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An Assessment of Seasonal Variation of Carbon Emission and Carbon Sequestration in Rural Areas of Belagavi District, Karnataka

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Introduction: Carbon emission cause climate change by trapping heat and they also contribute to respiratory disease from smog and air pollution. Therefore, reducing carbon emission is important because it mitigates the effects of global climate change, improves public health and maintains

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biodiversity. In carbon sequestration process atmospheric carbon is taken up by trees, grasses and plants through photosynthesis.
Aim: Analyse the carbon emissions and estimate the carbon sequestration.
Methodology: The study was conducted at Golihalli and Bidi village of Belagavi district, Karnataka in India to measure the carbon emission level through Air Quality Monitor and CO meter for one year. The carbon sequestration was assessed by non-destructive method.
Results: An annual mean concentration of CO_2 in Golihalli village was 924.33 ppm while in Bidi village 929.9 ppm and also the mean concentration of CO was 25.7 ppm in Golihalli village whereas 25.8 ppm in Bidi village. The mean concentration of $PM_{2.5}$ was 57.8 μm^3 and PM_{10} was 107.5 μm^3 in Golihalli village however $PM_{2.5}$ was 57.9 μm^3 and PM_{10} was 108 μm^3 in Bidi village. During the observation period, the maximum carbon emission concentration was measured in summer season and the minimum in rainy season. The largest value of carbon sequestration was seen in *Tamarindus indica* (530.22 gm) in Bidi village and *Azdirachta indica* (519.77 gm) in Golihalli village.
Conclusion: The carbon emission concentration was exceeding the safe level in both villages because of rural people’s day-today activities and vehicular pollution. The trees with higher age and DBH have more carbon sequestration which could help in mitigate the effects of carbon emitted in the village.

Keywords: Carbon dioxide (CO2); carbon emission; Carbon Monoxide (CO); carbon sequestration; Diameter at Breast Height (DBH); Particulate Matter (PM2.5 and PM10).

1. INTRODUCTION

The problem of carbon emission has become very serious today. It refers to the very bad condition of environment in terms of quantity and quality. Carbon emission is the release of carbon into the atmosphere which cause climate change, global warming, melting of the polar ice caps, rising of sea levels by trapping heat. The amount of carbon emission in the atmosphere has increased due to the industrial revolution. Global carbon emissions were 150 times increased from 1850 (198 Mt) to 2011 (32274 Mt) due to industrialization and population growth. Our India is the third largest carbon emitter after China and the US [1].

The main sources of carbon emission are both natural and man-made sources. Natural sources include decomposition, volcanoes, wildfires, respiration etc. Man-made sources include industries, deforestation, transportation, soil cultivation, biomass burning etc. [2]. Carbon emission pollutants can either be particles, liquids or gaseous in nature. In developing countries of Asia, people have exposure to carbon emission that is largely caused by particulate matter (PM), Carbon dioxide (CO_2) and Carbon monoxide (CO) [3].

The particulate matter is an atmospheric carbon particle which is a mixture of solid particles and liquid droplets found in the air. Some particles such as dust, dirt, soot, smoke, large and dark enough to be seen with the naked eye. Particulate matter ($PM_{2.5}$) and particulate matter (PM_{10}) are more dangerous particles which effects to cardiovascular and respiratory systems [4]. Carbon dioxide is an important heat-trapping (greenhouse) gas, which is released through natural process respiration, combustion and metabolic activity. It can lead to headache, dizziness, sweating, restlessness, tiredness, difficulty in breathing, increased heart rate and blood pressure.

Carbon monoxide is an odorless, colorless, tasteless and toxic air pollutant formed by the incomplete combustion of carbon containing fuels. The low concentration of carbon monoxide can cause fatigue and chest pain. The higher concentration of carbon monoxide can cause impaired vision, headache, dizziness and nausea. The prolonged exposure of carbon monoxide can cause memory problems, difficulty in concentrating and even death [5]. Other pollutants like Nitrogen dioxide (NO_2) and Sulfur dioxide (SO_2) are heavy and poisonous gas formed by fuel burning which irritates the respiratory tract, coughing, asthma and chronic lung disease [2].

Reducing carbon emission is important because it mitigates the effects of global climate change, improves public health, boosts the global economy and maintains biodiversity. Current strategies for coping with carbon emission include reducing fossil fuel combustion as well as curbing emission of other GHGs and increasing carbon sequestration [6]. One of the easiest ways to reduce the carbon emission concentration in the atmosphere is carbon sequestration.

Carbon sequestration is a natural or artificial process by which carbon is removed from the atmosphere and held in solid or liquid form. It is the process of capturing and storing atmospheric carbon. In this process atmospheric carbon is taken up by trees, plants and other grasses through photosynthesis and stored as carbon in biomass (trunks, branches, foliage and roots) and soil. The carbon sequestration capacity of trees depends upon its age, height, girth size, diameter at breast height and biomass [7]. Planting trees which sequestrate carbon in large amount will reduce the atmospheric carbon emission [8]. Hence, the present study was to analyse the carbon emissions and to estimate the carbon sequestration influenced by the microclimate in the Golihalli and Bidi village of Belagavi district, Karnataka, India.

2. MATERIALS AND METHODS

2.1 Study Area

The measurement of carbon emission and carbon sequestration has been carried out in Golihalli and Bidi village of Belagavi district, Karnataka, India [Fig. 1].

2.2 Sampling Design for Measurement of Carbon Emission

The selected parameters were horizontally measured at centre of the village, in a range of 100 m, 200 m, 300 m, 400 m, 500 m away from the centre of the village and 200 m away from the last house of the village in all four directions (North, East, West and South) [Fig. 2].

The selected parameters like temperature, relative humidity, Carbon dioxide (CO_2), Particulate Matter ($PM_{2.5}$) and Particulate Matter (PM_{10}) were measured by Air Quality Monitor and Carbon monoxide (CO) were measured by CO meter for one year from October 2021 to September 2022 [Fig. 3].

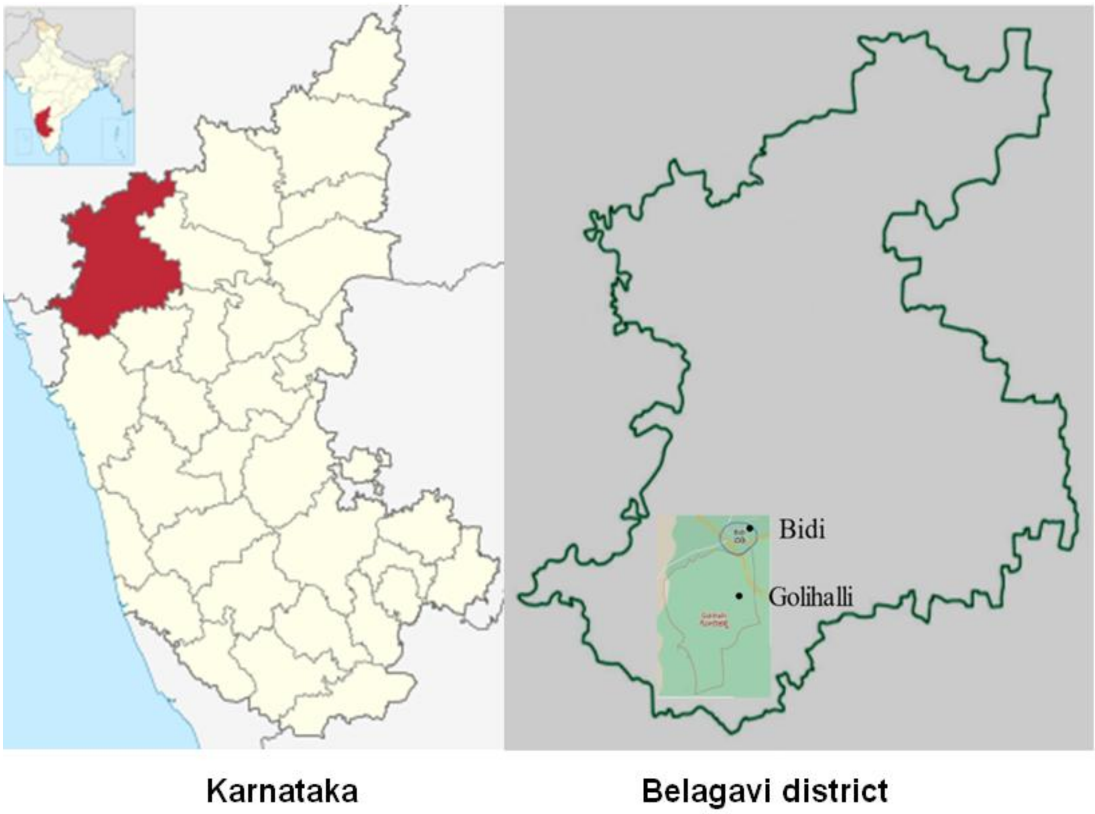

Fig. 1. Golihalli and Bidi village in Belagavi district of Karnataka, India

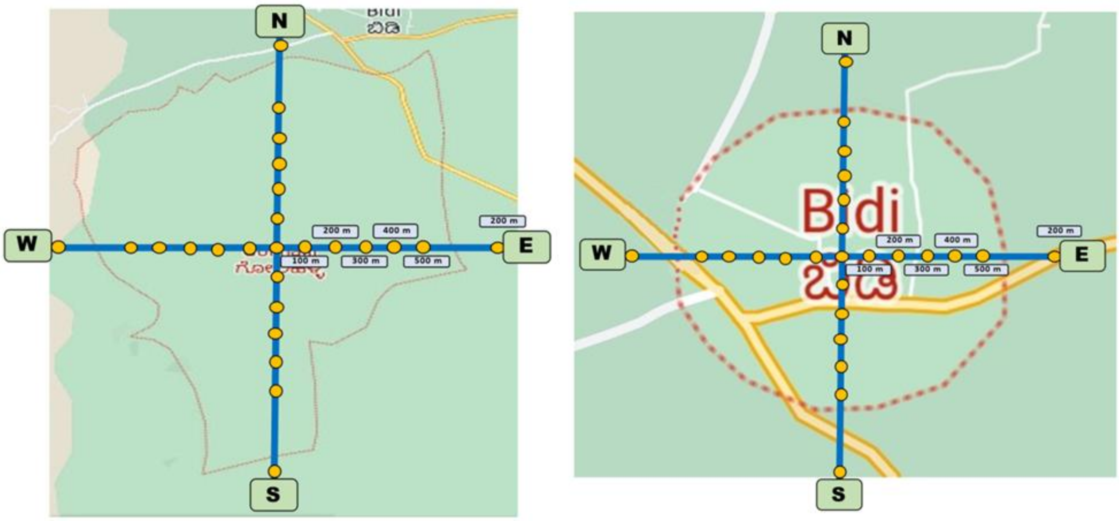

Fig. 2. Horizontal measurement at Golihalli and Bidi village

Fig. 3. Monitoring instruments

Fig. 4. Quadrate method

2.3 Sampling Design for Estimation of Carbon Sequestration

The carbon sequestration was assessed by non-destructive method which was estimated through calculating the biomass. The amount of carbon was measured based on the amount of standing woody biomass of trees in Golihalli and Bidi village of Belagavi district. Initially the trees were sampled by quadrate method. Quadrates of size 10 x10 m were taken at centre of the village, in a range of 300 m and 600 m away from the centre of the village in all four directions (North, East, West and South) [Fig. 4].

A non-destructive method of biomass estimation was used to measure the tree height and Girth at Breast Height, approximately 1.3 m from the ground by measuring tape. A brief description of the used formulae for carbon sequestration estimation in the analysis is given below:

- Diameter at Breast Height (DBH) = $\frac{\text{Girth at Breast Height}}{\pi}$
- Above Ground Biomass (AGB) = Volume x Wood density
  Volume = μhr^2
  Wood density = 0.6 gm/cm (0.06 kg/m3)
- Below Ground Biomass (BGB) = AGB X 0.26
- Total Biomass = AGB + BGB
- Carbon Storage = Biomass X 50 %
- Carbon Sequestration= Carbon Storage X 3.66

2.4 Statistical Analysis

The statistical variations in temperature, relative humidity, carbon dioxide, carbon monoxide, particulate matter ($PM_{2.5}$) and particulate matter (PM_{10}) between seasons were assessed through one-way ANOVA. A regression analysis was performed to study the relationship between age of trees and carbon sequestration and also DBH of trees and carbon sequestration per village. Pearson's correlation coefficients were used to determine the strength of association between different parameters of trees such as age of tree, DBH of tree, biomass, carbon storage and carbon sequestration in trees.

3. RESULTS AND DISCUSSION

3.1 Measurement of Carbon Emission

Table 1 indicated the monthly mean concentration of carbon emission at Belagavi district for one year from October 2021 to September 2022. The annual mean temperature of Golihalli village was 26.3°C and Bidi village was 26.1°C whereas the annual mean percentage of relative humidity in Golihalli village was 63.5 per cent and in Bidi village was 64.6 per cent. The annual mean concentration of carbon dioxide in Golihalli village was 924.3 ppm while in Bidi village 929.9 ppm and also the annual mean concentration of carbon monoxide was 25.7 ppm in Golihalli village whereas 25.8 ppm in Bidi village. The annual mean concentration of particulate matter ($PM_{2.5}$) was 57.8 μm^3 and particulate matter (PM_{10}) was 107.5 in Golihalli village however particulate matter ($PM_{2.5}$) was 57.9 µm3 and particulate matter (PM_{10}) was 108 µm3 in Bidi village (Fig. 5). The carbon emission concentration was exceeding the safe level in both villages because of rural people's day-to-day activities and vehicular pollution. Similarly, an overall mean value of CO_2 concentration was higher than the global mean atmospheric CO_2 value [9]. The vertical carbon dioxide distributions were measured by Chiba et al. [10]. The CO_2 concentration in all over the India was gradually increased from the year 2010-2015 [11]. According to Singh et al. [4] Delhi had highest diurnal and monthly mean $PM_{2.5}$ concentration during the year of 2014 – 2019.

3.2 Seasonal Variation of Carbon Emission

During the observation period, the maximum mean temperature was measured in summer season that is 26.7 °C in Golihalli village and 26.5 °C in Bidi village and the temperature was minimum in rainy season that is 25.7 °C in Golihalli village and 25.5 °C in Bidi village [Fig. 6(a)]. Whereas the maximum mean percentage of relative humidity was measured in summer season that is 76.7 per cent in Golihalli village and 76.1 per cent in Bidi village and the relative humidity was minimum in rainy season that is 48.8 per cent in Golihalli village and 52.9 per cent in Bidi village [Fig. 6(b)]. The maximum mean concentration of carbon dioxide was measured in summer season that is 989.5 ppm in Golihalli village and 1007.3 ppm in Bidi village and the concentration was minimum in rainy season that is 881.5 ppm in Golihalli village and 874.5 ppm in Bidi village [Fig. 6(c)]. While the maximum mean concentration of carbon monoxide was measured in summer season that is 29.5 ppm in Golihalli village and 29.8 ppm in Bidi village and the concentration was minimum in rainy season that is 23.5 ppm in Golihalli village and 23.3 ppm in Bidi village [Fig. 6(d)].

The maximum mean concentration of particulate matter ($PM_{2.5}$) was measured in summer season that is 69.5 μm^3 in both villages and minimum in rainy season that is 48.3 μm^3 in Golihalli village and 47.8 μm^3 in Bidi village [Fig. 6(e)]. However, the maximum mean concentration of particulate matter (PM_{10}) was measured in summer season that is 126.5 μm^3 in Golihalli village and 124.3 μm^3 in Bidi village and the concentration was minimum in rainy season that is 97.8 μm^3 in Golihalli village and 96.5 μm^3 in Bidi village [Fig. 6(f)]. The maximum carbon emission concentration was measured in summer season and minimum in rainy season. Because, during rainy season the rain water can dissolves atmospheric carbon. According to Chiba et al. [10] the higher CO_2 concentration was observed during April to May and low during June to August. The tropospheric CO_2 concentration in all over the India was increased from the year 2010-2015 during September to March month and decreased during April to August month [11]. The highest mean concentration of GHGs were in pre-monsoon season and lowest in monsoon season [12]. The mean $PM_{2.5}$ concentration during the year of 2014 – 2019 was highest in the post-monsoon season and lowest in monsoon season [4].

3.3 Variation of Carbon Emission among Seasons and Villages

Table 2 shows the results obtained due to the application of one-way Analysis of Variance (ANOVA) test for different parameters based on monitoring seasons. The F value was calculated to be 14 for temperature which was found to be significant (at P<0.01) due to variation in season. Further, the F values computed as114.34, 119.19, 362.87, 1128.89 and 89.85 for relative humidity, carbon dioxide (CO_2), carbon monoxide (CO), particulate matter ($PM_{2.5}$) and particulate matter (PM_{10}) respectively due to variation in seasons were found to be highly significant (at P<0.01). This indicates that there exists a significant variation among the different parameters due to variation in seasons. Dash and Dash [2] found the PM_{10}, $PM_{2.5}$, SO_2 and NO_2 concentrations were significantly varied based on the seasonal differences in their one-way ANOVA test considering data from March 2014 to February 2015 in India. According to Kumar and Dash [13] found that, the concentration of PM_{10}, $PM_{2.5}$, SO_2 and NO_2 were found to be significant (P<0.01) due to the variations in seasons. The PM_{10} and $PM_{2.5}$ concentrations in the atmosphere were found to be significant due to different seasons, stated by Roy et al. [3].

3.4 Estimation of Carbon Sequestration

Table 3 indicated that estimated the carbon sequestration by 17 different species including 57 individual trees were assessed from Golihalli village and 16 different species including 44 individual trees were assessed from Bidi village. The estimated total biomass of the trees in Golihalli village was 0.91 kg and in Bidi village was 0.849 kg. The total carbon storage by the trees in Golihalli village was 456.74 gm and in Bidi village was 423.63 gm. The carbon sequestration of the trees in Golihalli village was 1671.62 gm and in Bidi village was 1550.52 gm. Among the 17 species, major carbon sequestrating species were *Azdirachta indica* (Neem) that is 519.77 gm/tree which had the highest average age (50 years) and DBH (0.53 m) followed by *Tamarindus indica* (Tamarind) that is 438.27 gm/tree and *Cocos nucifera* (Coconut) that is 180.39 gm/tree in Golihalli village.

Whereas among the 16 species, the major carbon sequestrating species were *Tamarindus indica* (Tamarind) that is 530.22 gm/tree which had the highest average age (47.8 years) and DBH (0.46 m) followed by *Azdirachta indica* (Neem) that is 495.4 gm/tree and *Cocos nucifera* (Coconut) that is 167.89 gm/tree in Bidi village [Fig. 7]. The trees with higher age and DBH have more carbon sequestration. As a tree grows, it stores more carbon by holding it in its accumulated tissue. Maji et al. [7] found that among road side plant species the major carbon sequestrating species were Ficus religiosa (Peepal tree) that is 86.67 gm/tree in Hooghly district of West Bengal. The Millingtonia *hortensis* (Cork tree) was sequestrated carbon in large amount (52.583 kg/tree) in VIT University campus, Vellore of Tamil Nadu [8]. The highest carbon sequestrating species were *Leucaena leucocephala* (Wild tamarind) that is 23.887 Mg/ha in the campus of Indian Institute of Management (IIFM), Bhopal of Madhya Pradesh [14]. The *Ficus benjamina* (Weeping fig) sequestrated highest amount of carbon that is 30.53 tons in Amity University Campus Noida in Uttar Pradesh [15].

Table 1. Monthly mean variation of selected parameters at Belagavi district

		Selected Parameters											
		Temperature °C		**Relative Humidity %**		**Carbon dioxide (CO_2) ppm**		**Carbon monoxide (CO) ppm**		**Particulate Matter ($PM_{2.5}$) µm^3**		**Particulate Matter (PM_{10}) µm^3**	
Seasons	**Months**	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2
Winter Season	**October**	26.9	25.9	67	63.8	841	839	20	21	50	51	92	94
	November	26.3	26.8	60.3	64.3	878	887	24	25	53	55	95	97
	December	26.1	26.2	66.5	65.8	936	941	26	25	55	57	102	113
	January	26.9	25.9	65.9	65.4	953	965	26	27	64	63	104	109
Average		**26.6**	**26.2**	**64.9**	**64.8**	**902**	**908**	**24**	**24.5**	**55.5**	**56.5**	**98.3**	**103.3**
Summer Season	**February**	26.3	26.5	66.6	65.7	969	989	27	28	65	66	119	115
	March	26.5	26.2	79.6	78.8	967	1003	28	29	67	69	127	123
	April	27.2	26.8	81.8	82.3	1029	1039	34	34	78	76	138	135
	May	26.8	26.3	78.8	77.9	993	998	29	28	68	67	122	124
Average		**26.7**	**26.5**	**76.7**	**76.1**	**989.5**	**1007.3**	**29.5**	**29.8**	**69.5**	**69.5**	**126.5**	**124.3**
Rainy Season	**June**	25.7	25.6	56.6	64.3	981	989	26	27	56	58	117	112
	July	25.9	25.4	44.4	56.6	882	872	24	24	49	46	96	97
	August	25.3	25.3	52.5	48.4	874	859	23	22	47	44	91	93
	September	25.7	25.7	41.7	42.3	789	778	21	20	41	43	87	84
Average		**25.7**	**25.5**	**48.8**	**52.9**	**881.5**	**874.5**	**23.5**	**23.3**	**48.3**	**47.8**	**97.8**	**96.5**
Annual		**26.3**	**26.1**	**63.5**	**64.6**	**924.3**	**929.9**	**25.7**	**25.8**	**57.8**	**57.9**	**107.5**	**108**

V_1: Golihalli village, V_2: Bidi village

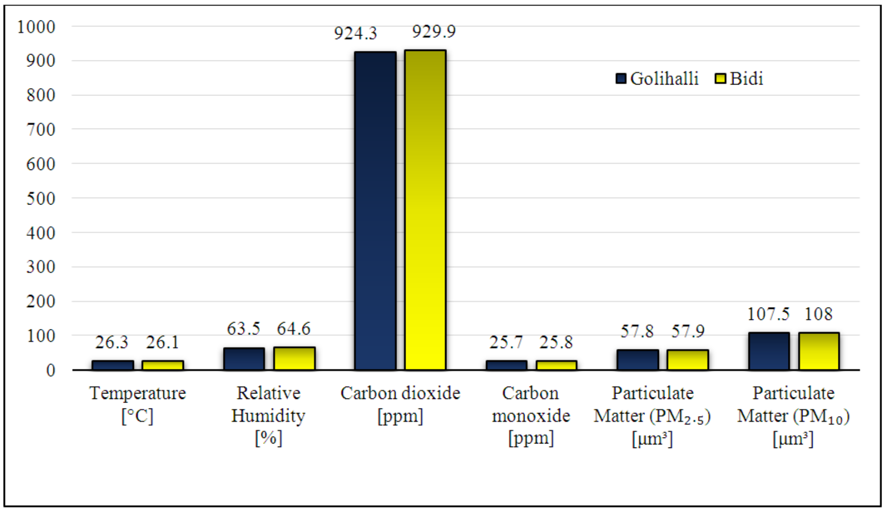

Fig. 5. Annual mean concentration of carbon emission

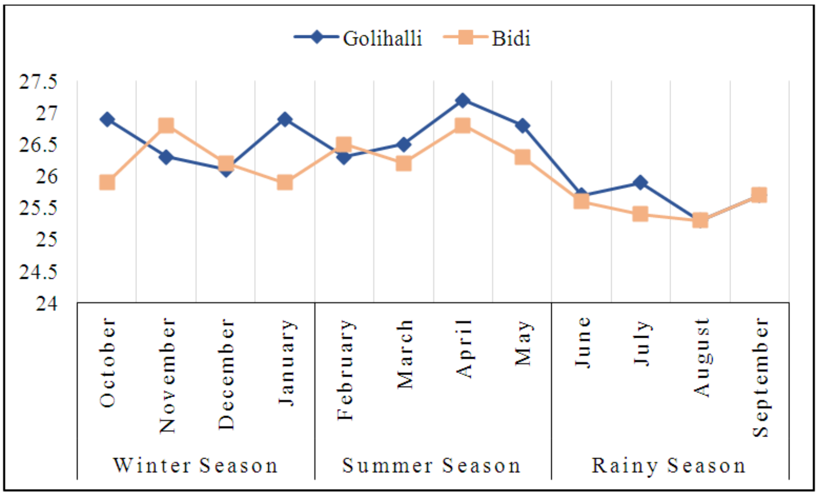

Fig. 6(a). Monthly mean variation of temperature

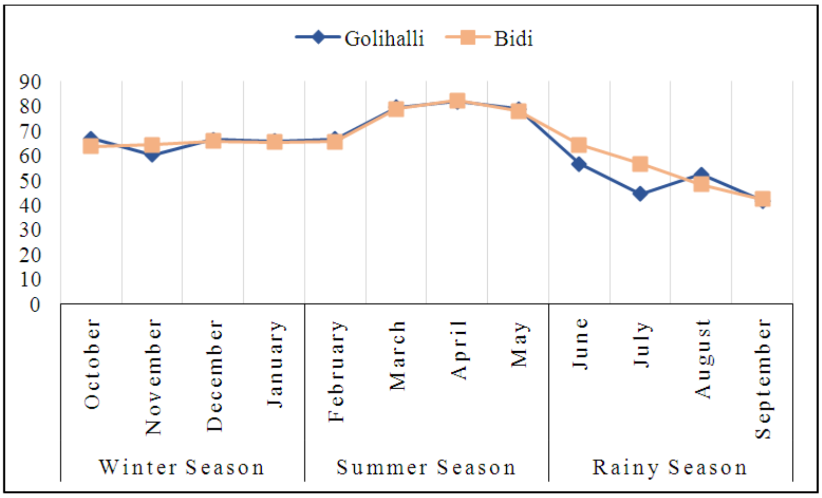

Fig. 6(b). Monthly mean variation of relative humidity

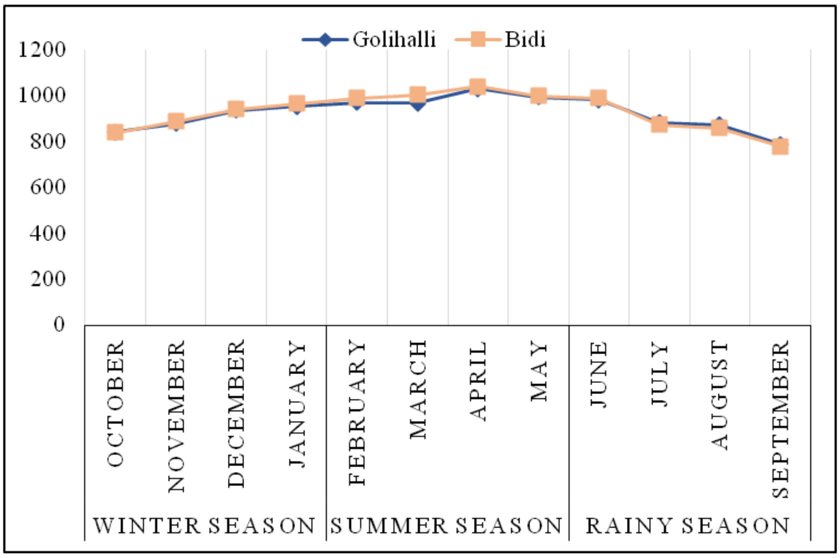

Fig. 6(c). Monthly mean variation of carbon dioxide (CO_2)

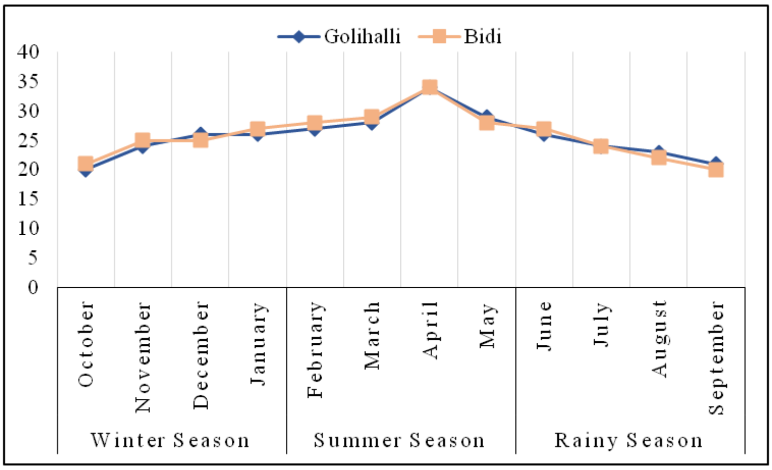

Fig. 6(d). Monthly mean variation of carbon monoxide (CO)

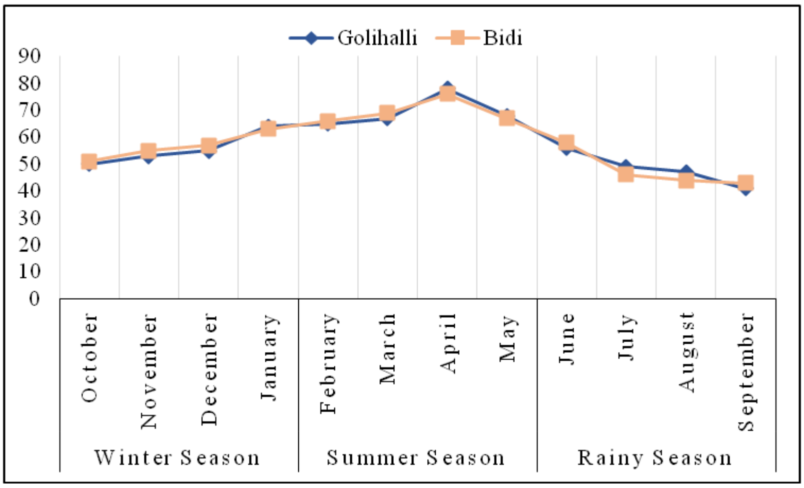

Fig. 6(e). Monthly mean variation of particulate matter ($PM_{2.5}$)

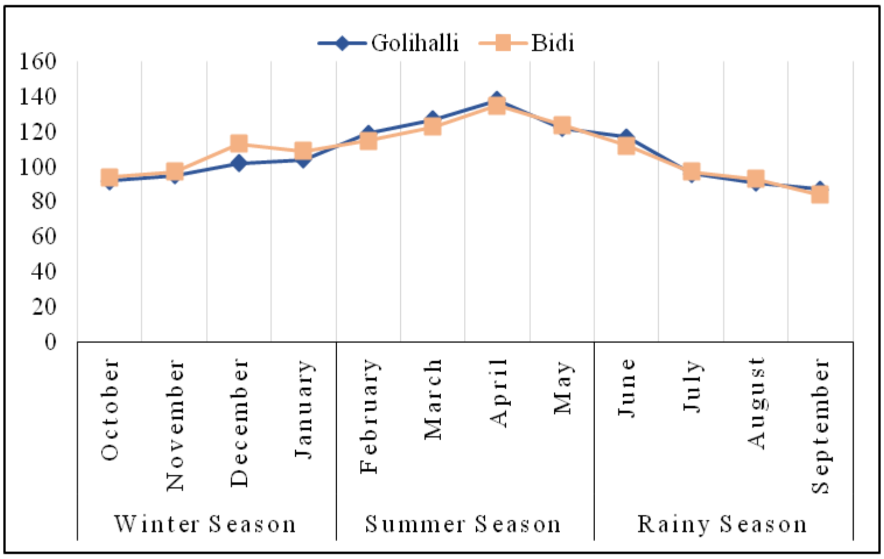

Fig. 6(f). Monthly mean variation of particulate matter (PM_{10})

Table 2. One-Way ANOVA test for selected parameters based on seasons

Parameters	Source of Variation	Sum of Squares	Degree of Freedom	Mean Squares	F-value	P-value
Temperature	Between Seasons	1.12	2	0.56	14*	0.03
	Within Seasons	0.12	3	0.04		
	Total	1.24	5			
Relative Humidity	Between Seasons	654.8	2	327.4	114.34**	0.001
	Within Seasons	8.59	3	2.86		
	Total	663.39	5			
Carbon dioxide (CO_2)	Between Seasons	15965.81	2	7982.91	119.19**	0.001
	Within Seasons	200.92	3	66.97		
	Total	16166.73	5			
Carbon monoxide (CO)	Between Seasons	45.96	2	22.98	362.87**	0.0003
	Within Seasons	0.19	3	0.063		
	Total	46.15	5			
Particulate Matter ($PM_{2.5}$)	Between Seasons	470.37	2	235.19	1128.89**	5E-05
	Within Seasons	0.63	3	0.208		
	Total	471	5			
Particulate Matter (PM_{10})	Between Seasons	944.36	2	472.2	89.85**	0.0021
	Within Seasons	15.77	3	5.26		
	Total	960.13	5			

** Significant at P<0.05, ** Significant at P<0.01*

Table 3. Carbon sequestration of tree species in Golihalli and Bidi village of Belagavi district

Sl. No.	Tree species (Common name)	Number of trees		Average age (year)		Average Tree Height (m)		Average DBH (m)		Total Biomass (Kg)		Carbon Storage (gm)		Carbon Sequestration (gm)	
		V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2
1	*Anacardium occidentale* (Cashew)	2	1	11.9	10.7	4.6	4.9	0.15	0.13	0.006	0.005	2.95	2.6	10.81	9.52
2	*Artocarpus heterophyllus* (Jack fruit)	2	1	11.6	12.2	4.9	5.2	0.14	0.15	0.006	0.007	3.12	3.42	11.4	12.53
3	*Azdirachta indica* (Neem)	8	7	50	47.7	15.8	16.1	0.53	0.51	0.28	0.271	142.01	135.36	519.77	495.4
4	*Cocos nucifera* (Coconut)	8	8	27.1	26.7	17.1	17	0.3	0.3	0.1	0.092	49.29	45.87	180.39	167.89
5	*Couroupita guianensis* (Cannonball tree)	1	-	25.4	-	10.9	-	0.28	-	0.051	-	25.91	-	94.83	-
6	*Ficus benhalensis* (Banyan)	4	3	11.8	10.7	21.7	19.4	0.15	0.13	0.027	0.021	13.66	10.64	49.99	38.94
7	*Ficus carica* (Fig)	3	2	26.1	22.7	11	11	0.29	0.26	0.055	0.043	27.68	21.38	101.29	78.23
8	*Magnolia champaca* (Champak)	2	1	10.2	11.3	7.7	7.8	0.13	0.14	0.008	0.009	3.8	4.53	13.92	16.6
9	*Mangifera indica* (Mango)	3	3	11.6	10.2	15.5	14.6	0.14	0.13	0.019	0.015	9.29	7.52	34.01	27.53
10	*Millettia pinnata* (Indian beech)	2	1	17.6	15.1	12.7	11.3	0.2	0.18	0.033	0.021	16.74	10.67	61.27	39.05
11	*Moringa oleifera* (Drumstick)	2	2	9.6	7.7	5.8	5.5	0.12	0.1	0.005	0.004	2.65	1.81	9.68	6.64
12	*Murraya koenigii* (Curry)	2	2	4.9	5.7	3.7	3.9	0.08	0.08	0.001	0.002	0.6	0.8	2.19	2.93
13	*Phyllanthus emblica* (Indian gooseberry)	3	2	9.3	10.8	5.6	6	0.12	0.14	0.005	0.007	2.41	3.28	8.82	12.01

Sl. No.	Tree species (Common name)	Number of trees		Average age (year)		Average Tree Height (m)		Average DBH (m)		Total Biomass (Kg)		Carbon Storage (gm)		Carbon Sequestration (gm)	
		V_1	**V_2**	**V_1**	**V_2**	**V_1**	**V_2**	**V_1**	**V_2**	**V_1**	**V_2**	**V_1**	**V_2**	**V_1**	**V_2**
14	*Saraca asoca* (Ashoka)	3	1	23.1	20.4	7.4	6.4	0.26	0.23	0.031	0.021	15.73	10.28	57.57	37.63
15	*Syzygium cumini* (Java plum)	3	2	20.8	21	11	11	0.24	0.24	0.038	0.036	18.9	18.08	69.16	66.17
16	*Tamarindus indica* (Tamarind)	6	6	42.3	47.8	17.7	17.6	0.46	0.51	0.24	0.29	119.75	144.87	438.27	530.22
17	*Tectona grandis* (Teak)	3	2	7.1	7.1	7.9	8.5	0.1	0.1	0.005	0.005	2.25	2.52	8.25	9.23
	Total	**57**	**44**	**320.4**	**287.8**	**181**	**166.2**	**3.69**	**3.33**	**0.91**	**0.849**	**456.74**	**423.63**	**1671.62**	**1550.52**

V_1: Golihalli village, V_2: Bidi village

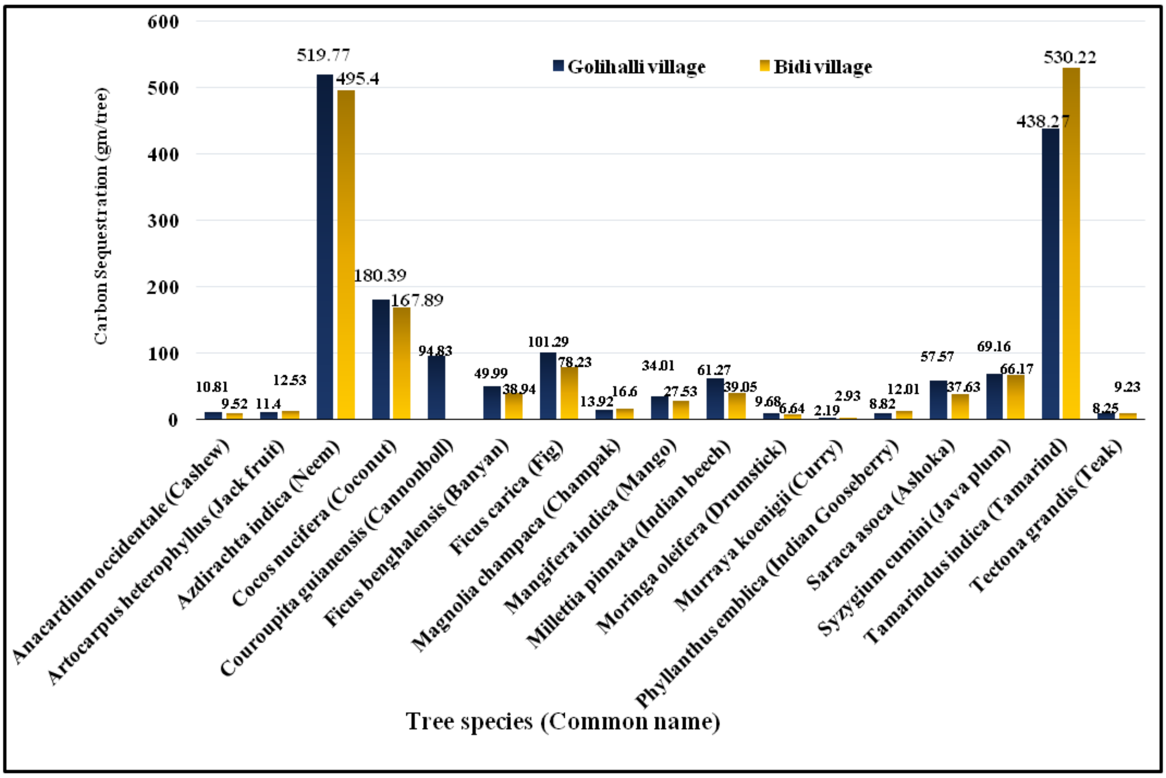

Fig. 7. Graphical representation of carbon sequestration of tree species

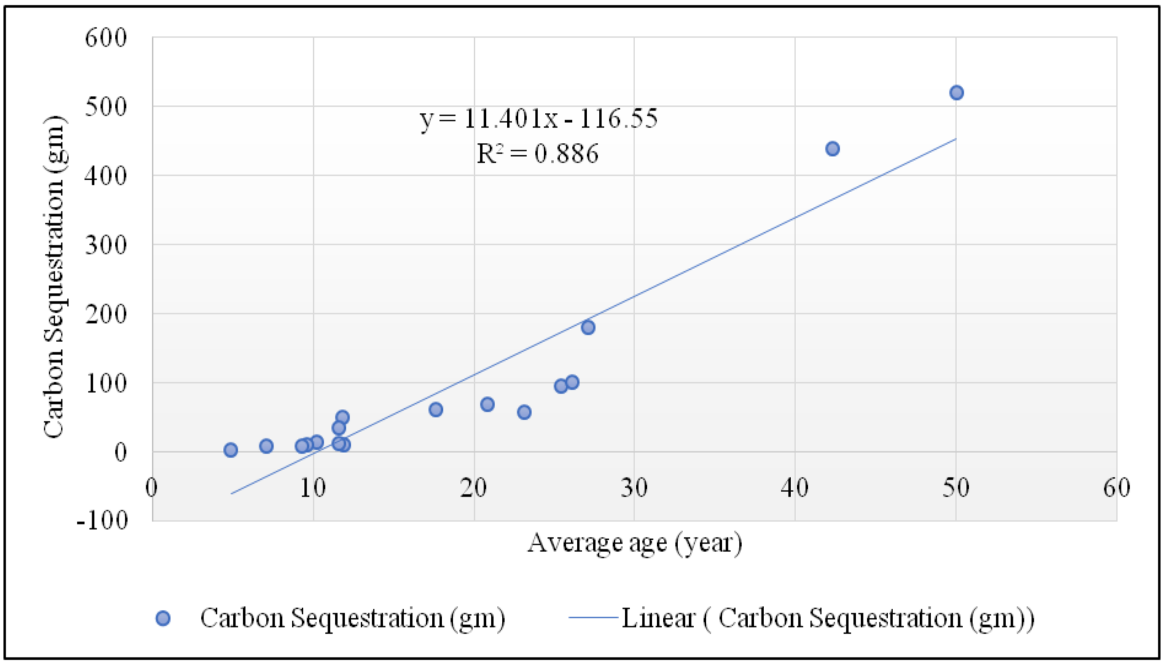

Fig. 8(a). Relationship between average age of trees and carbon sequestration in Golihalli village

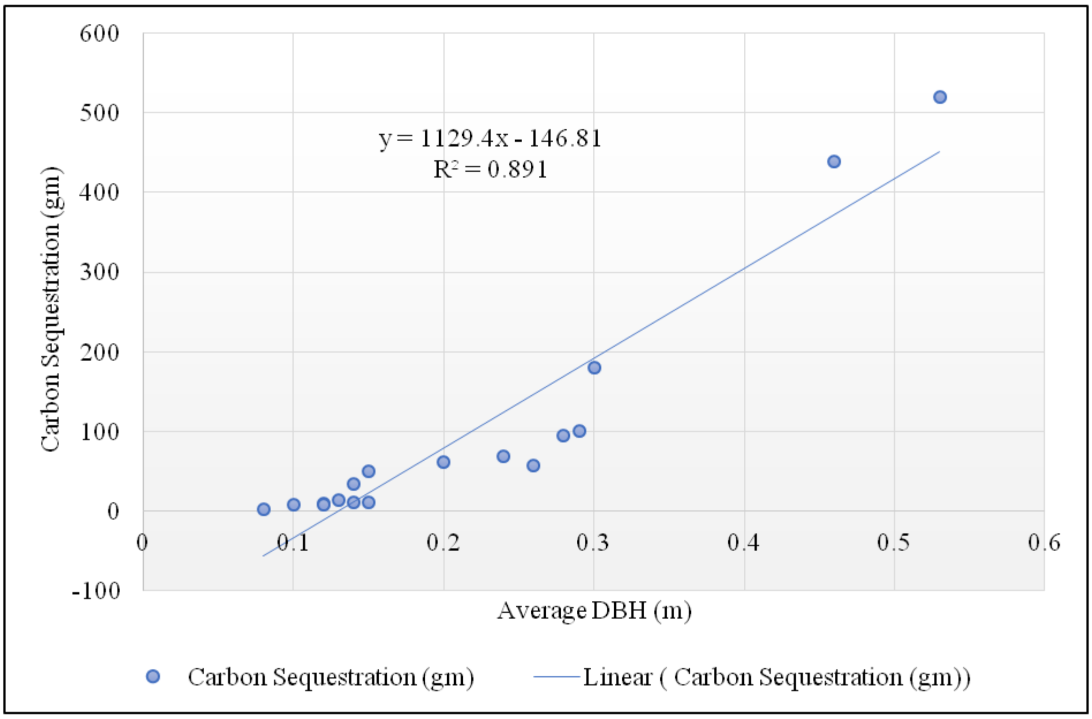

Fig. 8(b). Relationship between average DBH of trees and carbon sequestration in Golihalli village

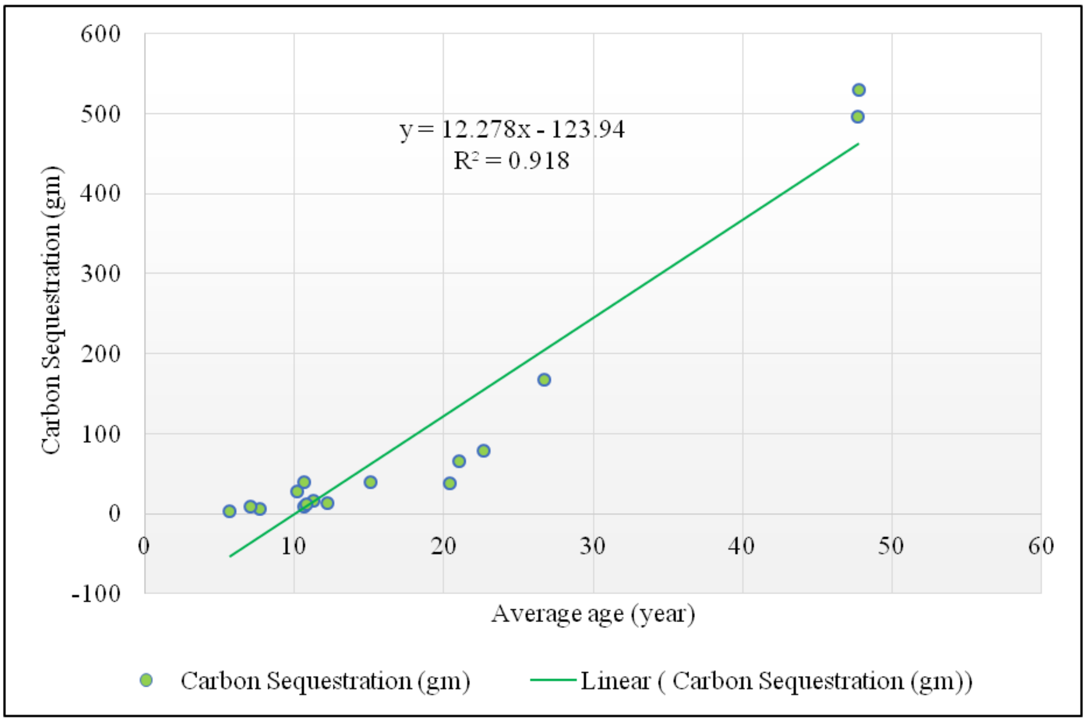

Fig. 8(c). Relationship between average age of trees and carbon sequestration in Bidi village

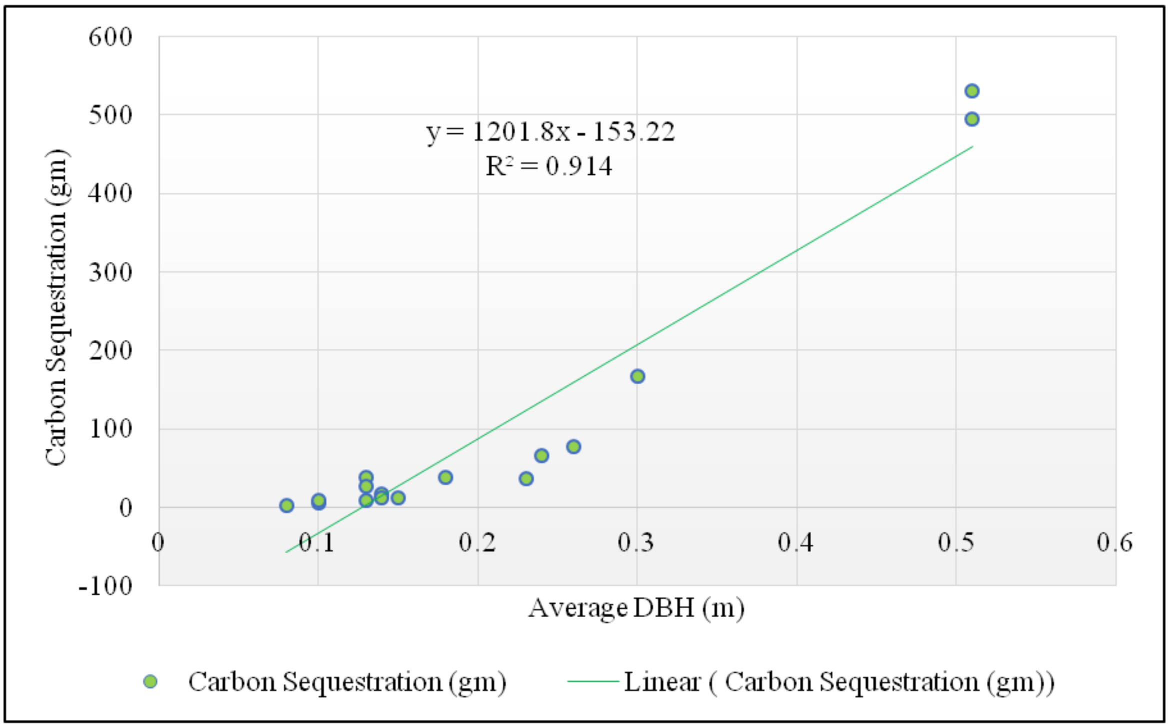

Fig. 8(d). Relationship between average DBH of trees and carbon sequestration in Bidi village

Table 4. Pearson Correlation analysis reflecting the relationship between different parameters of trees

Villages		Average Age	Average DBH	Total Biomass	Carbon Storage	Carbon Sequestration
Golihalli village	Average Age	1				
	Average DBH	1**	1			
	Total Biomass	0.94**	0.94**	1		
	Carbon Storage	0.94**	0.94**	1**	1	
	Carbon Sequestration	0.94**	0.94**	1**	1**	1
		Average age	Average DBH	Total Biomass	Carbon Storage	Carbon Sequestration
Bidi village	Average Age	1				
	Average DBH	1**	1			
	Total Biomass	0.97**	0.96**	1		
	Carbon Storage	0.97**	0.96**	1**	1	
	Carbon Sequestration	0.97**	0.96**	1**	1**	1

*** Significant at P<0.01*

3.5 Relationship between tree Age and DBH with Carbon Sequestration

The regression analysis showed that there was highly significant positive correlation between average age of trees and carbon sequestration (R^2 = 0.886) and also between average DBH of trees and carbon sequestration (R^2 = 0.891) in Golihalli village [Fig. 8 (a) & (b)]. Whereas in Bidi village, there was highly significant positive correlation between average age of trees and carbon sequestration (R^2 = 0.918) and also between average DBH of trees and carbon sequestration (R^2 = 0.914) [Fig. 8 (c) & (d)].

The variation in average age and DBH of trees could explain 88.6% and 89.1% respectively variation in carbon sequestration in Golihalli village. Whereas the variation in average age and DBH of trees could explain 91.8% and 91.4% respectively variation in carbon sequestration in Bidi village. Regression model with age and DBH of tree were best fitted for estimation of carbon sequestration. Therefore, the age and DBH of trees can be a good predictor of carbon sequestration in trees in both villages. These results were substantiated by Arora et al. [16] stated the allometric models were well fitted (R^2 = 0.94) between carbon sequestration with age and DBH. According to Jithila and Prasadan [17] assessed the DBH of trees had liner relationship with carbon sequestration (R^2 = 0.687). Nirala et al. [18] reported highly significant positive correlation (R^2 = 0.859) between carbon sequestration and DBH in teak plantations.

3.6 Strength of Association between Carbon Sequestration and Different Parameters of Tree

The Pearson's correlation analysis was performed to determine the strength of association between different parameters. A significantly strong positive correlation was observed between carbon sequestration and other parameters such as average age (r =0.94), average DBH (r =0.94), total biomass (r =1.00) and carbon storage (r =1.00). Similarly, a significantly strong positive correlation was also noted between carbon storage and other parameters such as average age (r =0.94), average DBH (r =0.94) and total biomass (r =1.00). However, the total biomass was also significantly strong positive correlation with average age (r =0.94) and average DBH (r =0.94) and also average DBH was significantly strong positive correlation with average age (r =1.00) in Golihalli village.

A significantly strong positive correlation was observed between carbon sequestration and other parameters such as average age (r =0.97), average DBH (r =0.96), total biomass (r =1.00) and carbon storage (r =1.00). Similarly, a significantly strong positive correlation was also noted between carbon storage and other parameters such as average age (r =0.97), average DBH (r =0.96) and total biomass (r =1.00). However, the total biomass was also significantly strong positive correlation with average age (r =0.97) and average DBH (r =0.96) and also average DBH was significantly strong positive correlation with average age (r =1.00) in Bidi village [Table 4]. If the tree age and DBH are increased then the biomass, carbon storage and carbon sequestration will also increase in tree. The total biomass of trees varied positively and linearly with diameter at breast height (r = 0.953) by Bohre et al. [19]. According to Bhattacharya et al. [20] there was a positive correlation between carbon stock and tree biomass (r = 0.865). Behera et al. [21] stated Pearson's correlation matrix established the positive relationship between growth performance and physiological traits of species with their capacity to sequester carbon.

4. CONCLUSION

The mean concentration of carbon dioxide (CO_2), carbon monoxide (CO), particulate matter ($PM_{2.5}$) and particulate matter (PM_{10}) were higher than the safe level in both villages because of rural people's day-today activities and vehicular pollution. The trees with higher age and DBH have more carbon sequestration which was in *Tamarindus indica* (Tamarind) and *Azdirachta indica* (Neem). Therefore, these plants are recommended for plantations in villages which can help in sequestrating carbon and mitigate the effects of carbon emitted from the rural people's day-today activities and vehicles. Planting healthy and large number of trees helps to maximize the amount of carbon sequestration in the atmosphere which in turn improves the rural people's health.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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