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Fruit tree-based agroforestry systems and their carbon sequestration potentials in different ecosystem of Bangladesh

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Abstract: Fruit tree based profitable agroforestry systems were investigated in different ecosystem of Bangladesh through an intensive survey and also calculated their carbon sequestration potential by algorithmic method to mitigate climate change. The major ecosystem of Bangladesh namely Coastal ecosystem (Khulna and Satkhira district), Barind ecosystem (Rajshahi and Dinajpur district), Terrace ecosystem (Gazipur and Narsingdi district) and Hill ecosystem (Rangamati and Khagrachari district) were considered. The study revealed that, jackfruit, mango, litchi, guava and ber based agroforestry systems were the most suitable considering benefit cost ratio (BCR) and land equivalent ratio (LER). The most profitable agroforestry systems were Mango+Lemon+Guava-Chilli (2.93), Litchi-Papaya-Bottlegourd (2.62), Ber-Okra-Redamaranth (2.52) and Jackfruit-Papaya-Brinjal (2.05) in hill, barind, coastal and terrace and ecosystem, respectively considering benefit cost ratio (BCR).On the other hand, considering the values of land equivalent ratio (LER), Mango-Frenchbean-Cabbage (3.14) in hill, Jackfruit-Lemon+Malta+Orange-Papaya-Brinjal (2.73) in terrace, Mango-Papaya-Okra (2.23) in coastal, and Litchi-Sweetgourd-Brinjal (1.98) in barind ecosystem. The total amount of carbon stock in agroforestry under different ecosystem varied significantly. Total carbon stock was estimated by summing the carbon of tree and the carbon of soil. Significantly the total highest carbon stock was recorded in terrace ecosystem (207.6 tha^{-1}) followed by barind ecosystem (174.62 tha^{-1}). The lowest carbon stock was recorded in hill ecosystem (155.42 tha^{-1}).

Key words: Fruit tree, agroforestry system, carbon sequestration.

Introduction

Bangladesh is one of the most densely populated countries in the world and the per capita forest area in Bangladesh is very low (0.009 ha) compare to average values in Asia (0.145 ha) and in the world (0.597 ha) (Farouque *et al.*, 2017 and FAO, 2015). The huge population (166.3 million) exerts immense pressure on her forest resources for the demand of timber, fuel wood, and other forest products (Mahmood *et al.*, 2016) and is among one of the most vulnerable countries resulting from the negative impacts of climate change (Hanif *et al.*, 2015). Climate change has become a major concern for the world. Poor countries suffer the most of the adverse effects of global warming (Makundi, 2014 and Traoré *et al.*, 2018). The concentration of carbon dioxide in Earth's atmosphere is currently at nearly 412 ppm and this represents a 47 percent increase since the beginning of the industrial age, when the concentration was near 280 ppm (Buis, 2019) and predicted to increase to approximately 470-570 ppm by 2050 (Tefera *et al.*, 2019). This huge amount of carbon in the atmosphere, however, should be removed. Carbon sequestration is the process by which carbon dioxide (CO_2) from the atmosphere is absorbed by trees, plants and crops through photosynthesis and stored as carbon in biomass such as tree trunks, branches, foliage, roots and soils (EPA, 2010 and Tom-Dery *et al.*, 2015). Carbon sequestration rates vary by tree species, soil type, regional climate, and topography and management practice (EPA, 2010 and Tom-Dery *et al.*, 2015). Soil can act as a sink or source for carbon in the atmosphere depending on the changes happening to the soil organic matter (Tom-Dery *et al.*, 2015). Reforestation and afforestation may have the greatest potential for sequestering carbon in soil and constitutes a major carbon sink as above and below ground biomass (Selvaraj *et al.*, 2016).Trees have important roles in reducing vulnerability, increasing resilience of farming systems and buffering households against climate related risks (Meragiaw, 2017) and in the reduction of carbon dioxide from atmosphere by carbon sequestration (Chavan and Rasal, 2012b). Agroforestry is all about using trees on farms and in landscapes for the benefit of rural communities and other land users (Dawson *et al.*, 2012 and Gebre, 2016). Estimates of carbon stocks and stock changes in tree biomass (above and belowground) are necessary for reporting to the United Nations Framework Convention on Climate Change (UNFCCC) and will be required for Kyoto Protocol reporting (Green *et al.*, 2007; Chavan and Rasal, 2012a; Selvaraj *et al.*, 2016).On the other hand, agroforestry practices are very important for Bangladesh as the cultivable land is shrinking due to increasing human pressure and rapid industrialization. So, to ensure maximum production and food security of the country, vertical increase in production through agroforestry would be a viable option. Consequently, to meet up the demand of fuel wood of the poor people also depend on the trees. Again, it is also important to identify the promising agroforestry species having potentiality to sequestrate maximum amount of carbon from the atmosphere and high profitable one. Therefore, the profitable agroforestry system of different ecosystem of Bangladesh is need to be identified as well as to know the amount of the carbon sequestered by the agroforestry system is essential, which is the aim of the study. Therefore, the objectives of the study were to identify suitable agroforestry practices/systems in different ecosystems of Bangladesh and their carbon sequestration ability.

Materials and Methods

The study was conducted during November, 2015 to December, 2016 in four major ecosystem of Bangladesh namely Coastal ecosystem (Khulna and Satkhira district), Barind ecosystem (Rajshahi and Dinajpur district), Terrace ecosystem (Gazipur and Narsingdi district) and Hill ecosystem (Rangamati and Khagrachari district) to know the profitable agroforestry systems. A pre tested and structured questionnaire was used for data collection. 240 farmers were randomly selected (60 from each ecosystem) for this purposes and a simple random sampling technique was followed. Direct interview method was followed with the respondents in data collection. The researcher himself collected the necessary information during the study period through questionnaire. Appointments with the respondents were made in advance through Sub Assistant Agriculture Officer (SAAO). After collection of data, the information's were summarized, scrutinized, coded and recoded in Statistical Package for Social Science (SPSS) computer software.

Selection procedure of profitable agroforestry system

For selecting profitable agroforestry system, benefit-cost ratio was analyzed.Benefit-cost ratio is the ratio of gross returns with total cost of productions. It was calculated by the following formula (Islam *et al*., 2004): Benefit-cost ratio = [{Gross return (Tk. ha^{-1} $year^{-1}$)}÷{ Total cost of Production (Tk. ha^{-1} $year^{-1}$)}].

The comparative advantages of land use through agroforestry and traditional farming were evaluated through calculating LER as follows (Mead and Willey, 1980): LER = (Xi/Xs + Yi/Ys), Where, X and Y are the component crops in intercrop (i) or sole crop (s).

Determination of total carbon stock: Total carbon sequestrated in Agroforestry system = {Total wt. of carbon in trees + soil carbon stock} (Chavan and Rasal, 2010).

$W = 0.25D^2H$ (when D < 11 inch) and $W = 0.15D^2H$ (when D > 11inch), Where, D = Diameter of the trunk in inches, W = Above-ground weight of the tree in pounds, H = Height of the tree in feet, Total green weight of the tree = W×120%, Dry weight of the tree = Green weight×72.5% The weight of carbon of the tree=dry weight×47%.

Soil carbon stock measurement: Soil sample analysis Soil carbon (t/ha) =carbon content (%) x soil bulk density (g/cc) x soil depth(cm) (Batjes, 1996).

Results and Discussion

Profitable agroforestry systems in different ecosystem considering BCR and LER:

The study explored the socio-economic condition of the farmer, land user pattern, different agroforestry systems and their contribution to the farmer's economy. The agroforestry systems and their profitability were presented below ecosystem wise.

Coastal ecosystem: Agroforestry systems varied widely among the study areas (Table 1). Financial analysis was done for each system through calculating by Benefit Cost Ratio (BCR) and Net return (NR). However, different fruit tree-based agroforestry systems dominated in all the study areas. Among the different agroforestry system, the highest BCR (2.52) as well as NR (210820 Tk ha^{-1}) were recorded in Ber-Okra-Red amaranth-based system followed by Mango-Papaya-Okra based system. Suitability rank of agroforestry systems were Ber-Okra-Red amaranth > Mango-Papaya-Okra > Papaya-Okra> Litchi-Red amaranth > Ber-Mukhikachu > Litchi-Ginger > Mango-Turmeric > Litchi-Turmeric > Mango-Rice. Considering LER Mango-Papaya-Okra based system ranked first whereas Ber-Okra-Red amaranth system was in second position. Considering both BCR and LER Mango-Rice based system scored the lowest position. Bashir (2017) found that Ber based agroforestry systems comprising different vegetables were the most profitable one than other agroforestry system.

Table 1. Major agroforestry systems in coastal ecosystem and their suitability considering BCR and LER

Systems	Total cost (Tk ha^{-1})	Gross income (Tk ha^{-1})	Net return (Tk ha^{-1})	BCR	Rank by BCR	LER	Rank by LER
Mango-Rice	126248.56	178945.42	52696.86	1.41	9	1.23	9
Mango-Turmeric	12842.78	18588.45	5745.67	1.44	7	1.28	7
Papaya-Okra	155860.75	289870.85	134010.1	1.85	3	1.85	3
Litchi-Ginger	115666.35	178246.55	62580.2	1.54	6	1.84	4
Litchi-Turmeric	122540.00	176240.00	53700.00	1.43	8	1.68	6
Litchi-Red amaranth	76890.00	126346.00	49456.00	1.64	4	1.46	8
Ber-Mukhikachu	66865.00	108920.00	42055.00	1.62	5	1.72	5
Mango-Papaya-Okra	135583.78	322582.96	186999.18	2.37	2	2.23	1
Ber-Okra-Red amaranth	138000.00	348800.00	210800.00	2.52	1	2.12	2

Table 2. Major agroforestry systems in barind ecosystem and their suitability considering BCR and LER

Systems	Total cost (Tk ha^{-1})	Gross income (Tk ha^{-1})	Net return (Tk ha^{-1})	BCR	Rank by BCR	LER	Rank by LER
Litchi-Wheat-Cucumber	78500.95	156800.45	78299.5	1.99	5	1.76	3
Litchi-Onion-Okra	82680.00	168720.00	86040.00	2.04	4	1.66	8
Ber-Mukhikachu	55230.00	95948.00	40718.00	1.73	9	1.73	7
Mango-Rice	48760.00	82600.00	33840.00	1.69	11	1.55	9
Mango-Garlic-Red amaranth	56800.00	112982.00	56182.00	1.98	6	1.48	10
Litchi-Papaya-Sweet gourd	120000.00	245000.00	125000.00	2.04	3	1.98	1
Papaya-Pointed gourd	98000.00	172000.00	74000.00	1.75	8	1.75	6
Mango-Papaya	112500.00	194000.00	81500.00	1.72	10	1.67	5
Lichi-Papaya-Bottle gourd	102000.00	268000.00	166000.00	2.62	1	1.88	2
Litchi-Onion	76400.00	143500.00	67100.00	1.87	7	1.36	11
Mango-Onion-Red amaranth	92800.00	238040.00	145240.00	2.56	2	1.69	4

Barind ecosystem: In Barind ecosystem, the farmers were used to cultivate different crops and vegetables with fruit tree species as agroforestry system. A total eleven production combinations were recorded (Table-2) in barind ecosystem. Litchi and mango-based agroforestry system were found dominant in this region. Among the different agroforestry system, the highest BCR (2.62) as well as NR (16630 Tk ha^{-1}) was recorded in Litchi-Papaya-Bottle gourd production system. Considering LER, Litchi-Papaya-Sweet gourd-based agroforestry system (1.98) ranked first followed by Lichi-Papaya-Bottle gourd-based system (1.88). The lowest BCR (1.69) and LER

(1.36) were recorded for Mango-Rice and Litchi-Onion based agroforestry system, respectively.

Terrace ecosystem: In terrace ecosystem, the farmers were growing different crops and vegetables in association with different tree species as agroforestry system (Table 3). Among the different agroforestry system, the highest BCR (2.05) was recorded in Jackfruit-Papaya-Brinjal combination. On the other hand, the maximum net return (220900.00 Tk ha^{-1}) was obtained from Jackfruit-Lemon + Malta + Orange-Papaya-Brinjal based agroforestry system. The second highest BCR (1.72) as well as NR (208280.00 Tk.ha^{-1}) were recorded for Mango-Papaya-Okra combination. Considering BCR, the suitability ranked was Jackfruit-Papaya-Brinjal > Mango-Papaya-Okra > Jackfruit + Lemon + Malta + Orange-Papaya-Brinjal> Mango-Rice > Jackfruit-Papaya-Wax gourd > Jackfruit-Pineapple > Jackfruit + Burmese grape-Turmeric > Guava-Pineapple >Jackfruit-Turmeric. Considering LER Jackfruit + Lemon + Malta + Orange-Papaya-Brinjal based agroforestry system (2.73) ranked first followed by Jackfruit-Papaya-Brinjal system (2.34). Considering BCR and LER Jackfruit-Papaya-Brinjal, Mango-Papaya-Okra, Jackfruit + Lemon + Malta + Orange-Papaya-Brinjal were the most profitable, efficient and acceptable agroforestry practice in terrace ecosystem. Islam (2015) found that Jackfruit + Lemon + Malta + Orange-Papaya-Brinjal based agroforestry system was the most profitable and acceptable multistoried production system of this ecosystem.

Table 3. Major agroforestry systems in terrace ecosystem and their suitability considering BCR and LER

Systems	Total cost (Tk ha^{-1})	Gross income (Tk ha^{-1})	Net return (Tk ha^{-1})	BCR	Rank by BCR	LER	Rank by LER
Mango-Rice	142300.00	235700.00	93400.00	1.65	4	1.75	5
Jackfruit-Papaya-Brinjal	135800.00	278690.00	142890.00	2.05	1	2.34	2
Jackfruit-Pineapple	86590.00	136870.00	50280.00	1.58	6	1.44	7
Guava-Pineapple	98350.00	152305.00	53955.00	1.54	8	1.35	9
Jackfruit-Turmeric	88700.00	133978.00	45278.00	1.51	9	1.38	8
Jackfruit + Burmese grape-Turmeric	289284.00	456800.00	167516.00	1.57	7	2.31	3
Jackfruit-Papaya-Wax gourd	247820.00	394500.00	146680.00	1.59	5	1.69	6
Jackfruit + Lemon + Malta + Orange-Papaya-Brinjal	312000.00	532900.00	220900.00	1.70	3	2.73	1
Mango-Papaya-Okra	287600.00	495880.00	208280.00	1.72	2	1.94	4

Table 4. Major agroforestry systems in hill ecosystem and their suitability considering BCR and LER

Systems	Total cost (Tk ha^{-1})	Gross income (Tk ha^{-1})	Net return (Tk ha^{-1})	BCR	Rank by BCR	LER	Rank by LER
Mango-Bottle gourd	156800.00	345600.00	188800.00	2.20	4	1.87	7
Litchi-Bottle gourd-Coriander	172400.00	465215.00	292815.00	2.69	2	1.98	6
Jackfruit-Pineapple	123450.00	196875.00	73425.00	1.59	7	1.75	8
Jackfruit-Turmeric	136780.00	213480.00	76700.00	1.56	8	1.64	9
Mango-French bean-Cabbage	246735.00	578736.00	332001.00	2.34	3	3.14	1
Mango + Lemon + Guava-Chili	175960.00	515830.00	339870.00	2.93	1	2.94	2
Jackfruit-Papaya-Long yard bean	162540.00	246075.00	83535.00	1.51	9	2.76	3
Mango-Ginger	128360.00	252540.00	124180.00	1.96	6	2.35	5
Mango-Papaya-Cabbage	184550.00	388970.00	204420.00	2.10	5	2.46	4

Hill ecosystem: In hill ecosystem, the farmers were producing different crops and vegetables beneath the tree canopies. Mango and jackfruit were found the most dominant species in this ecosystem. Among the different agroforestry systems, the highest BCR (2.93) as well as NR (339870.00 Tk ha^{-1}) were recorded in Mango + Lemon + Guava-Chili based agroforestry system. The second highest BCR (2.69) was recorded for Litchi-Bottle gourd-Coriander combinations. Although second highest NR (332201 Tk ha^{-1}) for Mango-French bean-Cabbage-based agroforestry system. On the basis of LER, Mango-French bean-Cabbage (3.14) was found the most efficient land use system followed by Mango + Lemon + Guava-Chili (2.94). This system was also ranked first considering BCR. Hence, considering both LER and BCR suitable agroforestry practice of hill ecosystem was Mango + Lemon + Guava-Chili, Mango-French bean-Cabbage and Litchi-Bottle gourd-Coriander (Table 4).

Carbon estimation of agroforestry system

For determining carbon stock of agroforestry system, allometric equation was used where tree carbon was measured from its biomass and tree biomass was estimated using their height and diameter at breast height.

Plant height: Carbon stock by different trees varied significantly with respect to plant height. Among the agroforestry species, significantly the tallest average plant height (55.75 ft) was recorded in mango followed by jackfruit, litchi, jujube and guava; whereas the shortest plant height (7.35 ft) was recorded in guava (Table 5). In case of jackfruit, the highest (50.26 ft) and lowest (38.52 ft) plant height was recorded in terrace ecosystem and barind ecosystem, respectively. In mango, the highest (55.75 ft) and lowest (49.85 ft) plant height was recorded in barind ecosystem and terrace ecosystem, respectively. The average plant height of mango at terrace and hill ecosystem was found statistically similar. In case of litchi, the highest (26.64 ft) and lowest (22.82 ft) plant height was recorded in barind ecosystem and hill ecosystem, respectively. In guava, the highest (9.22 ft) and lowest (7.35 ft) plant height was recorded in terrace ecosystem and hill ecosystem, respectively. While the plant height of jujube at terrace and hill ecosystem was statistically similar. Hanif *et al.* (2015) observed that *L. leucochephala* species was the highest plant height.

Table 5. Plant height of different tree species in the study area

Ecosystem	Plant height (ft)				
	Jackfruit	Mango	Litchi	Guava	Jujube
Coastal	48.68b	52.44b	23.58c	7.82c	10.62c
Terrace	50.26a	49.85c	24.82b	9.22a	16.12a
Barind	38.52d	55.75a	26.64a	8.13b	14.33b
Hill	42.37c	50.88c	22.82d	7.35d	16.25a
CV (%)	5.33	3.95	5.67	4.83	5.12

Table 6. Plant diameter at breast height (DBH) of different tree species in the study area

Ecosystem	Plant diameter (inch)				
	Jackfruit	Mango	Litchi	Guava	Jujube
Coastal	27.85c	34.72b	21.88c	5.28c	14.65a
Terrace	32.15a	35.12a	23.78b	6.13a	12.33b
Barind	31.95a	35.26a	25.35a	5.72b	12.15b
Hill	29.38b	32.77c	22.34c	6.35a	10.98c
CV (%)	0.76	0.94	4.79	3.82	2.46

Plant diameter at breast height (DBH): The diameter of trunk at breast height of a tree influences the carbon sequestration potential of the species. Maximum diameter of a tree represents maximum weight of tree consequently the maximum amount of carbon stock by the species. Tree diameter at breast height (1.37 m) showed distinct variations at different study location in different species. Among the tree species, the maximum and minimum tree diameter (35.26 and 5.28 inch) was recorded in mango and guava at barind and coastal ecosystem; respectively followed by jackfruit, litchi and jujube (Table 6). In case of jackfruit, the highest (32.15 inch) and lowest (27.85 inch) plant diameter was recorded in terrace ecosystem and coastal ecosystem, respectively. The plant diameter of jackfruit at terrace and barind ecosystem showed statistically similar. In mango, the highest (35.26 inch) and lowest (32.77 inch) plant diameter was recorded in barind ecosystem and hill ecosystem, respectively. The plant diameter of mango at barind and terrace ecosystem showed statistically similar. In case of litchi, the highest (25.35 inch) and lowest (21.88 inch) plant diameter was recorded in barind ecosystem and coastal ecosystem, respectively. There was no significant difference of litchi diameter between coastal and hill ecosystem. In guava, the highest (6.35 inch) and lowest (5.28 inch) plant diameter was recorded in hill ecosystem and coastal ecosystem, respectively. Plant diameter of guava at hill and terrace ecosystem was statistically similar. While the plant diameter of jujube at terrace and barind ecosystem was statistically similar. The highest (14.65 inch) and lowest (10.98 inch) plant diameter of jujube was recorded in coastal ecosystem and hill ecosystem, respectively. Almost similar result was recorded by Hanif *et al.* (2015).

Table 7. Amount of carbon (kg tree^{-1}) in different tree species at different ecosystem

Ecosystem	Jackfruit	Mango	Litchi	Guava	Jujube
	CS kg tree^{-1}				
Coastal	1117.31c	1870.66b	334.05c	10.75c	67.45c
Terrace	1537.29a	1819.48b	415.33b	17.09a	72.52b
Barind	1163.59b	2051.07a	506.60a	13.12b	62.60c
Hill	1082.27d	1616.86c	337.02b	14.62b	96.62a
CV (%)	1.78	2.44	1.95	1.62	2.13

Carbon sequestration in tree: The carbon stock by major tree species was calculated by traditional algorithm method. The amount of carbon was varied significantly by tree species as well as by ecosystem (Table 7). Among the species, mango tree sequestered significantly the highest amount of carbon in barind (2051.07 kg tree^{-1}) ecosystem followed by coastal (1870.66 kg tree^{-1}) ecosystem which was statistically similar to that of terrace ecosystem (1819.48 kg tree^{-1}) while significantly the lowest amount (1616.86 kg tree^{-1}) of carbon was stored by mango tree in hill ecosystem. In case of jackfruit, significantly highest amount of carbon (1537.29 kg tree^{-1}) was recorded in terrace ecosystem followed by barind ecosystem (1163.59 kg tree^{-1}). The lowest amount of carbon was stored by jackfruit tree in hill ecosystem (1082.27 kg tree^{-1}). The moderate amount of carbon was recorded in coastal ecosystem (1117.31 kg tree^{-1}). In litchi, significantly the highest amount of carbon was recorded in barind ecosystem (506.60 kg tree^{-1}) followed by terrace ecosystem (415.33 kg tree^{-1}) and the lowest amount of carbon were recorded in coastal ecosystem (334.05 kg tree^{-1}) which was statistically similar to hill ecosystem (337.02 kg tree^{-1}). Accordingly, in guava, significantly the highest and the lowest amount of carbon were recorded in terrace ecosystem (17.09 kg tree^{-1}) and in coastal ecosystem (10.75 kg tree^{-1}), respectively. There was no significant difference between barind (13.12 kg tree^{-1}) and hill (14.62 kg tree^{-1}) ecosystem. On the other hand, in jujube, significantly the highest amount of carbon (96.62 kg tree^{-1}) was recorded in hill ecosystem followed by terrace (72.52 kg tree^{-1}) ecosystem. The lowest amount of carbon (62.60 kg tree^{-1}) was recorded in barind ecosystem which was statistically similar to coastal (67.45 kg tree^{-1}) ecosystem.

Carbon sequestration per hectare: The carbon stock by major tree species per hectare was calculated by traditional algorithm method. The amount of carbon was varied significantly by tree species as well as by ecosystem (Table 8). Among the species, jackfruit contained significantly high amount of carbon (239.82 tha^{-1}) in terrace ecosystem followed by barind ecosystem (181.52 tha^{-1}). The lowest amount of carbon was recorded in hill ecosystem (168.83 tha^{-1}). The moderate amount of carbon was recorded in coastal ecosystem (174.30 tha^{-1}). In case of mango, significantly the highest and the lowest amount of carbon were recorded in barind (319.97 tha^{-1}) and hill (252.23 tha^{-1}) ecosystem, respectively while the second highest amount of carbon was recorded in coastal (291.82 tha^{-1}) ecosystem followed by terrace ecosystem (283.84 tha^{-1}). In litchi, significantly the highest amount of carbon was recorded in barind ecosystem (79.03 tha^{-1}) followed by terrace ecosystem (64.79 tha-1) and the lowest amount of carbon were recorded in coastal ecosystem (52.11 tha^{-1}) which was statistically similar to hill ecosystem (52.57 tha^{-1}). Accordingly, in guava, significantly the highest amount of carbon was recorded in terrace ecosystem (6.83 tha^{-1}) which was statistically similar to hill ecosystem (5.85 tha^{-1}) and the lowest amount of carbon was recorded in coastal ecosystem (4.30 tha^{-1}). The moderate amount of carbon was recorded in barind ecosystem (5.25 tha^{-1}). In case of jujube, significantly high amount of carbon was recorded in hill ecosystem (26.86 tha^{-1}) followed by terrace ecosystem (20.16 tha^{-1}). The lowest amount of carbon was recorded in barind ecosystem (17.40 tha^{-1}) which was statistically similar to coastal ecosystem (18.75 tha^{-1}).

Table 8. Amount of carbon (tha^{-1}) in different tree species at different ecosystem

Ecosystem	Jackfruit	Mango	Litchi	Guava	Jujube	Average
	CS tha-1					
Coastal	174.30c	291.82b	52.11c	4.30c	18.75c	108.26
Terrace	239.82a	283.84c	64.79b	6.83a	20.16b	123.09
Barind	181.52b	319.97a	79.03a	5.25b	17.40c	120.63
Hill	168.83d	252.23d	52.57c	5.85a	26.86a	101.27
CV (%)	2.26	4.22	3.57	1.84	2.55	

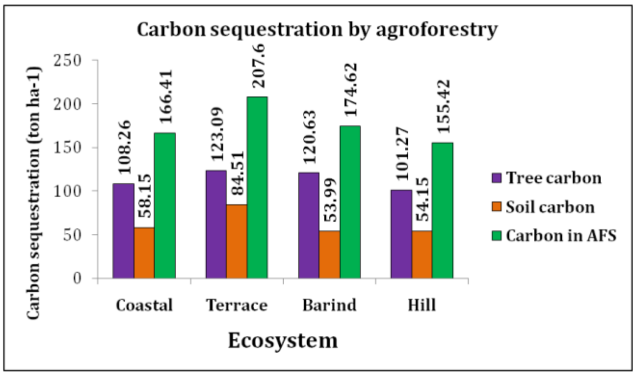

Figure 1. Total carbon stock by agroforestry system at different ecosystem.

Total carbon stock by agroforestry system: The amount of total carbon stock in agroforestry under different ecosystems were varied significantly. This might be due to various stock of trees and soil carbon. The maximum amount of carbon was recorded the tree of terrace ecosystem (123.09 tha^{-1}) followed by barind ecosystem (120.63 tha^{-1}). The lowest amount of tree carbon was recorded in hill ecosystem (101.27 tha^{-1}). In case of soil, the highest amount of carbon was recorded in terrace ecosystem soils (84.51 tha-1) followed by coastal ecosystems soil (58.15 tha-1). On the other hand, the least soil carbon was found in barind ecosystem (53.99 tha^{-1}) which was statistically similar to that of hill (54.15 tha^{-1}) ecosystem. Total carbon was estimate by summing the carbon of tree and the carbon of soil (Fig. 1). Significantly the total highest carbon was found in terrace ecosystem (207.60 tha^{-1}) followed by barind ecosystem (174.62 tha^{-1}). The lowest carbon stock was recorded in hill ecosystem (155.42 tha^{-1}). The moderate amount of carbon was recorded in coastal ecosystem and the value was 166.41 tha^{-1}. Many authors have been cited the carbon estimation results for different trees and ecosystems of different countries. The total carbon stock for the mixed multistoried system was 162 Mg C ha^{-1} in an experiment on the carbon stocks of three selected agroforestry systems located within the Province of Bukidnon, Philippines. This was almost higher than that of a second-growth forest in the General Nakar side of the Kaliwa Watershed with carbon stock of 151 Mg C ha^{-1} (Lasco *et al.* 2007). Carbon stock for the falcata-coffee multistoried system amounted to 92 Mg C ha^{-1} which is higher than that of a computed value of a 4-year old *Paraserianthes falcataria* pure stands in Manupali watershed in Bukidnon using Uriarte and Pinol's model equation (Shively *et al* 2004). Gordon and Thevathasan (2005) reported net additions of 0.99 Mg C ha^{-1} $year^{-1}$ in a popular based silvopastoral system and a ryegrass prairie in southern Canada, in agreement with the values indicated for the silvopasture and prairie. Kunhamu *et al.* (2009) reported an average litter-fall production of 11.18 Mg ha^{-1} for 9 year old *Acacia mangium* trees (stand density 1,600 trees ha^{-1}).

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