-1}) of tree layer vegetation in different sized agroecosystems

Tree species	Bole	Branches	Twigs	Foliage	R. Parts	TAG	TBG	TCS
Small sized AGE								
Juglans regia	21.03	2.73	1.15	0.33	-	28.04	7.01	35.04
Malus domestica	0.54	-	-	0.28	-	0.82	0.20	1.02
Total	**21.57**	**2.73**	**1.15**	**0.61**	**-**	**28.85**	**7.21**	**36.07**
Medium sized AGE								
Malus domestica	1.41	-	-	0.65	-	2.06	0.51	2.57
Prunus persica	5.05	2.90	1.61	0.82	-	10.39	2.60	12.98
Total	**6.46**	**2.90**	**1.61**	**1.46**	**-**	**12.44**	**3.11**	**15.55**
Large sized AGE								
Malus domestica	1.29	-	-	0.43	-	1.72	0.43	2.15
Prunus domestica	22.46	19.08	2.03	0.91	1.36	45.85	11.46	57.31
Total	**23.75**	**19.08**	**2.03**	**1.34**	**1.36**	**47.56**	**11.89**	**59.45**

R. Parts= reproductive parts; TAG= total aboveground; TBG= total belowground; TCS= total carbon stock

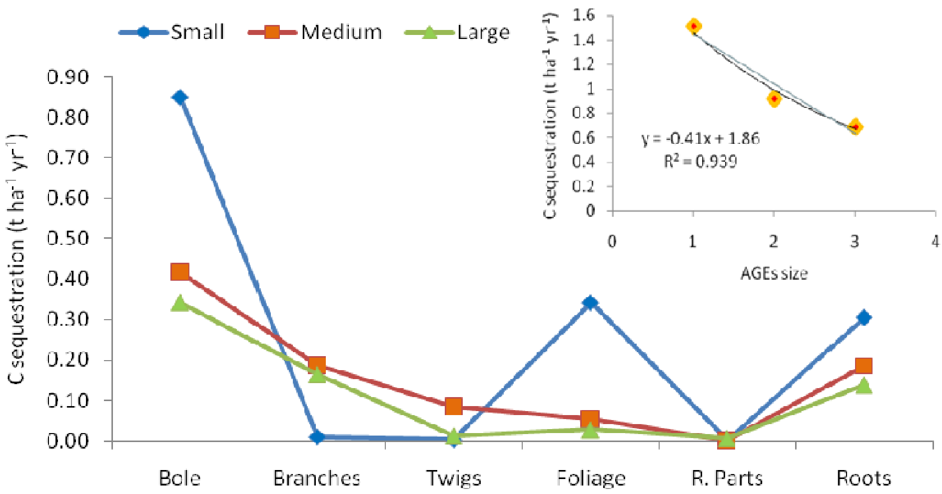

Figure 2. Carbon sequestration (t ha^{-1} yr^{-1}) by tree layer in different sized agroecosystems

CONCLUSION

The results of present study clearly showed that the small and medium sized AGEs stocked more herb layer carbon than the larger one. Similarly the tree layer carbon sequestration depicted the significant decrement towards large sized AGEs. Thus the results revealed that the small sized AGEs have the potential to fulfil the need and essential requirements of human being as well as its surrounding environment. Different land-use types, ecological and socio-economicfactors, and the management strategies significantly affect the carbon sequestration potential of Himalayan agroecosystems.

ACKNOLEDGEMENT

Authors are grateful to the villagers and local inhabitants for their support and cooperation during field study.

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CITATION OF THIS ARTICLE

C Shahi, S Singh Bargali and K Bargali. Carbon Stock and Sequestration Potential of Different Sized Agroecosystems in Kumaun Himalaya. Bull. Env. Pharmacol. Life Sci., Vol 8 [Suppl. 1] November 2019: S26-S31