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Assessment of Carbon Stocks in Dominated Forest of Palash of the Malwa Plateau Region of the India

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ABSTRACT: The present study was carried out to estimate the C-stocks in the dominated palash forest of the Malwa plateau region of the India through forest inventory. Stem density (ha^{-1}), tree height (m), diameter at breast height (DBH) (m), basal area (m^2. ha^{-1}), tree volume (m^3. ha^{-1}), total biomass (Kg.ha^{-1}), and total C-stock (Kg. ha^{-1}), were determined. Stem density varied between 34.00 to 39.00 trees ha^{-1}, with a mean value of 36.25 tress ha^{-1}. The average tree height (m), DBH (m), basal area (m^2. ha^{-1}) and tree volume (m^3. ha^{-1}) were 5.96, 0.28,0.03 and 0.53 respectively. The estimated total biomass (Kg. ha^{-1}) was ranging 127.00 to 150.00 with an average value of 139.25. The calculated Carbon stock (Kg. ha^{-1}) in the dominated forest of palash ranged from 57.00 to 67.00 and the mean Carbon stocks was 62.50. Semi interquartile range (SIQR) and Interquartile range (IQR) values of Stem density (ha^{-1}), tree height (m), DBH (m), basal area (m^2. ha^{-1}), tree volume (m^3. ha^{-1}), total biomass (Kg. ha^{-1}), and total C-stock (Kg. ha^{-1}) are 0.56 and 1.06, 1.50 and 2.84,0.06 and 0.11,0.02 and 0.03,0.08 and 0.16,2.51 and 4.77 and 1.13 and 2.15. A significant Polynomial cubic positive (R^2 = 0.999) relationship was observed between total biomass with basal area. The results of the study confirmed that the dominated forest of palash acts as a valuable sink of carbon, but this valuable storage factory of carbon faced the problems of excess uses of wood for domestic purpose and no scientific management. Proper utilization and scientific management of the forest can be significant measures to enhance the potential of the forest to stored and sink more carbon.

Keywords: Biomass, Carbon stocks, Jhalawar forest, Palash and Tree girth.

INTRODUCTION

Palash (*Butea monosperma* (Lam.) Kuntze) is a deciduous forest tree popularly known as a flame forest and belongs to the family Fabaceae. It is a growing to 12-15 meter tall, with a crooked trunk diameter of up to 20-40 cm in mature tree, leaves are pinnate, with an 8-16 cm petiole and three leaflets, each leaflet 10-20 cm long, flowers are large 2.5 cm long, bright orange-red and produced in rigid racemes up to 15-20 cm long (Randhawa, 1983). The flower buds appear in January-February and orange-coloured blossoms appear during February-April, when the tree is leafless. The fruit is a pod (about 15-20 cm long and 4-5 cm broad, ripening brown). It is native to India and also distributed in South Asia and other countries like Indonesia, Nepal, Thailand, Cambodia, Japan, Laos, Myanmar, Sri Lanka, Vietnam, and China (Singh *et al*., 2017). The plant parts of palash namely root, leaves, fruit, stem bark, flowers, and gum are used for medicine, food, fibre, and other miscellaneous purposes.

Various human activities like land use change, fossil fuels burning, and deforestation increase the concentration of carbon dioxide in the atmosphere and cause the problem of climate change and global warming. The concentration of carbon dioxide increases from 280 ppm (pre-industrial time) to 419.20 ppm (NOAA, 2022). The fourth assessment report recommended for serious measure to check the problem of global warming to coup the serious ecological, social and economic consequences (Metz, 2007). Terrestrial ecosystem, oceans, atmosphere and geological reservoirs are main components of global carbon cycle. Among terrestrial ecosystem, the forest ecosystem has the significant potential to store and sink carbon and therefore globally forest are considering a potential tool to mitigate global climate change (Sharma *et al*., 2011). Forest ecosystem stores 20 to 50 more carbon as compare to other ecosystems due to its woody character and long-life span (Sharma *et al*., 2011). The world has a total forest area of 4.06 billion hectares (10.0 billion acres), which is 31percent of the total land area. The world's total growing stock in forests is 527 billion m^3 or 131 m^3/ha, while the total stored carbon in world forest is 650 billion tons (FAO, 2020). The total forest area of India is 7, 13,789 km^2 and the Malwa plateau is 83,535 km^2covered (FSI, 2022). The carbon should be measured in different carbon pools that includes carbon store in above ground biomass, below ground biomass, dead wood, litter and soil in forest ecosystem.

In India, the forest department conducts forest survey on regular basis for the estimation of the growing stock in the shape of working plan and may be used to determined carbon stock, but these estimates can be error prone (FSI, 2022). The present study provides detail information and forest protocol regarding growing stock, biomass and carbon stock assessment in the dominated forest of palash of Malwa plateau region of India.

MATERIALS AND METHODS

The study was carried out in four (Aklera, Asnawar, Jhalawar, and Khanpur) dominated forest sites of Palash (*Butea monosperma* (Lam.) Kuntze) in Jhalawar forest division. It is the part of Malwa plateau region of the India. The Malwa region occupies a plateau in Western Madhya Pradesh and South-Eastern Rajasthan (Between 21°10'N 73°45'E and 25°10'N 79°14'E) with Gujarat in the West. The plateau is an extension of the Deccan traps formed between 60 and 68 million years ago at the end of the Cretaceous period. Jhalawar forest division is situated at the edge of the Malwa plateau at 23°45' to 25°53' North Latitudes and 75°90' to 77°26' East Longitude. The region lies in South-Eastern Rajasthan and dominated by rocky-hilly terrain with shallow soil depth. It receives an average rainfall of 900-1000 mm with sub-humid conditions and remains almost free from frost. During summers the temperature touches the mark of 42-45°C and during winter in fall to 5-7°C. The forest survey was carried out in the month of November 2021 to December, 2022. In each forest site, 20 quadrats of 10m ×10m size were laid randomly to conduct the study of palash trees. The various parameters were observed and analysed in each quadrat of each forest site of palash trees as underneath.

1. Density of trees was calculated by counting tree.
2. Tree height (m) was measured with the help of Ravi's multimeter.
3. Diameter at breast height (DBH) (m): Individual tree was recorded by using tree calliper at 1.37m above ground level by standard method as prescribed by Chaturvedi and Khanna (1982).
4. Basal area (m^2) of each tree was determined by tree calliper or tap. It refers to the cross-sectional area of the stems and calculated by using following relation and expression (Basal area = $\pi/4\times (D)^2$). Where, D is DBH in m.
5. Estimation of tree volume (m^3): The tree volume was determined with help of volume equation (Annexure-I of volume equation used for different tree species in each physiographic zone, Carbon Stock in India Forests).
6. Determination of total biomass (Kg ha^{-1}): Total biomass was analysed by the use of biomass equations. (Annexure-II of biomass equation used for different tree species in each physiographic zone, Carbon Stock in India Forests).
7. Calculation of C-Stocks (Kg $plot^{-1}$): Biomass will be converted into carbon by multiplying with a factor of 0.45 (Negi *et al.*, 2003).

After measurement and estimation of various parameters, the basic statistical analysis was carried out as per Gopinath *et al.* (2021) and Polynomial regression model developed.

RESULTS AND DISCUSSIONS

Characteristics, growing stock volume and Carbon-Stocks in the dominate palash forest of the Malwa plateau region of India. The stem density (ha^{-1}), tree height (m), diameter at breast height (DBH) (m), basal area (m^2. ha^{-1}), tree volume (m^3. ha^{-1}), total biomass (Kg. ha^{-1}), and total Carbon-Stocks (Kg. ha^{-1}), were determined in each forest site of palash by using appropriate methods and equations. The details of basic statistical analysis of various parameters under studied are given in Table 1. The stem density of studied sites ranges from 34.00 (Aklera) to 39.00 (Asnawar) trees ha^{-1} with the average value of 36.25 tress ha^{-1}. The SIQR (0.56), IQR (1.06), SD (1.02) and CV (%) (56.00) were analysed and showed variation in the stem density of plash tree. In present study it was found that there is great variation in stem density of palash forest between sites (Aklera, Asnawar, Jhalawar, and Khanpur). The dominated palash forest of the study area belongs to the local community. The community use the forest for the purposes of wood, forage and other domestic uses like construction of their houses and agriculture tools. For the present study quadrats (10m × 10m) were taken in all these four forest sites. So those quadrats that were taken from the forest that were located near to the local community and surrounded by local community have lower density. The reason of lower density in these study sites are the more use of forest for wood, forage and other domestic uses. While those forest which were located away from the community or located at high altitude have more density because of less disturbance received from the local population in terms of wood and forage and domestic uses. Stem density decreases with increase in DBH (Ahmad *et al*., 2014; Ahmad and Nizami 2014). In present study the relationship between Stem density and DBH was established. The relation of stem density and DBH is presented in Fig. 1a-d. The relation of Stem density and DBH is Polynomial, Cubic. The values of R^2 are 0.747, 0.887, 0.803 and 0.503.

The tree height (m) of palash in studied sites was observed from 3.10 to 9.20 (Aklera), 3.10 to 11.0(Asnawar), 3.20 to 9.50 (Jhalawar) and 3.30 to 9.10 (Khanpur). The mean tree height (m) was recorded as 5.96 (Aklera), 6.12 (Asnawar), 6.05(Jhalawar) and 5.72 (Khanpur). The value of SIQR (1.50), IQR (2.84), SD (1.95) and CV (%) (32.75) also showed variation in the tree height(m) in each studied forest sites. The height of 3.0 m to 15.0 m of palash tree was reported (Randhawa, 1983). Tree height (m) is the main function of tree girth (m). The tree height (m) has a direct relation with the girth (m) of tree. Tree height increases with increase in girth (Ahmad *et al.*, 2014; Singh and Rajpoot 2021). The height of tree increases with increase in DBH was observed in the studied. To study the relationship of DBH and tree height a regression model was developed

(Fig. 2a-d). The relationship of DBH and tree height is Polynomial, Cubic. The values of R^2 are 0.904, 0.954, 0.937 and 0.859.

The diameter at breast height (DBH) (m) of the dominated palash forest ranges from 0.1 to 0.34 at Aklera, Asnawar, Jhalawar and Khanpur forest sites. The mean of DBH was found 0.19 m at all studied forest sites. The determined value of SIQR (0.06), IQR (0.11), SD (0.07) and CV (%) (39.25) were also showed variation in the DBH. The present finding of DBH (m) are similar with the results of (Moinuddin *et al.*, 2011).

The basal area (m^2. ha^{-1}) of the dominated palash forest ranges from 0.01 to 0.08 at Aklera, Jhalawar and Khanpur forest sites and 0.01 to 0.09 at Asnawar forest site. Over all the mean basal area was 0.03at all studied forest sites. The analysed values of SIQR (0.02), IQR (0.03), SD (0.02) and CV (%) (75.75) were showed huge variation and Singh *et al*. (2018) were observed similar results. Raha *et al*. (2020) reported that each forest type with varying diversity, basal area and diameter class differs in their capacity to sequester C; and therefore, Reducing Emission from Deforestation and Degradation should provide incentives as per the forest type. This would favour a fair Reducing Emission from Deforestation and Degradation mechanism. Hence proper conservation, monitoring and management plans in these forest types should aim in enhancing the C storage potential of similar forest types in India and elsewhere.

The mean value of tree volume (m^3. ha^{-1}) was determined 0.53 in studied forest sites. It can be seen from the Table 1 that the minimum volume was found in the Jhalawar forest site and the maximum volume was observed in the Asnawar forest site. Tree volume is the functional of the basal area of tree. With increase in basal area the volume also increases (Fig. 3a-d). Variation in volume performance in the study follow the second category growth characters for the purpose of fixing the rotation age as mentioned by Singh (1982).

The total biomass (Kg. ha^{-1}) of the dominate palash forest ranges from 127.0 to 150.0, while the mean of total biomass was observed 139.25. The value of SIQR (2.51), IQR (4.77), SD (4.00) and CV (%)(57.50) also showed variation in the total biomass. In present study it was found that total tree biomass increases with increase in basal area of tree. To study the relation of basal area and total tree biomass a regression model was developed (Fig. 4a-d). The relation of basal area and total tree biomass is Polynomial, Cubic. The value of R^2 is 0.999. The low biomass estimates in Indian forests is for global carbon cycle in the area of carbon mitigation. It is generally assumed that the tropical forests are mature and thus in steady state with respect to carbon accumulation (Brown and Lugo 1992). When mitigation options through forest management are sought, attention is usually given to the notion of establishing plantations on degraded lands (Grainger, 1990). Establishing sufficient areas of plantation to significantly reduce atmospheric carbon dioxide would entail planting vast areas, which would probably be not feasible in the short run (Grainger, 1990). Ahmad *et al.* (2014) was reported similar result in coniferous forest. The biomass of a tree is time dependent process. Old growth forest stored more carbon due to more accumulation of biomass (Nizami, 2012).

The finding of the present study revealed that the total C-stock (Kg. ha^{-1}) ranges from 57.0 to 67.0 with the mean C-stock of the dominate palash forest was 62.50. The value of SIQR (1.13), IQR (2.15), SD (1.80) and CV (%) (57.50) also showed variation in the Carbon-Stocks. The value of CV indicated that there is great variation in the quantity of C-stocks. As the amount of the Carbon-Stocks in a forest depends upon the biomass of the forest. The carbon stock of this forest is important as it contributes to the sustainable management of these forest ecosystems to support the Reducing Emission from Deforestation and Degradation process and is a useful tool in formulating further conservation strategies (Salunkhe *et al*., 2023). According to Ahmad *et al.* (2014) forest comprise of old age trees having large diameter resulted more biomass carbon. As it has been discussed earlier that in the study site those forest areas that were near to local community have less density and also these areas comprise of small diameter trees so the plots which were taken in those sites have less amount of carbon in their biomass.

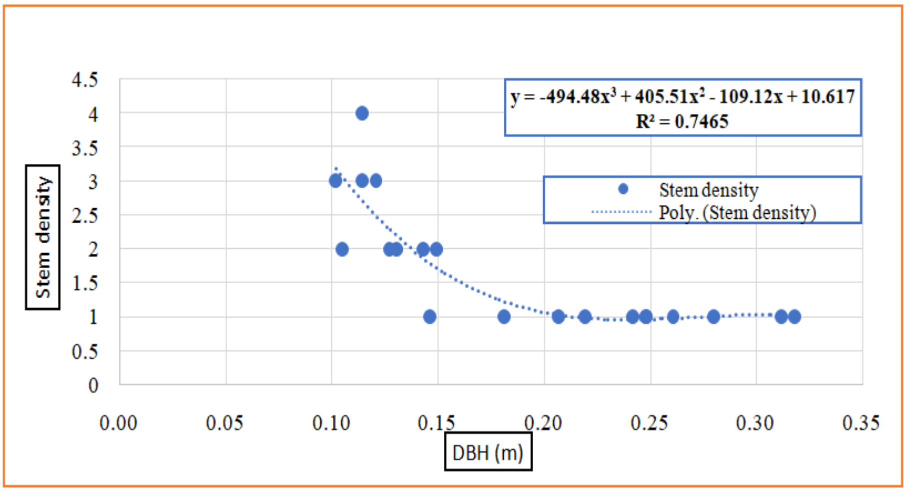

Fig. 1a. Relationship between DBH and stem density at Aklera forest site.

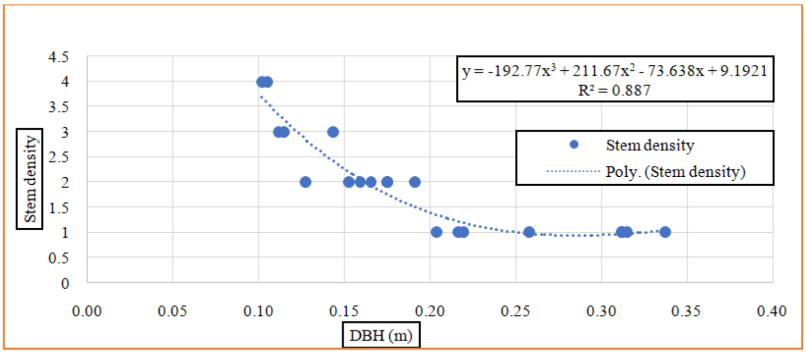

Fig. 1b. Relationship between DBH and Stem density at Asnawar forest site.

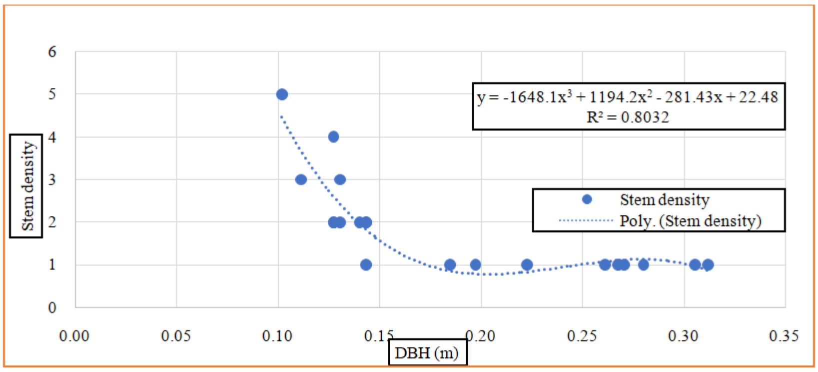

Fig. 1c. Relationship between DBH and Stem density at Jhalawar forest site.

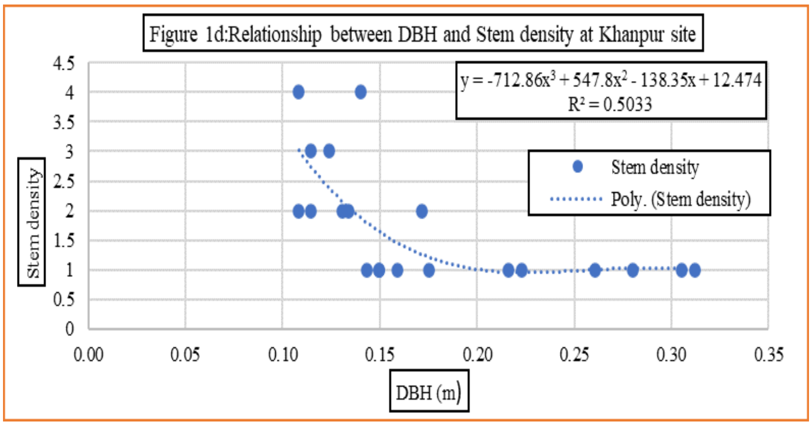

Fig. 1d. Relationship between DBH and stem density at Khanpur forest site.

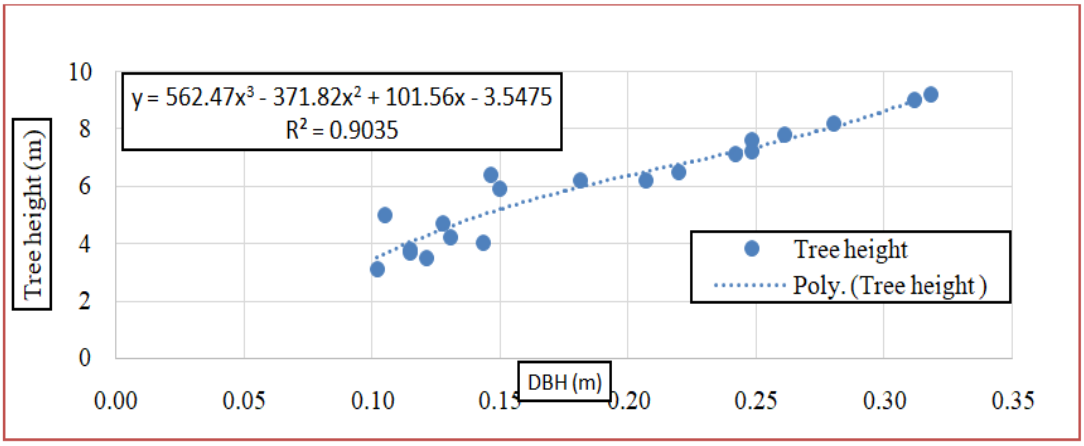

Fig. 2a. Relationship between DBH and Tree height at Aklera forest site.

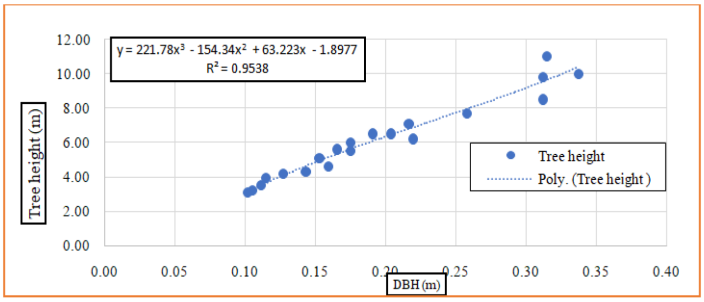

Fig. 2b. Relationship between DBH and Tree height at Asnawar forest site.

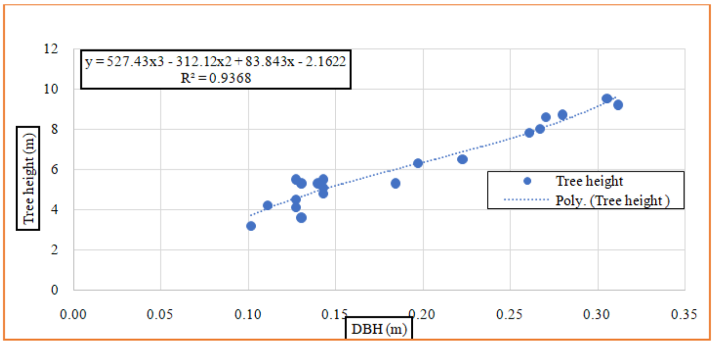

Fig. 2c. Relationship between DBH and Tree height at Jhalawar forest site.

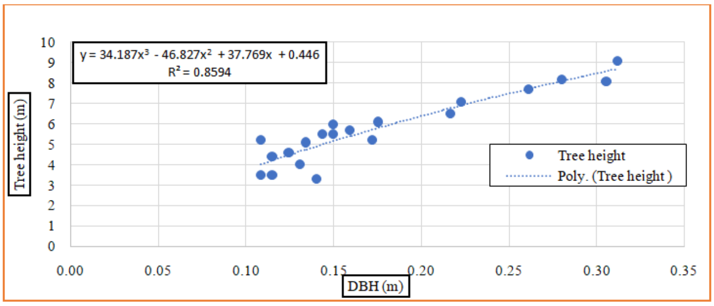

Fig. 2d. Relationship between DBH and Tree height at Khanpur forest site.

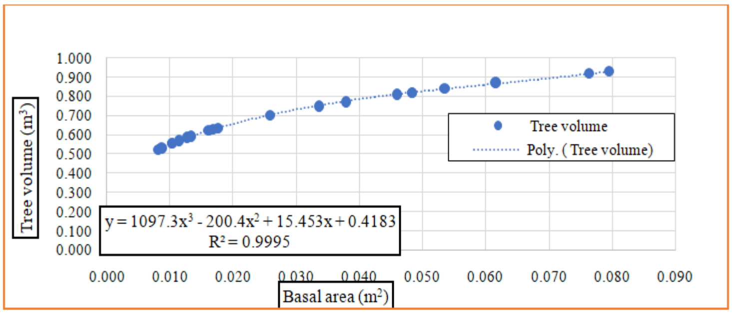

Fig. 3a. Relationship between Basal area and Tree volume at Aklera forest site.

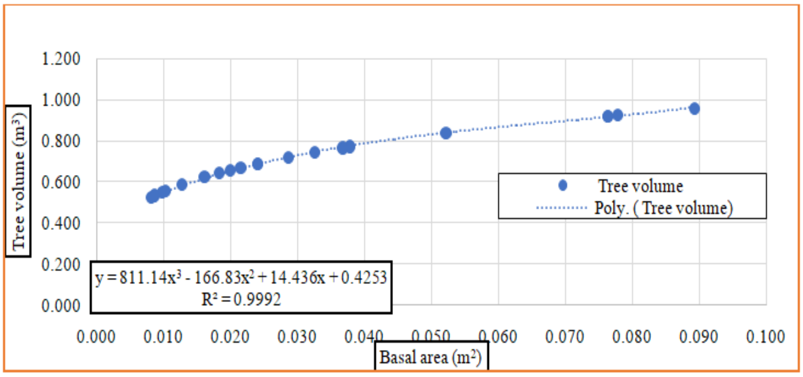

Fig. 3b. Relationship between Basal area and Tree volume at Asnawar forest site.

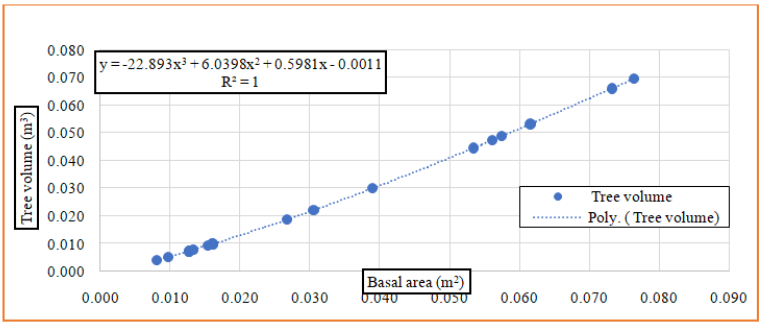

Fig. 3c. Relationship between Basal area and Tree volume at Jhalawar forest site.

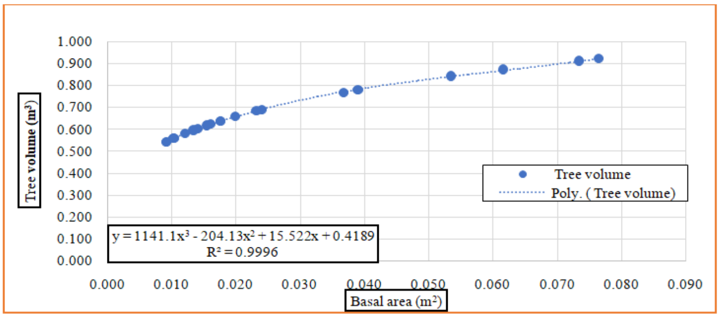

Fig. 3d. Relationship between Basal area and Tree volume at Khanpur forest site.

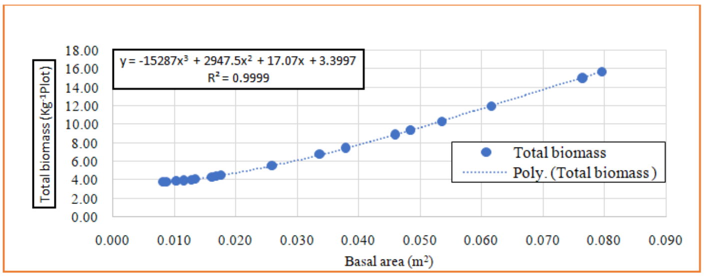

Fig. 4a. Relationship between Basal area and Total biomass at Aklera forest site.

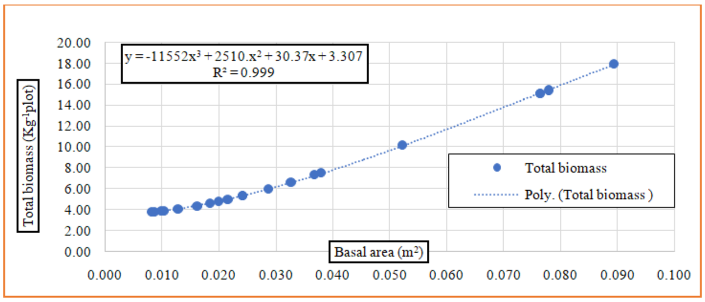

Fig. 4b. Relationship between basal area and Total biomass at Asnawar forest site.

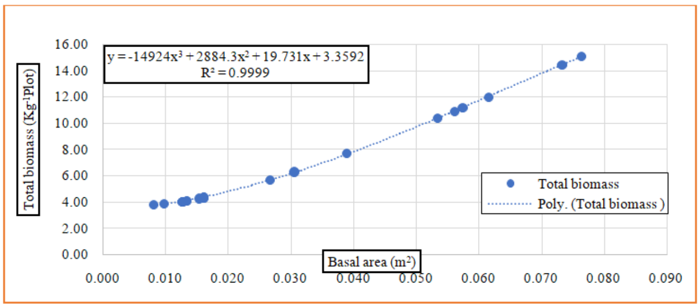

Fig. 4c: Relationship between Basal area and Total biomass at Jhalawar forest site.

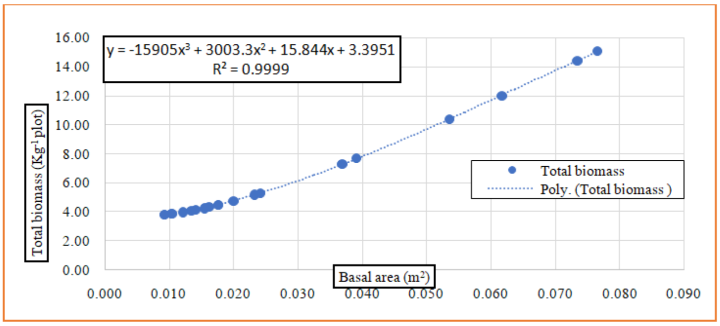

Fig. 4d. Relationship between Basal area and Total biomass at Khanpur forest site.

Table 1: Analysis of basic statistics of all studied parameters at different forest sites.

Parameters	Forest sites	Basic Statistics							
		Total	Mean	Minimum	Maximum	SIQR	IQR	SD	CV
Stem density	Aklera	34.00	1.70	1.00	4.00	0.50	1.00	0.92	54.00
	Asnawar	39.00	1.95	1.00	4.00	0.75	1.25	1.00	51.00
	Jhalawar	37.00	1.85	1.00	5.00	0.50	1.00	1.14	61.00
	Khanpur	35.00	1.75	1.00	4.00	0.50	1.00	1.02	58.00
	Average	**36.25**	**1.81**	**1.00**	**4.25**	**0.56**	**1.06**	**1.02**	**56.00**
Tree height(m)	Aklera	119.00	5.96	3.10	9.20	1.65	3.15	1.89	32.00
	Asnawar	122.00	6.12	3.10	11.00	1.58	2.97	2.32	38.00
	Jhalawar	121.00	6.05	3.20	9.50	1.63	3.12	1.93	32.00
	Khanpur	114.00	5.72	3.30	9.10	1.15	2.10	1.66	29.00
	Average	**119.00**	**5.96**	**3.18**	**9.70**	**1.50**	**2.84**	**1.95**	**32.75**
Diameter at breast height (DBH) (m)	Aklera	4.00	0.19	0.10	0.32	0.07	0.12	0.07	39.00
	Asnawar	4.00	0.19	0.10	0.34	0.05	0.09	0.08	40.00
	Jhalawar	4.00	0.19	0.10	0.31	0.07	0.13	0.07	39.00
	Khanpur	4.00	0.18	0.11	0.31	0.05	0.09	0.07	39.00
	Average	**4.00**	**0.19**	**0.10**	**0.32**	**0.06**	**0.11**	**0.07**	**39.25**
Basal area(m^2)	Aklera	1.00	0.03	0.01	0.08	0.02	0.04	0.02	73.00
	Asnawar	1.00	0.03	0.01	0.09	0.02	0.03	0.03	76.00
	Jhalawar	1.00	0.03	0.01	0.08	0.02	0.04	0.02	75.00
	Khanpur	1.00	0.03	0.01	0.08	0.02	0.02	0.02	79.00
	Average	**1.00**	**0.03**	**0.01**	**0.08**	**0.02**	**0.03**	**0.02**	**75.75**
Tree volume (m^3)	Aklera	14.00	0.70	0.53	0.93	0.12	0.24	0.14	19.00
	Asnawar	14.00	0.71	0.53	0.96	0.10	0.17	0.14	19.00
	Jhalawar	0.50	0.02	0.00	0.07	0.02	0.04	0.02	91.00
	Khanpur	1.00	0.68	0.54	0.92	0.09	0.18	0.12	18.00
	Average	**7.38**	**0.53**	**0.40**	**0.72**	**0.08**	**0.16**	**0.11**	**36.75**
Total biomass (Kg. ha^{-1})	Aklera	141.00	7.07	3.80	15.75	2.71	5.40	3.86	55.00
	Asnawar	150.00	7.48	3.80	17.89	2.32	3.90	4.61	62.00
	Jhalawar	139.00	6.94	3.80	15.07	3.29	6.44	3.87	56.00
	Khanpur	127.00	6.36	3.83	15.07	1.74	3.35	3.65	57.00
	Average	**139.25**	**6.96**	**3.81**	**15.95**	**2.51**	**4.77**	**4.00**	**57.50**
Carbon stock (Kg. ha^{-1})	Aklera	64.00	3.18	1.71	7.09	1.22	2.43	1.74	55.00
	Asnawar	67.00	3.36	1.71	8.05	1.04	1.75	2.07	62.00
	Jhalawar	62.00	3.12	1.71	6.78	1.48	2.90	1.74	56.00
	Khanpur	57.00	2.86	1.72	6.78	0.79	1.51	1.64	57.00
	Average	**62.50**	**3.13**	**1.71**	**7.18**	**1.13**	**2.15**	**1.80**	**57.50**
SIQR: Semi Interquartile Range, IQR: Interquartile Range, SD: Standard deviation and CV: Coefficient of variance									

CONCLUSIONS

The present study was aimed to find out the growing stock, biomass and carbon stock in the dominated palash forest of Malwa plateau region of India. The palash forest belongs to the local community. The local community used the forest for the purposes of fuel wood and for forage for their livestock. The finding of the study that the palash forest stored about 57.0 to 67.0 Kg·ha^{-1} of carbon in their total biomass. The study confirmed that the dominated palash forest of Malwa plateau region of India is valuable sink of carbon. But this valuable storage factory faced threats in terms of excess use of wood, forage, domestic uses and unscientific management. The proper scientific management and proper utilization of the forest, rehabilitation of degraded forest and afforestation and reforestation can be significant measures to enhance the potential of the forest to stored and sink more carbon. Furthermore, this study also frames a working plan and forest protocol regarding growing stock, biomass and carbon stock assessed in the dominated forest of palash of Malwa plateau region of India for future.

FUTURE SCOPE

The result also indicates the dry deciduous forest of Malwaplateau region of India has a good reservoir of plant diversity and carbon stock. We also found the positive Polynomial cubic relationship between DBH and basal area as both increase the biomass and carbon would increase substantially. The present study provided valuable data on forest biomass and carbon stock of woody plant species, thereby accentuating the role of woody plants of dry deciduous forests in carbon sequestration potential. These are baseline data that might attract and help conservation managers, researchers and scientists in understanding the role of dry deciduous forest ecosystems in carbon stocking and sequestration potential.

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Conflict of Interest. None.

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