SKUAST Journal of Research 25(4): 592-600; (2023)
(*DOI: 10.5958/2349-297X.2023.00070.3*); NASS rating: 4.17

Research Paper

Assessment of biomass and carbon stock of mung bean and garlic under apricot based agroforestry system in the temperate region of Northern Himalaya, India

Vaishnu Dutt*, Mohd. Tariq, K. N. Qaisar, J.A. Mugloo, S.A. Gangoo and Shiba Zahoor

Faculty of Forestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Benhama, Watlar, Ganderbal-191 202, Jammu and Kashmir, India
*e-mail: *vaishnudutt@gmail.com*

(Received July 1, 2023; accepted September 22, 2023)

ABSTRACT

Estimating carbon stocks in various land-use systems is essential for addressing the global climate catastrophe. The present study recognized the potential of the apricot-based agroforestry land use framework for biomass production and carbon stock assessment to alleviate the global climate change crisis. For conducting the experiment y, two intercrops, namely mung bean (Vigna radiata) and garlic (Allium sativum), were intercropped with an 11-year-old orchard of apricot. The maximum total biomass of mung bean (1667.44 kg ha^{-1}) was recorded under mung bean+ recommended doses of manure and fertilizers; 20 t FYM; 10 kg N; 40 kg P_2O_5, and 35 kg K_2O/ha, whereas the maximum biomass of garlic (2,472.23 kg ha^{-1}) was registered under garlic + recommended doses of manure and fertilizers; 20 t FYM, 50 kg N, and 62.5 Kg P_2O_5/ha The treatment, wild apricot + mung bean - garlic + recommended doses of manure and fertilizers for mung bean; 20 t FYM, 10 kg N: 40 Kg P P_2O_5 and 35 Kg K_2O/ha + recommended amounts of manure and fertilizers for garlic; 20 t FYM, 50 kg N, and 62.5 Kg P_2O_5/ha displayed the highest value of total tree biomass (59.22 t ha^{-1}). The treatment combination of wild apricot + mungbean – garlic + recommended doses of manure and fertilizers for mung bean; 20 t FYM, 10 kg N: 40 Kg P_2O_5 and 35 Kg K_2O/ha + recommended quantities of manure and fertilizers for garlic; 20 t FYM, 50 kg N, and 62.5 Kg P_2O_5/ha (74.58 t ha^{-1}) stored highest ecosystem carbon which is around 1.5 folds more elevated than the mono crop-based land-use system. The current study's findings could help to determine the best crop combinations for fruit-based land-use systems, estimation of biomass and carbon density of different ecosystem components, and above all, land use planning in other related Himalayan ecosystems.

Key words: Agroforestry, apricot, biomass, carbon, garlic, himalayas, mung bean

Agroforestry, as a traditional land use framework and resource management, has enormous potential to ensure livelihood security by providing ecosystem services such as food, fodder, fuelwood, fruit, timber, and a variety of other non-timber forest products, in addition to their ability to provide environmental services such as watershed protection, carbon sequestration, and relief from the adverse effects of climate change (Paustian *et al.*, 2016; Quli *et al.*, 2017). Appropriate policy responses that include agroecosystems as critical assets can help communities and households adapt to local and global change and create resilience (AFD *et al.*, 2003). Fruit-tree-based systems have high ubiquity among different agroforestry frameworks among resource-restricted producers around the world due to their high market value and nutritional necessities (Bellow, 2004).

One option for dealing with problems related to land use and CO_2 driven global warming is to introduce more tree-based land-use systems, such as agroforestry (Albrecht and Kandji, 2003). Agroforestry frameworks actively contribute to climate change mitigation by accumulating carbon in tree biomass, products, and soil and indirectly by reducing deforestation (Jose and Bardhan, 2012; Zomer *et al.*, 2016). According to the IPCC Report (2000), there are already 400 million hectares under agroforestry worldwide, with an estimated C gain of 0.72 Mg C ha yr^{-1} and the capacity to sequester 26 Tg C yr^{-1} by 2010 and 45 Tg C yr^{-1} by 2040. In India, the potential for agroforestry was estimated to be 25 tonnes of carbon per hectare over 96 million hectares (Sathaye and Ravindranath, 1998); however, there is significant fluctuation in different places depending on biomass output (Dhyani *et al*., 2009; Ram *et al*., 2013). The soil organic carbon (SOC) pool is the only terrestrial carbon (C) storage pool that may be purposely enhanced by agroforestry practices (Lorenz and Lal, 2014). Only freshly stored carbon through agroforestry practices is considered a carbon credit under the Kyoto Protocol to achieve its emission reduction objectives. However, there is a push to include soil carbon (Lal, 2004).

The people of Himalayan region rely on agroforestry land-use practices to provide for their fundamental requirements, especially during times of scarcity (Kala, 2010). Various agroforestry frameworks have evolved in the Himalayan region based on individual demands and site-specific distinctiveness at multiple locations (Yadav and Bisht, 2014). Growing more woody perennials in and around the fields and other agricultural landscapes of the Himalayan region can help preserve and protect biodiversity and improve livelihood prospects (Singh *et al*., 2017).

Due to its importance in climate change prevention and adaptation, agroforestry is garnering more attention in global efforts such as Reducing Emissions from Deforestation and Forest Degradation (REDD+) (Jose and Bardhan, 2012). Agri-horticulture (growing crops with fruit trees) is a unique and extraordinary land-use technique in the Himalayan region (Singh *et al*., 2017; Zahoor *et al*., 2021). Several authors (Banyal *et al*., 2016; Dar *et al*., 2018) have conducted studies on the different types of agroforestry systems in Kashmir and other parts of the Indian state of Jammu and Kashmir. The apricot-based agroforestry system was chosen because apricot fruits and kernels are valuable in the Kashmir region of Jammu and Kashmir (Union Territory), and a large majority of farmers like to cultivate apricot trees. The study will help determine the capability of an apricot-based agroforestry land-use system in terms of biomass and carbon and provide data to decision-makers, farmers, and other stakeholders for effective and successful carbon budgeting and climate change mitigation in the Kashmir Himalayan ecosystem's temperate region.

MATERIALS AND METHODS

Study area: The investigation region is situated in the Ganderbal district of Jammu and Kashmir, India, between 34°16′44′′N latitude and 74°46′31′′E longitude at an elevation of 1619 m above MSL. The experimental plots were laid in an apricot orchard at Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir's Faculty of Veterinary Sciences, Shuhama (J and K). Average rainfall of around 698 mm was witnessed during the crop duration. The minimum temperature ranged from -2.95°C to 13.4°C, and the maximum temperature from 21.7°C to 32.5°C (Meteorological data, 2017). Almost 70% of the district is uneven and semi-sloppy, surrounded by lush green trees with few areas which remain inaccessible for long periods during the winter.

Experimental setup and design: For conducting this study, in the Kharif season, eight treatments, viz., T_1 (wild apricot without manures), T_2 (wild apricot + Mung bean without manures), T_3 (wild apricot + Mung bean + 20 t FYM / ha), T_4 (wild apricot + Mung bean + 2 t Dalweed Manure/ha), T_5 (wild apricot + Mung bean + 2 t Vermicompost/ha), T_6 (wild apricot + Mung bean + 5g Biofertilizer (Rhizobium/kg seed), T_7 (wild apricot + Mung bean + Recommended doses of manure and fertilizers; 20 t FYM, 10 kg N: 40 Kg P_2O_5 and 35 Kg K_2O/ha) and T_8 (control Mung bean + Recommended doses of manure and fertilizers; 20 t FYM, 10 kg N: 40 Kg P_2O_5 and 35 Kg K_2O/ha) were selected in replicates of 3. During the rabi season, the following eight treatment combinations were chosen: T_1 (wild apricot without manures), T_2 (wild apricot + garlic without manures), T_3 (wild apricot + Garlic + 20 t FYM/ha), T_4 (wild apricot + garlic + 2 t Dalweed Manure/ha), T_5 (wild apricot + garlic + 2 t Vermicompost/ha), T_6 (wild apricot + Garlic +5g Biofertilizer (Azotobacter/kg seed), T_7 (wild apricot + garlic + Recommended doses of manure and fertilizers; 20 t FYM, 50 kg N, and 62.5 Kg P_2O_5/ha) and T_8 (control Garlic + Recommended quantities of manure and fertilizers; 20 t FYM, 50 kg N, and 62.5 Kg P_2O_5/ha). The RBD (factorial) design with 24 treatment combinations {8 (treatments) x 3 (replications)} was used to estimate total biomass and ecosystem carbon in the apricot-based agroforestry system.

Crop Biomass: At the harvesting stage, plants were uprooted from a 1m x 1m sized plots for each replication, and their various plant parts (roots and above ground) were separated. The plant samples were sun-dried for 4 to 5 days before being dried in the oven at 60°C. The plant sample weight was measured in grams and then converted to kg ha^{-1}. Rajput *et al*. (2015) proposed that biomass be multiplied by the IPCC default value factor of 0.5 to convert biomass to carbon.

For tree biomass estimation, twenty-four plots of size (4m x 4m) with four trees each were used. A measuring tape was used to determine the diameter and height of the collar. Stem biomass was calculated using the regression equation given by Brown *et al*. (1989), which is based on tree height, collar diameter, and crown length, as shown below:

$Y= \exp\{-2.4090+0.9522 \ln(D2HS)\}$

Where, Y= Biomass/tree (kg), D= Fruit tree collar diameter, H= Tree height (cm) and S= Density of wood (g cm^{-3}).

The density of the wood was estimated using the Bhatt and Toderia (1992) method. The canopy biomass was calculated using the following formula:

Canopy biomass = Canopy volume x Specific gravity.

Smith's (1954) maximum moisture method calculated specific gravity. The formula calculated the crown volume (Avery and Burkhart, 2002). The total above-ground tree biomass was calculated by adding stem biomass and canopy biomass. The formula suggested by Singh (2010) was employed for estimating tree below-ground biomass. The IPCC default value of 0.45 multiplied with biomass to obtain the carbon stock in t ha^{-1}.

Soil samples from each treatment plot were taken out at a depth of 20 cm, and composite samples were made for each replication. The composite soil samples were air-dried, pulverized with mortar and pestles, and then put through a 2 mm sieve. Bulk density was calculated using the weighing bottle method. To calculate soil carbon (t ha^{-1}), Nelson and Sommers's (1996) equation was employed. The total above-ground tree biomass was computed by adding crop carbon density, tree carbon density and soil carbon stock.

RESULTS AND DISCUSSION

Biomass of crops and trees: In the present study, the treatment, T_8 recorded highest above ground and below-ground biomass (1471.04 kg ha^{-1}; 196.4 kg ha^{-1}), followed by treatment T_7 (1334.56 kg ha^{-1}; 178.80 kg ha^{-1}), whereas minimum (1022.95 kg ha^{-1}; 132.38 kg ha^{-1}) was registered under T_2 (Table-1). Organic manures are thought to increase soil nutritional status and the quality and quantity of a product by contributing to organic matter. Total crop biomass was higher in sole cropping systems with manures than in apricot-based agroforestry systems without manures, with maximum total crop biomass (mung bean and garlic) in T_8 (1667.44 kg ha^{-1}; 2,472.23 kg ha^{-1}) and minimum total crop biomass (mung bean and garlic) in T_2 (1155.33 kg ha^{-1}; 2067.76 kg ha^{-1}) respectively (Table-1).

Table -1. Biomass of mung bean and garlic under apricot based agro forestry system

Treatments	Above ground Biomass (kg/ha) (Mung bean)	Below ground Biomass (kg/ha) (Mung bean)	Total biomass (kg/ha) (Mung bean)	Total Biomass (kg/ha) (Garlic)
T_1(wild apricot without manures)	-	-	-	-
T_2(wild apricot + Mung bean without manures)	1022.95	132.38	1155.33	2067.77
T_3(wild apricot + Mung bean + 20 t FYM / ha)	1152.89	158.45	1311.34	2301.43
T_4(wild apricot + Mung bean + 2 t Dalweed Manure / ha)	1077.60	147.70	1225.3	2170.11
T_5(wild apricot + Mung bean + 2 t Vermicompost / ha)	1265.50	170.67	1436.17	2397.51
T_6(wild apricot + Mung bean +5 g Biofertiliser (Rhizobium / kg seed)	1235.54	164.73	1400.27	2357.69
T_7(wild apricot + Mung bean + Recommended doses of manure and fertilizers; 20 t FYM, 10 kg N : 40 Kg P_2O_5 and 35 Kg K_2O /ha)	1334.56	178.80	1513.36	2413.30
T_8(Mung bean + Recommended doses of manure and fertilizers; 20 t FYM, 10 kg N: 40 Kg P_2O_5 and 35 Kg K_2O /ha)	1471.04	196.40	1667.44	2472.23
C.D($p \leq 0.05$)	**18.56**	**6.69**	**35.29**	**71.88**
SE(m)±	**6.25**	**2.21**	**11.76**	**23.94**

T_1: Not included in statistical analysis

The present findings indicate that using organic manures and fertilizers increased biomass and carbon stocks in agriculture land-use systems, followed by apricot-based systems. This could be attributed to the addition of nutrients to the soil by applying organic manures and fertilizers in tandem. Scheffer *et al*. (1993), Paturde *et al*. (2002) and Zohra *et al*. (2005) all found similar results. In addition, the poor nutrient content of organic manures compared to inorganic fertilizer may have been compensated for by combining the two (Singh *et al*., 2002). The findings of this study support Shah's conclusions (2012) that varying doses of organic manures and fertilizers and green gram intercrop have a positive impact on nutrient availability. These findings are consistent with Sehgal (2007), who found that using organic manures under agroforestry conditions boosted intercrop growth. Organic manures combined with chemical fertilizers increased the growth of intercrop under coconut palms, according to George and Pillai (2000). Organic fertilizer use in *Ocimum basilicum* boosted the dry mass output of leaves (Chaves *et al*., 2002).

In the current study, the highest value of crop biomass was found in a mono-crop system rather than a fruit-based agroforestry system, possibly due to the presence of uninterrupted and adequate amounts of incident sunlight, as well as the absence of tree-crop competition for light, nutrient, and moisture in mono cropping, resulting in increased crop biomass accumulation (Reynolds *et al*., 2007). The outcomes of the current examination are consistent with those of Yadav *et al*. (2017), who found the highest crop biomass in wheat as a pure crop system (5.84 t ha^{-1}), followed by pecan nut + wheat pure lentil system (2.75 t ha^{-1}), and pecan nut + lentil system (2.52 t ha^{-1}) in the Indian Himalayan mid highlands. In another study, Zahoor *et al*. (2021) found that in the temperate zone of the northwestern Himalayas, the greatest total crop biomass was recorded under the control french bean and oats (9.48 t ha^{-1}) as compared to green gram + apple (7.45 t ha^{-1}) based agroforestry system. Pant *et al*. (2010) studied the performance of taro (*Colocasia esculenta*) under poplar (*Populus deltoides*) in Himachal Pradesh's subtropical zone. They found that shadows from trees significantly affected crop growth and yield compared to open fields. Reduced production of intercrops in agroforestry systems is due to a lack of solar energy available beneath the canopy (Caron *et al*., 2018). The present study reported a loss in crop growth and production in intercropping compared to mono-cropping more in the summer season. The shedding of fruit tree leaves during the winter reduces the shadowing impact and light competition, resulting in improved light availability for photosynthesis, which boosts yield in the winter season compared to the summer season.

Trees in agroforestry land-use systems aid in climate change mitigation (Chavan *et al*., 2015). The biomass of apricot trees was significantly larger in intercropping systems with manure treatment than in solitary apricot cropping systems in the current study. T_7 recorded the highest above-ground and below-ground biomass (44.53 t ha^{-1}; 14.69 t ha^{-1}) (Table-2). The lowest value of above-ground and below-ground biomass (33.67 t ha^{-1}, 11.11 t ha^{-1}) was recorded in T_1 and remained statistically at par with T_2 with 36.00 t ha^{-1} and 11.88 t ha^{-1}, respectively. From Table-2, it is clear that the maximum total tree biomass (59.22 t ha^{-1}) was displayed by T_7, whereas the lowest value (44.78 t ha^{-1}) was recorded in T_1 and was statistically at par with T_2 (47.88 t ha^{-1}). Zahoor *et al*. (2021) found considerably higher biomass of apple trees in the apple-based land-use system (29.16 t ha^{-1}) compared to the agriculture-based land-use system (26.48 t ha^{-1}) while working on apple based agroforestry system in the temperate Himalayas. In the present study, the application of manures and fertilizers to agroforestry-based treatments enhanced apricot biomass values due to soil nutrient enrichment, resulting in more significant apricot tree growth and yield, resulting in increased biomass accumulation. The comparatively enhanced productivity was found in apple trees intercropped with red clover, followed by white clover than the clean cultivation Ahmad *et al*. (2018). They reasoned that this could be due to legumes' enhanced ability to absorb water and nutrients, resulting in biological nitrogen fixation and their ability to maintain a little higher temperature, which could increase yield. The outcomes of this study suggest that improved intercultural operations and extra inputs supplied to the intercrops in an apricot-based agroforestry system can be attributed to more significant apricot growth and fruit output than in single cropping.

Biomass carbon density: In the present study, among various treatments, T_7 recorded the highest value of tree carbon density (26.64 t ha^{-1}) whereas the lowest (20.15 t ha^{-1}) was recorded in T_1, which remained statistically at par with T_2 (21.55 t ha^{-1}) (Table-3). From Table-3, it is quite obvious that T_8 (4.63 t ha^{-1}) recorded a significantly highest value of crop carbon density, followed by T_7 (4.30 t ha^{-1}) which remained statistically at par with T_5 with a value of 4.18 t ha^{-1}. When agroforestry systems were compared to solo cropping systems, the total biomass carbon density (tree and crops) was higher in agroforestry systems, with the highest overall total biomass (30.94 t ha^{-1}) and the lowest (4.63 t ha^{-1}). For temperate Kashmir Himalayas and dry temperate north western Himalayas, Zahoor *et al*. (2021) and Chisanga *et al*. (2018) reported the highest carbon densities in the fruit-based land-use system and lowest in agriculture, with values of 18.42 t ha^{-1} and 4.73 t ha^{-1}; 4.59 t ha^{-1} and 3.34 t ha^{-1}, respectively, which are much lower than the current investigation's estimates (30.94 t ha^{-1} and 4.63 t ha^{-1} respectively). Variations in temperature and other location factors could cause this, causing the carbon density to fluctuate. Perennial vegetation is more effective than yearly vegetation because it distributes a higher level of carbon to the subsoil and routinely extends the growing season (Morgan *et al*., 2010), allowing agricultural systems to significantly improve their carbon sequestration capabilities (Oelbermann *et al*., 2006). Fang *et al*. (2005) from temperate Japanese forests and Manhas *et al*. (2006) from temperate Indian forests reported vegetation C densities of 53.60 t ha^{-1} and 47.42 t ha^{-1}, respectively, which are nearly identical to the current study's values. According to Chisanga *et al*. (2018), poor fertility and intensive management methods in agricultural land-use systems have lower biomass and carbon densities. As a result, efficient agroforestry framework design and management can boost biomass accumulation rates, making them critical and successful carbon sinks (Shepherd and Montagnini, 2001).

Table-2. Biomass (t ha^{-1}) of apricot tree under mung bean and garlic based agroforestry system

Treatments	Stem Biomass	Canopy Biomass	Above Ground Biomass	Below Ground Biomass	Total Biomass
T_1(wild apricot without manures)	21.15	12.52	33.67	11.11	44.78
T_2(wild apricot + Mung bean - Garlic without manures)	21.55	14.46	36.00	11.88	47.88
T_3(wild apricot + Mung bean - Garlic + 20 t FYM / ha)	21.40	19.19	40.59	13.39	53.98
T_4(wild apricot + Mung bean - Garlic + 2 t Dalweed Manure / ha)	21.44	15.17	36.61	12.08	48.69
T_5(wild apricot + Mung bean - Garlic + 2 t Vermicompost / ha)	21.63	21.23	42.86	14.14	57.00
T_6(wild apricot + Mung bean - Garlic +5 g Biofertiliser / kg seed)	21.39	14.10	35.49	11.71	47.20
T_7(wild apricot + Mung bean - Garlic + Recommended doses of manure and fertilizers for mung bean; 20 t FYM, 10 kg N : 40 Kg P_2O_5 and 35 Kg K_2O /ha + Recommended doses of manure and fertilizers for garlic; 20 t FYM, 50 kg N, and 62.5 Kg P_2O_5 /ha)	21.71	22.82	44.53	14.69	59.22
T_8(Mung bean - Garlic+ Recommended doses of manure and fertilizers for mung bean; 20 t FYM, 10 kg N : 40 Kg P_2O_5 and 35 Kg K_2O /ha + Recommended doses of manure and fertilizers for garlic; 20 t FYM, 50 kg N, and 62.5 Kg P_2O_5 /ha)	-	-	-	-	-
C.D($p \leq 0.05$)	**0.25**	**4.19**	**8.16**	**2.69**	**10.86**
SE(m)±	**0.08**	**1.61**	**2.62**	**0.86**	**3.49**

Cells with “-” were not included in statistical analysis

Soil carbon stock: The present study registered the highest soil organic carbon density (45.52 t ha^{-1}) in agroforestry land-use systems with organic manure and fertilizer application than sole cropping systems with no tree component and no manure application (42.73 t ha^{-1}) (Table-3). The significant increase in soil organic carbon stocks under agroforestry systems could be attributed to increased deposition and degradation of leaf litter and root turnover from trees (Rajput *et al*., 2015, 2017). In contrast, in agriculture, a large amount of carbon is depleted each year due to removing a large amount of biomass as agriculture produce (Chisanga *et al*., 2018). According to some experts, SOC can change due to various factors such as vegetation and land use, climate, nutrient accessibility, and a variety of management approaches (Baker *et al*., 2007). Loria *et al*. (2015) pointed out that agroforestry systems had higher SOC than cereal, vegetable, and control systems because of the substantial litter fall contribution. Shah *et al*. (2014) reported carbon density values of 190.89 t ha^{-1} for subtropical sub-Himalayan pine forests, which are higher than the current study's reported values. According to Shi *et al*. (2018), worldwide agroforestry soil carbon stores are estimated to be 126 Mg C ha^{-1}, around 19% higher than pasture or cropland.

Total carbon stock of the system: The total carbon accumulation limit of an agroforestry system is determined by the growth and character of tree species, and it varies by region (Newaj and Dhyani 2008). In India's steep Kupwara district of Kashmir valley, Ajit *et al*. (2017) estimated the carbon sequestration capabilities of existing agroforestry systems to be on the order of 0.88 Mg C ha^{-1} yr^{-1}. The data presented in Table-3 shows that the agroforestry framework has the most considerable overall ecosystem carbon accumulation (74.58 t ha^{-1}), which is around 1.5 times greater than the agriculture-based system. Furthermore, the data also revealed that the lowest total carbon stock of the system (48.06 t ha^{-1}) was recorded in T_8. The order of total ecosystem carbon density under different treatments was $T_7 > T_5 > T_3 > T_4 > T_6 > T_2 > T_1 > T_8$ (Table-3). In contrast, the mono-cropping systems had the lowest values of 63.44 t ha^{-1} and 48.06 t ha^{-1}, respectively. This could be due to the more balanced administration of nutrients followed by uptake at the necessary level instead of treatment without manure or fertilizers. Furthermore, increased ecosystem carbon under fruit-based agroforestry systems can be attributed to consistent carbon storage in tree- based LUS and regular addition of leaf litter to the soil, which helps in the storage of a good amount of carbon in the soil and thus improves the productive capacity of the systems (Chisanga *et al*., 2018). In the Thrissur district of Kerala, India, Saha *et al*. (2010) reported the most extensive total C stock (Mg ha^{-1}) in forests (176.6 Mg ha^{-1}), followed by managed tree-based systems, and the lowest in rice paddy fields (55.6 Mg ha^{-1}).

Table 3: Carbon stock (t ha^{-1}) of apricot tree under mung bean and garlic based agroforestry system

Treatments	Tree Carbon Density	Crop carbon density	Soil Carbon	Total Carbon Stock of System
T_1(wild apricot without manures)	20.15	-	43.29	63.44
T_2(wild apricot + Mung bean - Garlic without manures)	21.55	3.43	42.73	67.71
T_3(wild apricot + Mung bean - Garlic + 20 t FYM / ha)	24.29	3.87	43.07	71.23
T_4(wild apricot + Mung bean - Garlic + 2 t Dalweed Manure / ha)	21.91	3.71	45.52	71.14
T_5(wild apricot + Mung bean - Garlic + 2 t Vermicompost / ha)	25.65	4.18	43.46	73.29
T_6(wild apricot + Mung bean - Garlic +5 g Biofertiliser / kg seed)	21.24	4.07	42.87	68.18
T_7(wild apricot + Mung bean - Garlic + Recommended doses of manure and fertilizers for mung bean; 20 t FYM, 10 kg N : 40 Kg P_2O_5 and 35 Kg K_2O /ha + Recommended doses of manure and fertilizers for garlic; 20 t FYM, 50 kg N, and 62.5 Kg P_2O_5 /ha)	26.64	4.30	43.64	74.58
T_8(Mung bean - Garlic+ Recommended doses of manure and fertilizers for mung bean; 20 t FYM, 10 kg N : 40 Kg P_2O_5 and 35 Kg K_2O /ha + Recommended doses of manure and fertilizers for garlic; 20 t FYM, 50 kg N, and 62.5 Kg P_2O_5 /ha)	-	4.63	43.43	48.06
C.D($p\leq0.05$)	**2.86**	**0.25**	**0.40**	**4.09**
SE(m)±	**0.95**	**0.08**	**0.13**	**1.36**

Cells with "-" were not included in statistical analysis

CONCLUSION

As the data show, the highest biomass density capacity has been reported for fruit-based systems rather than the agriculture land-use system. Combining organic manures and chemical fertilizers is more effective than using organic manures alone. Because of the exceptional financial value of apricot fruits and kernels with attractive market prices in both national and international markets, the apricot tree-based land-use strategy is optimal for the region's farmers. Aside from that, fruit tree-based land-use frameworks offer a better potential for carbon stores in Kashmir's temperate zone. The present study results conclude that mung bean and garlic can be successfully grown in an apricot-based agroforestry system and that this diversification practice can be a viable option for boosting the economy of farming communities while also meeting both carbon mitigation and economic growth objectives.

REFERENCES

AFD. 2003. Poverty and climate change: reducing the vulnerability of the poor through adaptation, DFID, London.

Ahmad, S., Khan, P.A., Verma, D.K., Mir, N.H., Sharma, A. and Wani, S.A. 2018. Forage production and orchard floor management through grass/legume intercropping in apple-based agroforestry systems. *International Journal of Chemical Studies*, **6**: 953-958

Ajit., Handa, A. K., Dhyani, S. K., Bhat, G. M., Malik, A. R., Dutt, V., Masoodi, T. H., Uma and Jain, A. 2017. Quantification of carbon stocks and sequestration potential through existing agroforestry systems in hilly Kupwara district of Kashmir valley in India. *Current Science*, **113**: 782-785.

Albrecht, A. and Kandji, S. T. 2003. Carbon sequestration in tropical agroforestry systems. *Agriculture, Ecosystem and Environment*, **99**: 15-27.

Avery, T. E. and Burkhart, H. E. 2002. Forest measurements, 5th edn. McGraw-Hill Higher Education, New York, pp 137-156.

Baker, J. M., Ochsner, T. E., Venterea, R. T. and Griffis, T. J. 2007. Tillage and soil carbon sequestration—what do we really know? *Agriculture, Ecosystem and Environment*, **118**: 1-5.

Banyal, R., Qaiser, K. N. and Abidi, R. A. 2016. Temperate agroforestry systems in Jammu and Kashmir. **In:** Gupta S (ed) Agroforestry for increased production and livelihood security, Ist New India. Publishing Agency, New Delhi, pp 41–59.

Bellow, J. G. 2004. Fruit-tree-based agroforestry in the Western highlands of Guatemala: an evaluation of tree-crop interactions and socio-economic characteristics. Ph.D dissertation, University of Florida, USA.

Bhatt, B. P. and Toderia, N. P. 1992. Fuel wood characteristics of some mountain trees and shrubs. *Biomass*, **21**: 233-238.

Brown, S., Gillespie, A. J. R. and Lugo, A. E. 1989. Biomass estimation method for tropical forests with application to forestry inventory data. *Forest Science*, **35**: 881-902.

Caron, B.O., Pinheiro, M. V. M., Korcelski, C., Schwerz, F., Elli, E. F., Sgarbossa, J. and Tibolla, L. B. 2018. Agroforestry systems and understory harvest management: The impact on growth and productivity of dual-purpose wheat. *Annals of the Brazilian Academy of Sciences*, **91**: e20180667 (*doi: 10.1590/0001-3765201920180667*).

Chavan, D. S., Keerthika, A., Dhyani, S. K., Handa, A. K., Newaj, R. and Rajarajan. K. 2015. National Agroforestry Policy in India: a low hanging fruit. *Current Science*, **108**: 1826-1834.

Chaves, F. C. M., Ming, L. C., Ehlert, P. A. D., Marques, M. O. M., Fernandes, D. M. and Meireles, M. A. A. 2002. Influence of organic fertilization on leaves and essential oil production of *Ocimum gratissimum* L. [Eds. Bernath, Zamborine Nemeth E, Craker L. and Kock O 2002]. In : *Proceedings of the International Conference on Medicinal and Aromatic Plants, Possibilities and Limitations of Medicinal and Aromatic Plant Production in the 21st Century*, Budapest, Hungary, 8-11 July, 2001 [cf : *Acta Horticulture* **576** : 273-275].

Chisanga, K., Bhardwaj, D. R., Pala, N. A. and Thakur, C. L. 2018. Biomass production and carbon stock inventory of high-altitude dry temperate land use systems in North Western Himalaya. *Ecological Process*. (*https://doi.org/10.1186/s13717- 018-0134-8).*

Dar, M., Qaisar, K. N., Ahmad, S. and Wani, A. A. 2018. Inventory and composition of prevalent agroforestry systems of Kashmir Himalaya. *Advanced Research*, **14**: 1-9.

Dhyani, S., K. Ramnewaj and A. R. Sharma. 2009. Agroforestry, its relation with agronomy, challenges and opportunities. *Indian Journal of Agronomy*, **54**: 249-266.

Fang, J. Y., Oikawa, T., Kato, T., Mo, W. H. and Wang, Z. H. 2005. Biomass carbon accumulation by Japan's forests from 1947 to 1995. *Global Biogeochemical Cycle*, **19**: GB2004.

George, S. and Pillai, G.R. 2000. Effect of vermicompost on yield and economics of guinea grass (*Panicum maximum*) grown as an intercrop in coconut (*Cocos nucifera*) gardens. *Indian Journal of Agronomy*, **45**: 693-697.

Gupta, S. R. and Singh, J. S. 1981. Influence of floristic composition on the net primary production and dry matter turnover in tropical grassland. *Australian Journal of Economics*, **7**: 363-374.

IPCC. 2000. Land use, land-use change, and forestry, in: R.T. Watson, I.R. Noble, B. Bolin, N.H Ravindranath, D.J. Verardo, D.J. Dokken (Eds.), Intergovernmental Panel on Climate Change (IPCC), Special Report, Cambridge Univ. Press, New York, 2000.

Jose, S. and Bardhan, S. 2012. Agroforestry for biomass production and carbon sequestration: an overview. *Agroforestry Systems*, **86**: 105-111.

Kala, C. P. 2010. Status of an indigenous agro-forestry system in changing climate: a case study of the middle Himalayan region of Tehri Garhwal. *India. Journal of Forest Science*, **56**: 373-30.

Kaur, B., Gupta, S. and Singh, G. 2002. Carbon storage and nitrogen cycling in silvipastoral system on sodic soils in north western India. *Agroforestry Systems*, **54**: 21-29.

Lal, R. 2004. Soil carbon sequestration to mitigate climate change. *Geoderma*, **123**:1-22.

Li, D. J., Niu, S. L. and Luo, Y. Q. 2012. Global patterns of the dynamics of soil carbon and nitrogen stocks following afforestation: a meta-analysis. *New Phytologist*, **195**: 172-181.

Lorenz, K. and Lal, R. 2014. Soil organic carbon sequestration in agroforestry systems. A review. *Agronomy for Sustainable Development*, **34**: 443-454.

Loria, N., Verma, K. S., Bhardwaj, S. K. and Brahmi, M. K. 2015. Impact of catchment land use on water quality of Pong wetland of Himachal Pradesh. *Indian Journal of Ecology*, **42**: 21-26.

Manhas, R. K., Negi, J. D. S., Kumar, R. and Chauhan, P. S. 2006. Temporal assessment of growing stock, biomass and carbon stock of Indian forests. *Climate Change*, **74**: 191-221.

Meteorological data. 2017. Indian meteorological department, Srinagar, Jammu and Kashmir, India.

Morgan, J. A., Follett, R. F., Allen, L. H., Grosso, S. D., Derner, J. D., Dijkstra, F., Franzluebbers, A., Fry, R., Paustian, K. and Schoeneberger, M. M. 2010. Carbon sequestration in agricultural land of the United States. *Journal of Soil and Water Conservation*, **65**: 6-13.

Nelson, D. W. and Sommers, L. E. 1996. Total carbon, organic carbon and organic matter. In: Methods of soil analysis. Part 3. Chemical methods. Soil Science Society of America. Book Series no. 5, pp 961–1010.

Newaj, R. and Dhyani, S. K. 2008. Agroforestry for carbon sequestration: scope and present status. *Indian Journal of Agroforestry*, **10**: 1-9.

Oelbermann, M., Voroney, R. P., Kass, D. C. L. and Schlonvoigt, A. M. 2006. Soil carbon and nitrogen dynamics using stable isotopes in 9 and 10-yr old tropical agroforestry systems. *Geoderma*, **130**: 356-367.

Pant, K. S., Mishra, V. K., Sanwal, C. S. and Dinssa, K. U. 2010. Effect of nitrogen and poplar spacing on yield and nutrient content of Taro (*Colocasia esculenta* L.). *Indian Journal of Agroforestry*, **12**: 18-22.

Paturde, J. T., Wankhade, S. G., Khode, P. P., Chatol, P. U., Deo, D. D. and Bhuyar, S. A. 2002. Effect of organic manures and plant population on yield of safed musli (*Chlorophytum borivallianum*). *Agricultural Sciences Digest*, **22**: 51-52.

Paustian, K., Lehmann, J., Ogle, S., Reay, D., Robertson, G. P. and Smith, P. 2016. Climate-smart soils. *Nature*, **532**:49-57.

Quli, S. M. S., Islam, M. A. and Singh. P. K. 2017. Mitigating livelihood crisis through agroforestry interventions In Rural India. *Journal of Development and Management Studies*, **15**: 7159-7178.

Ram, N., S. Chavan and R. Prasad. 2013. Agroforestry as a strategy for climate change adaptation and mitigation. *Indian Journal of Agroforestry*, **15**: 41-48.

Rajput, B, S., Bhardwaj, D. R. and Pala, N. A. 2015. Carbon dioxide mitigation potential and carbon density of different land use systems along an altitudinal gradient in north-western Himalayas. *Agroforestry Systems*, (*https://doi.org/10.1007/s10457- 015-9788-8Springer*).

Rajput, B. S., Bhardwaj, D. R. and Pala, N. A. 2017. Factors influencing biomass and carbon storage potential of different land use systems along an elevational gradient in temperate northwestern Himalaya. *Agroforestry Systems*, **91**:479-486.

Reynolds, P. E., James, A., Simpson, N. V. and Thevasan, G. A. M. 2007. Effects of tree competition on corn and soyabean photosynthesis, growth and yield in a temperate tree-based agroforestry intercropping system in southern Ontario, Canada. *Ecological Engineering*, **29**: 362-371.

Saha, S., Rajwar, G. S. and Kumar, M. 2018. Soil properties along altitudinal gradient in Himalayan temperate forest of Garhwal region. *Acta Ecol Sinica*, **38**: 1-8.

Sathaye, J. A. and Ravindranath, N. H. 1998. Climate change mitigation in the energy and forestry sectors of developing countries. *Annual Review of Energy & Environment*, **23**: 387–437.

Scheffer, M. C., Ronzelli, J. P. and Koehler, H. S. 1993. Influence of organic fertilization on the biomass, yield and composition of the essential oil of *Achillea millefolium* L. In: *Proceedings of First World Congress on Medicinal and Aromatic Plants for Human Welfare (WOCMAP),* Masstricht, Netherlands [Eds. D. Palevitch, J.E. Simon and A. Mathe). *Acta Horticulture* **331**: 109-114.

Sehgal, S. 2007. Effect of tree hedgerows and manures on growth and production behaviour of *Ocimum basilicum* L. and *Tagetus minuta* L. Ph.D. Thesis, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P), India.

Shah, M. H. 2012. Studies on Green-gram Plum Based Agroforestry System in Kashmir Valley. M.Sc. Thesis, Sher-e-Kashmir University of Agricultural Sciences and Technology, Kashmir, India.

Shepherd, D. and Montagnini, F. 2001. Carbon sequestration potential in mixed and pure tree plantations in the humid tropics. *Journal of Tropical Forest Science*, **13**: 450-45.

Shi, L., Feng, W., Xu, J. and Kuzyakov, Y. 2018. Agroforestry systems: Meta-analysis of soil carbon stocks, sequestration processes, and future potentials. *Land Degradation and Development*, **29**: 3886-3897.

Singh, U.B., Kothari, S.K. and Verma, B.S. 2002. Growth, yield and quality of mint species as intercrop in sugarcane under sub-tropical climate of north Indian plains. *Journal of Medicinal and Aromatic Plant Sciences*, **24**: 60-64.

Singh, B. 2010. Bioeconomic appraisal and carbon sequestration potential of different land use systems in temperate northwestern Himalayas. Ph.D thesis. Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan.

Singh, R., Bhardwaj, D. R., Pala, N. A. and Rajput, B. S. 2017. Variation in floral diversity of eight agro-ecosystems along elevational gradient in northwestern Himalaya. *Range Management and Agroforestry*, **38**: 181-190.

Smith, D. M. 1954. Maximum moisture content for determining specific gravity of small wood samples. Forest product laboratory. USDA Forest Service report.

Yadav, R. P. and Bisht, J. K. 2014. Litter fall and potential nutrient returns from pecan nut (Carya illinoinensis) in agroforestry system in Indian Himalaya. *International Journal of Herbal Medicine*, **2**: 51-52.

Yadav, R. P., Bisht, J. K. and Bhatt, J. C. 2017. Biomass, carbon stock under different production systems in the mid hills of Indian Himalaya. *Tropical Ecology*, **58**: 15-21.

Zahoor, S., Dutt, V., Mughal, A. H., Pala, N. A., Qaisar, K. N. and Khan, P. A. 2021. Apple-based agroforestry systems for biomass production and carbon sequestration: Implication for food security and climate change contemplates in temperate region of Northern Himalaya, India. *Agroforestry Systems*, **95**: 367-382.

Zohra, M., Imed, C., Jinhe, C., Amina, B. and Kamel, B. 2005. Effect of fertilization on growth and solasodine content of four natural Solanum sodomeum L. *Journal of Food, Agriculture and Environment,* **3**: 341-344.

Zomer, R. J., Neufeldt, H. and Xu, J. 2016. Global tree cover and biomass carbon on agricultural land: the contribution of agroforestry to global and national carbon budgets. *Scientific Reports*, **6**:1-12.