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Contribution of *Mangifera indica* L. in carbon storage of the Rajshahi University campus of Bangladesh

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Abstract
Mangifera indica L. is one of the most important horticultural crops in Bangladesh. The contribution *Mangifera indica* in the agricultural economy sector is increased day by day at a geometrical rate. Monoculture plantation was investigated to find out the carbon stocks in different ages of *Mangifera indica*. A systematic sampling method using Global Positioning Systems and a non-destructive method was used for estimation of tree biomass and carbon. The maximum, minimum and mean biomass were 1332.84, 463.40 and 922.04 kg/tree found in 20 to 55 years old trees. The highest, lowest and mean values of above ground carbon, belowground carbon and mean carbon were 0.56, 0.18, 0.37, 0.11, 0.05, 0.09, 0.76, 0.23 and 0.46 t/tree respectively. The study showed that maximum, minimum and mean values of above ground biomass, below ground biomass and total biomass were 28.17, 13.15, 21.05, 4.97, 2.31, 3.70, 3314, 15.46 and 24.76 t ha^{-1} in 20 to 55 years old trees respectively. The maximum, minimum and mean carbon were 16.76, 7.73 and 12.40 tha^{-1} in different ages in 20 to 55 years old trees. The total biomass and carbon were increased with increasing of ages and statistical analysis showed that biomass carbon stocks were varied significantly ($p<0.05$) among different ages of trees. The study indicated that carbon storage capacity of *Mangifera indica* was higher than other horticultural fruit trees. *Mangifera indica* is the most famous horticultural crop in north west parts of Bangladesh due to well adaptability, sustainability and drought tolerant capacity. So, *Mangifera indica* can be selected for the implementation of massive plantation program of the horticultural sectors.

Keywords: Allometric Equations, Biomass, Mango, Organic Carbon, Storage, Warming

1. Introduction

The worldwide population will be 9.10 billion by 2050, which will be 34 % higher than the present population (UN, 2019) [25] and food demand will be enhanced for the rising population. In this case, horticultural crop production should be emphasized for meeting their essential food demand (Sharma *et al*., 2021). The mean global temperature of the land and the ocean showed a warming of 0.85^0C (Wolf *et al*., 2017) [27]. The main cause of this situation is anthropogenic interference (Hartmann *et al*., 2013) [9]. There is evidence that food systems might be risk due to climate change (Wheeler and Von Braun, 2013) [26]. However, consequences are less in developed countries, but climate change will directly impact on food security in developing countries to hunger and malnutrition (Hartmann *et al*., 2013) [9]. The emissions of greenhouse gas (GHG) is increasing day by day in the world and many practices are introduced to control the emission of these gases. Plantation and conservation of trees is the best way to reduce global warming such as; fruit orchards and agroforestry (Kumar *et al*., 2020; Sarkar *et al.*, 2021 [16]). It may be a vital solution to reduce the emission of harmful gases and has many positive effects on the environment, which is known as climate-smart cultivation (Chakraborti, 2017) [4]. Usually, Fruit cultivation is considered a potential tool for good agricultural practices and helps to reduce the impact of climate change (Jhalegar *et al.*, 2012) [11]. In this process, the combination of trees increases productivity, improves the nutrient cycle and maintains the ecological balance (Rai *et al*., 2021; Sheikh *et al*., 2021) [14, 19]. The perennial fruit orchards play a vital role in reducing CO_2 from the atmosphere like forests (Thakur *et al*., 2021) [24]. Scientists observed that the carbon storage levels in *Mangifera indica* similar to terrestrial forest ecosystems (Ganeshamurthy *et al*., 2016; Tamang *et al*., 2021) [7, 23].

Mangifera indica is one of the most important fruit crop of Bangladesh and cultivation is increasing day by day due to its economic important, well tolerant, High nutritional value, rich in vitamin, delicious taste and excellent flavor. The estimation of carbon of fruit trees is an urgent need for extension of horticultural orchards in Bangladesh. Therefore, the present study is an attempt to estimate the carbon storage of planted *Mangifera indica* in the Rajshahi University campus area which will be helpful to the planters and contribute to reduce climate change mitigation.

2. Materials and methods

Study area

The study was conducted in the Rajshahi University campus. The campus is located at Motihar thana under Rajshahi district. The campus is situated about 5 km south of the Rajshahi town and nearby the Dhaka- Rajshahi Highway Road. The Rajshahi University campus lies between 24°37´45″-24°35´30″ North latitudes and 88° 63´70 ″-88° 60´ 40 ″ East longitudes. (Fig 1). The elevation of the study area is 22.01 meters above mean sea level (MSL).

Climatic condition

The study area has a tropical wet and dry or savanna climate with low rainfall. The mean maximum and minimum temperature is 32.42° and 22.91°C respectively. The study area receives about 94.94 mm of precipitation and 127.54 days with rain. The average humidity is 59.11% and the driest, coldest, warmest and wettest months are December, January, April and July respectively (Weather Department, 2021).

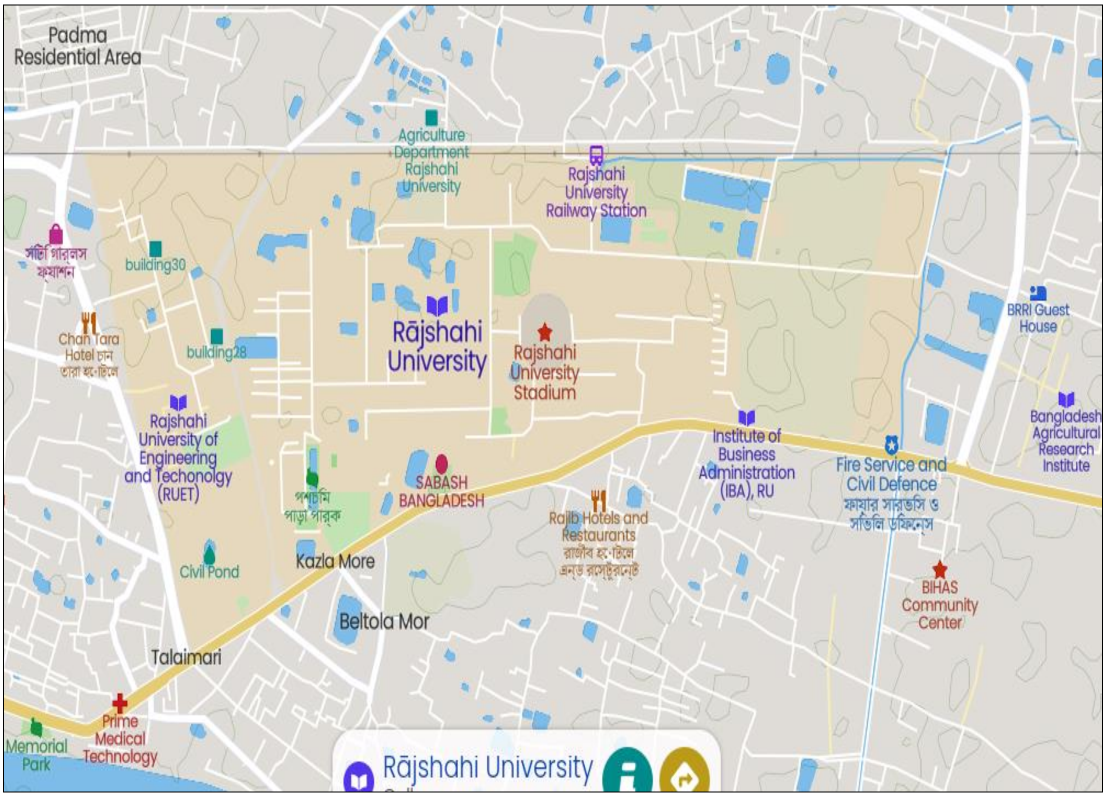

Fig 1: Map of the study area

Vegetation

The campus area is covered by various planted timber tree species. The planted species are mainly, *Mangifera indica, Azadirachta indica*, *Swietenia mahagoni*, *Polyalthia longifolia*, *cocos*, *nucifera*, *Albizia lebbeck*, *Albizia richardiana*, *Lagerstroemia speciosa*, *Michelia champaca*, *Eucalyptus camaldolensis*, *Samanea saman*, *Artocarpus heterophyllus*, *Delonix regia*, *Caesalpinia pulcherrima* and *Citrus maxima* etc. Besides, there are many kinds of indigenous and exotic species planted in the campus area. The campus of Rajshahi University is fall under the tropical region and evergreen and semi- evergreen tree species are the dominant of the study area.

Selection of plots and sub-plots

The main aim of the study was to estimate the carbon storage of *Mangifera indica* which will be helpful to the planters and reduce climate change mitigation. The study was carried out in the period of January 2022 to June 2022. The coordinates were recorded using the Global Positioning System (GPS) and the map of the research region was located using the Geographical Information System (GIS). A systematic sampling method was used for the selection of each plot with the help of Global Positioning System which is recognized all over the world. (Pearson *et al.*, 2007) [13]. Each plot was 100 meters apart from each other. Four sub-plots (20 m radius) were set at 100 m intervals from the center of each plot in north-south and east-west directions. The total numbers of the plots were 213 (two hundred thirteen) and sub-plots 852 (eight hundred fifty-two). Although the minimum sampling intensity (number of plots per hectare) required for such studies was suggested to be 1 % by Rana *et al.* (2012) [15], but more than 20 % were taken in the present study. After laying out of the plots, the number of trees in each plot were counted, identified and recorded. The trees were measured for height and diameter at breast height (DBH). Each tree was marked and numbered to prevent double counting. A diameter tape was used to measure the DBH (1.30 m above from the ground level) of all the trees in each plot. Height of the trees having DBH equal or greater than 5 cm was measured with a Hega-altimeter. Trees on the border was included in a plot if > 50 % of their basal area fell within the plots and excluded if < 50 % of their basal area fell outside the plot. Trees overhanging to the plots were excluded, but with their trunk inside of the sampling plots, and branches out were included. Care was taken to ensure that the diameter tape is put around the stem exactly at the point of measurement.

Estimation of trees biomass

A non-destructive method was used to measure the aboveground biomass of an individual tree. The model of Brown *et al.* (1989) [2] was used to determine the AGB of each tree from its height and DBH values. This method is taken to be one of the most suitable methods for biomass estimation in tropical forests (Alves *et al*., 1997; Brown, 1997; Schroeder *et al.*, 1997) [1, 3, 22].

The model for aboveground biomass is as follows.

$$AGB=\exp.\{-2.4090+0.9522\ln(D^2HS)\}$$

Where,

AGB is the aboveground biomass (kg),

H is the height of the trees (m),

D is the diameter at breast height (cm),

S is the wood density (kg /m^3) for specific species.

Wood density values of the species of the present study were obtained from Sattar *et al*. (1999) [17].

Aboveground biomass per plot, per track and per hectare were calculated by the following formulas:

AGB per plot = Summation of the AGB values of all the trees in a plot.

AGB per track = Summation of AGB values of all the plots in a track.

$$\text{AGB per hectare} = \frac{\text{Sum of AGB values of all the plots in a track}}{\text{Total area of all the plots in a track}} \times 10,000$$

BGB was considered to be 15 % of the aboveground biomass as suggested by Mac Dicken (1997) [12]. The formula is given below:

$$BGB = AGB \times (15 / 100)$$

The aboveground and belowground biomass was added to get the total biomass of a tree. Total biomass (TB) per plot, per track and per hectare were calculated by the following formulas:

TB per plot = Summation of the total biomass values of all the trees in a plot.

TB per track = Summation of the total biomass values of all the plots in a track.

$$\text{TB per hectare} = \frac{\text{Sum of total biomass values of all the plots in a track}}{\text{Total area of all the plots in a track}} \times 10,000$$

Data analysis

Descriptive statistics were calculated to describe biomass and carbon in trees. Analysis of variance (ANOVA) was done at different age aspects. Duncan's multiple range tests were used to determine the significance of the variation in the mean. Statistical Package for Social Science (SPSS) version 21 was used to perform these analyses.

3. Results and discussion

The above ground biomass and below ground biomass of trees were estimated on the basis of the diameter at breast height, height and wood density. The study revealed that maximum, minimum and average above ground biomass were 1110.70, 386.17 and 768.38 kg/tree respectively (Table 1). The highest, lowest and mean below ground biomass were 221.14, 77.23 and 153.67 kg/tree in 20 to 55 years old trees (Table 1). The study revealed that maximum, minimum and mean biomass were 1332.84, 463.40 and 922.04 kg/tree in 20 to 55 years old trees. Below ground biomass is a part of total biomass and only 20 % biomass was added to get total biomass. Finally, total biomass was calculated on the basis of numbers of tree and expressed on t ha^{-1}. In this case, the study showed that maximum, minimum and mean values of above ground biomass below ground biomass and total biomass were 28.17, 13.15, 21.05, 4.97, 2.31, 3.70, 3314, 15.46 and 24.76 t ha^{-1} in 20 to 55 years old trees respectively (Table 1).

Table 1: Above ground biomass, below ground biomass and total biomass of *Mangifera indica*

Age (years)	AGB (kg/tree)	BGB (kg/tree)	TB (kg/tree)	AGB (t/ha)	BGB (t/ha)	TB (t/ha)
55	1110.70	222.14	1332.84	28.17	4.97	33.14
50	1053.30	210.70	1264.10	26.69	4.71	31.40
45	952.02	190.40	1142.42	24.82	4.30	29.20
40	846.09	169.20	1015.29	22.97	4.05	27.02
35	691.24	138.20	829.44	20.35	3.59	23.94
30	614.19	122.80	736.99	17.53	3.09	20.62
25	493.31	98.66	591.97	14.73	2.59	17.32
20	386.17	77.23	463.40	13.15	2.31	15.46
Mean	768.38	153.67	922.04	21.05	3.70	24.75

The highest amount of biomass was found in 55 years old trees and the lowest value was found in 20 years old trees. Biomass was increased with increasing of ages and their growth patterns were diversified. The experiment was conducted on the same environment and management practices were also equal. Many scientists worked on the above ground tree biomass in different states of India and they observed that the above ground biomass ranged from 776.90 to 1574 kg/tree and on an average value was 1123.39 kg/tree (Ganeshamurthy *et al.*, 2019) [8]. The below ground biomass ranged from 234.30 to 474 kg/tree with average values was 338.80 kg/tree. Their total biomass values were higher than the present findings. Total biomass values depended on genotype, tree age, planting density and input additions (Ganeshamurthy *et al*., 2019) [8]. Their orchards were more than 25 years old and tree density was also satisfied. The present study revealed that tree diameter, height and density were low due to lack of proper management which was the most important factor. A study was conducted by Chavan and Rasal (2011) [6] in the University campus of Aurangabad and found that above ground, below ground and total standing biomass of *Mangifera indica* were 32.31, 8.40 and 40.71 tha^{-1} which was higher compared to the present findings.

The main focus of the study was to find out the total organic carbon of *Mangifera indica* of different ages in the Rajshahi University campus area. In this case, the findings showed that the highest, lowest and mean values of above ground carbon, belowground carbon and total carbon were 0.56, 0.18, 0.37, 0.11, 0.05, 0.09, 0.76, 0.23 and 0.46 t/tree in 20 to 55 years old trees respectively (Table 2). The final results were expressed on t ha^{-1} and maximum carbon was 16.76 tha^{-1} in 55 years old tree which was the summation of above ground carbon and below ground carbon. In the same way the minimum carbon was 7.73 t ha^{-1} and their mean carbon was also 12.40 t ha^{-1}. The total carbon was increased with increasing of ages and statistical analysis revealed that carbon stocks were varied significantly ($p<0.05$) among 20, 25, 30, 35, 40, 45, 50, 55 years old trees.

Table 2: Above ground carbon, belowground carbon and total carbon of *Mangifera indica*

Age (years)	AGC (t/tree)	BGC (t/tree)	TC (t/tree) (t/tree)	AGC tha^{-1}	BGC tha^{-1}	$tCha^{-1}$
55	0.56	0.11	0.67	14.26	2.49	16.75
50	0.53	0.12	0.63	13.34	2.36	15.70
45	0.46	0.11	0.57	12.45	2.15	14.60
40	0.41	0.10	0.51	11.48	2.03	13.51
35	0.33	0.08	0.41	10.17	1.80	11.97
30	0.30	0.07	0.37	8.77	1.54	10.31
25	0.24	0.06	0.30	7.36	1.30	8.66
20	0.18	0.05	0.23	6.58	1.15	7.73
Mean	0.37	0.09	0.46	10.55	1.85	12.40

Chavan and Rasal (2011) [6] estimated that the total organic carbon was 30.60 t ha^{-1} in *Mangifera indica* of the Aurangabad University campus area. In this case, their results were two and half times more than the present findings. Several scientists compared to sequester the carbon storage capacity of Mangifera indica with other forest trees and found that its carbon storage capacity was higher than the following forest species such as: *Artocarpus integrifolia, Albizia lebbeck, Shorea robusta, Tectona grandis* were 7.28, 6.26, 5.22 and 7.97 tCha-1 respectively (Jana, 2009; Chava 2011) [10, 6]. Chavan and Rasal (2012) [5] also observed that the organic carbon was 56.35 tha^{-1} in *Mangifera indica* in Maharashtra of India. *Mangifera indica* sequestered 6.58 t carbon/tree in 41 years old plantation, whereas 11 years *Mangifera indica* sequestered only 5.9 kg carbon per tree in Sarlahi, Nepal. Similarly, *Litchi chinensis* tree had sequestered 75 kg/tree carbon in its total biomass. On an average carbon stock of 53.5 kg/tree was found in 14 years old of *Litchi chinensis*. *Aegle marmelos* was able to sequester 44 kg carbon/tree in 14 years old plantation (Shrestha and Malla 2016) [21]. Scientists (Shinde *et al.*, 2015) [20] worked on carbon sequestration capacity of fruit tree species and reported that average above ground biomass and below ground biomass of *Mangifera indica, Cocos nucifera, Psidium guajava* were 137.71, 145.16, 69.20 and 35.80, 37.74, 18.99 kg /tree respectively in 10 to 15 years old plantation. The average biomass and carbon were 173.51, 183.40 and 87.19 kg/tree in 10 to15 years old plantation. A study was conducted in China by Wu *et al. (*2012) [28] and observed that carbon storage capacity of *Pyrus malus* was 14 t C ha^{-1} in 18 to 22 years old plantation. Scientists (Selvaraj *et al.*, 2016) [18] worked on estimation of organic carbon storage in fruit orchards and observed that the total standing carbon, 0.93 to 40.37tC ha^{-1} in *Mangifera indica* from 5 to 20-year orchards, 8.97 to 182.93 t C ha^{-1} in *Tectona grandis* plantation, 1.43 to 12.22 t C ha^{-1} in *Manikara zapota* orchards and 4.57 to 142.84 t C ha^{-1} in *Cocos nucifera* coconut trees were recorded. The highest total standing biomass was recorded in *Tectona grandis* followed *Tectona grandis, Mangifera indica Cocos nucifera* and *manikara zapota*. Whereas the standing biomass per tree of *Tectona grandis, Mangifera indica Cocos nucifera* and *manikara zapota* contained 0.37, 0.36, 0.154 and 1.14 t/tree respectively in 20 years. The total carbon values depended on species, age, diameter, height and density of trees. Besides, *Mangifera indica* was also influenced by genotypic quality, edaphic and climatic conditions. The study showed that the tree density varied among different locations. The average carbon storage of the present study was lower than the above value. Tree height, diameter and density were also higher than the present study. Management and high yielding variety should be developed for increasing of higher carbon storage in *Mangifera indica*.

4. Conclusion

Many kinds of fruit orchards have shown their potentiality of carbon sequestration and play a vital role in improving to reduce CO_2 from the atmosphere. *Mangifera indica* is one of the most important fruits tree for carbon sequestration in view of geographical condition. The findings of the present study will help to estimate the carbon storage from fruit orchards in the future under CO_2 enrichment and global warming. Many kinds of fruit trees are planted in the horticultural sectors every fiscal year to maintain fruit demand. So, *Mangifera indica* should be selected for massive plantation program implementation in Bangladesh due to well adaptability, drought tolerant capacity and more carbon storage capacity. The present findings of the study will be helpful to administrators and policy makers for selection of *Mangifera indica* species for increasing cultivation and reduce global warming.

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6. References

1. Alves DS, Soares JVS, Amaral EMK, Mello SAS, Almeida O, Fernandes S, *et al*. Biomass of primary and secondary vegetation in Rondonia, Western Brazilian Amazon. Global Change Biol. 1997; 3(5):451-462.
2. Brown S, Gillespie AJ, Lugo AE. Biomass estimation methods for tropical forests with applications to forest inventory data. Forest Science. 1989; 35(4):881-902.
3. Brown S. Estimating biomass changes of tropical forests: A primer, FAO Forestry Paper 134 eds. Food and Agriculture Organization (FAO UN), Rome, Italy, 1997.
4. Chakrabarti S. The Nutrition Advantage: Harnessing Nutrition Co-benefits of Climate-Resilient Agriculture," in IFAD Advantage Series, Rome, September, 2017 (Rome IFAD), 2017, 1-49.
5. Chavan B, Rasal G. Total sequestered carbon stock of Mangifera indica. Journal of Environment and earth science. 2012; 2(1):37-45.
6. Chavan B, Rasal G. Potentiality of carbon sequestration in six-year ages young plant from university campus of Aurangabad. Global Journal of Researches in Engineering. 2011; 11(7):15-20.
7. Ganeshamurthy AN, Ravindra V, Panneslvam P, Sathyarahini K, Bhatt RM. Conservation horticulture in

mango orchards: Comparative conservation management practices on soil properties of an Alfisols under seasonally dry tropical savanna climate, J. Agri, Sci. 2016; 8(12):1-16.
8. Ganeshamurthy AN, Ravindra V, Rupa TR, Bhatt RM. Carbon Sequestration Potential of Mango Orchards in the Tropical Hot and Humid Climate of Konkan Region, India. Current Science. 2019; 116(8):1417-1423.
9. Hartmann DL, Tank AMGK, Matilde Rusticucci LRR, Bronnimann S, Abdul Rahman Charabi Y, Dentener FJ. Observations: Atmosphere and Surface. In Climate Change 2013 the Physical Sciences Basis: Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. United Kingdom: Cambridge University Press, 2013, 154-254.
10. Jana BK, Biswas S, Majumder M, Roy PK, Mazumdar A. Carbon sequestration rate and above ground biomass carbon potential of four young species. Journal of Ecology and Natural Environment. 2009; 1(2):15-24.
11. Jhalegar MJ, Sharma RR, Pal RK, Rana V. Effect of Postharvest Treatments with Polyamines on Physiological and Biochemical Attributes of Kiwifruit (*Actinidia Deliciosa*) Cv. *Allison. Fruits*. 2012; 67(1):13-22.
12. Mac Dicken KG. A guide to monitoring carbon storage in forestry and agro forestry projects USA. Winrock Int. Institute Agri. Development, 1997, 19-99.
13. Pearson RG, Raxworthy CJ, Nakamura M, Pterson A. T. Predicting species distributions from small numbers of occurrence records: A test case using cryptic geckos in Madagascar. Journal of Biogeography. 2007; 34(1):102-117.
14. Rai P, Vinceta G, Shukla G, Manohar KA, Bhat HA. Carbon Storage of Single Tree and mixed Tree Dominant Species Stands in a Reserve Forest –Case study of the eastern Sub- Himalayan Region of India. Land. 2021; 10(4):345-352.
15. Rana BS, Singh SP, Singh RP. Biomass and net primary productivity in Central Himalayan forests along an altitudinal gradient. Forest Ecology and Management. 2012; 27(3-4):199-218.
16. Sarkar PK, Sarkar P, Kumar A, Pala NA, Kumar M. Carbon Storage Potential of a Waterlogged Agroforestry System of Tripura, India. Water Air and Soil Pollution. 2021; 232:151-164.
17. Sattar MA, Bhattacharjee DK, Kabir MF. Physical and mechanical properties and uses of timber of Bangladesh. Report 57, Seasoning and Timber Division, Bangladesh Forest Research Institute Chittagong, Bangladesh, 1999.
18. Selvaraj A, Jayachandan S, Thirunavukkarasu DP, Jayaraman A, Karuppon P. Carbon sequestration potential, physicochemical and microbiological properties of selected trees *Mangifera indica* L., *Manilkara zapota* L., *Cocos nucifera* L. and *Tectona grandis* L. Bioscience Discovery. 2016; 7(2):131-139.
19. Sheikh MA, Kumar M, Todaria NP, Bhat JA, Kumar A, Pandey R. Contribution of *Cedrus Deodara* Forests for Climate Mitigation along Altitudinal Gradient in Garhwal Himalaya, India. Mitigation Adaptation Strategy. Global Change. 2021; 26(1):1-19.
20. Shinde SM, Turkhade PD, Deshmukh SB, Narkhede GW. Carbon sequestration potential of some fruit trees in Satara district of Maharashtra India, Ecol. Env. & Cons. 2015; 21(1):359-362.
21. Shrestha G, Malla G. Estimation of atmospheric carbon sequestration by fruit plants in mid-western terai region Nepal. Nepalese Journal of Agricultural Sciences. 2016; 14:211-215.
22. Schroeder P, Brown S, Mo J, Birdsey R, Cieszewski C. Biomass estimate for temperate broadleaf forests of the US using inventory data. Forest Science. 1997; 43(3):424-434.
23. Tamang M, Chettri R, Vineeta G, Shukla G, Bhat JA, Kumar A, *et al.* Stand Structure, Biomass and Carbon Storage in *Gmelina arborea* Plantation at Agricultural Landscape in Foothills of Eastern Himalayas. Land. 2021; 10(4):387-402.
24. Thakur U, Bisht NS, Kumar M, Kumar A. Influence of Altitude on Diversity and Distribution Pattern of Trees in Himalayan Temperate Forests of Churdhar Wildlife Sanctuary, India. Water Air and Soil Pollution. 2021; 232(5):205-217.
25. UN. World Population Projected to Reach 9.8 Billion in 2050, and 11.2 Billion in 2100. Department of Economic and Social Affairs, 2019.
26. Wheeler T, Von Braun J. Climate Change Impacts on Global Food Security. Science. 2013; 341:508-513.
27. Wolf E, Arnell N, Friedlingstein P, Gregory J, Haigh J, Haines A, *et al*. Climate Updates: What Have We Learnt since the IPCC 5th Assessment Report ? 2017, 1-36.
28. Wu T, Wang Y, Yu C, Chiarawipa R, Zhang X, Hang Z, Wu L. Carbon Sequestration by Fruit Trees - Chinese Apple Orchards as an Example. PLoS ONE. 2012; 7(6):1371-1383.