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A Case Study of Carbon Sequestration by Sacred Groves of Mundra Taluka, Kachchh District, Gujarat.

MALSATAR ALPESH[1]* and P.K. MEHTA[2]

[1]Department of Earth and Environmental Science, KSKV Kachchh University. Bhuj-Kachchh.
[2]Government Science College, Mandvi- Kachchh.

Abstract

Sacred groves are those forest patches that are connected with the religious and traditional values and beliefs of local people. Plants which are grown near the grove are called sacred plants. Sacred groves include several endemic, endangered and ecologically important plant species. In other words, sacred groves are natural conservation units for biodiversity. Sacred groves and sacred plants are protected and conserved due to the strong religious and mythological beliefs of local people. Their beliefs are as strong as their social traditions. The religious and cultural rites that are performed in the groves give it protection, as well as assisting in keeping the sacred grove in immaculate condition and ensuring the maintenance of its plants. As it is known that the trees are cutting day- by- day and on the other hand Sacred trees which grow near sacred groves are not under threat of cutting due to religious and cultural beliefs. Therefore, Sacred trees or sacred forest a potential role in the sequestration of atmospheric CO_2 in the form of biomass. To estimation of Biomass and carbon sequestration in the Sacred tree species have been using a non-destructive method. The main focus of the current article is on estimating the carbon sequestration of sacred tree species in sacred groves found in selected areas Mundra Taluka of Kachchh District. Total 32 sacred groves were recorded from 18 villages which cover approximately 12.77 hectares of land area. Carbon sequestration of 172 individuals of 16 tree species was estimated through the standard method. *Ficus benghalensis* L. sequestered maximum carbon, i.e., 5.48 tones followed by Azadirachta indica A. Juss. (4.34 tones), *Syzigium cumini* (L.) Skeels (3.79 tones) While the lowest carbon sequestration was recorded in *Pithecellobium dulce* (Roxb.) Benth (0961 tones), *Prosopsis cineraria* (L.) Druce (0.907 tones), *Acacia catechu Willd*. (0.39 tones) and *Tamarindus indica* L. (0.173 tones).

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CONTACT Malsatar Alpesh alpeshmalsatar11@gmail.com Department of Earth and Environmental Science, Kskv Kachchh University. Bhuj-Kachchh.

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Introduction

The daily anthropogenic advancements of humans have led to an increase in global carbon emissions. In the modern world, Industrialization and Urbanization will lead to a continuous increase in air pollution and the earth's average temperature. According to studies, the amount of carbon in the atmosphere is increasing by about 2,600,000 kg every year.[1] India has the second-highest population after China and is the third-largest emitter of greenhouse gases, accounting for around 5.3% of all emissions worldwide.[2] To achieve the goal of the UNFCC Paris agreement to reduce the rise in the world average temperature far below 2 °C, Carbon sequestration projects are necessitated in every part of the world.[3]

Over the decade of 2020, to achieve net-zero carbon targets by 2050, it is predicted that global CO_2 emissions reduced by 7.6% annually4. The least expensive way to minimize this gas is by biological sequestration of carbon in plants. Traditional protected landscapes or sacred forests typically have higher levels of biomass, plant diversity, and tree cover than nonsacred areas.[5-7] Sacred groves are known as the small patches of conserved forests protected by man's spiritual beliefs and cultural practices. These sacred forest patches were studied from the ecological, environmental, and floristic points of view by several research workers. Due to their religious and mythological myths and beliefs, sacred groves and sacred plants are conserved well. Apart from being conserved, these sacred plants can also have a higher potential for carbon sequestration.

The Current paper presents the carbon sequestration potential of sacred trees of sacred groves of Mundra taluka of Kachchh district. This paper provides also a total number of sacred groves and sacred trees with their taxonomical details.

Material and Methods

Study Sites

The present study was conducted in selected study areas in Mundra taluka of Kachchh district from October 2021 to September 2022. A total of 32 sacred groves was observed in 18 villages of Mundra taluka. Mundra is a small town and it is situated near the Arabian Sea. It is situated between 22.8396º N and 69.7241º E. It is one of the largest Private ports of Mundra situated on the north shores of the Gulf of Kachchh. The maximum and minimum temperatures were recorded 15º C in winter and 38º C in summer respectively. The average temperature of this region is about 27 ºC.

Enumeration Method for Sacred plant species

The plants that grow near the grove which considered Sacred plant species. By using local flora, Gujarat state flora8 all the recorded plant species were identified and arranged according to Bentham & Hooker's classification system.

Method for Biomass

The biomass of sacred tree species was estimated using a non-destructive method. The above-ground biomass was calculated by using a model created by.[9] The following formula is used for estimating the biomass of sacred tree species.

$$Y = \exp. \{ -2.4090 + 0.9522 \ln (D^2 \times H \times S)\}$$

Where Y is the above-ground biomass (kg), H is the height of trees (meter), D is the diameter at breast height (1.3m) in cm, and S is the wood density (t/m^3), Exp. = [.....] signifies "raised to the power of [.....]". The wood densities for tree species were obtained from the website www.worldagroforestycentre.org. The 15% value of the above-ground biomass was used to determine the below-ground biomass.[10]

Method for Measuring the Height of Tree Species

Using an Abney Clinometer, tree species' heights were measured. The formula used to calculate the tree species' height is as follows[11]

$\tan\theta = BC/AC$, where AB is equal to $\tan\theta$ and AC is the distance from the tree as measured by a measuring tape.

Method for measurement of DBH

Trees with girth at breast height (GBH) greater than 10 cm were classified as part of an established regeneration sampling, and the DBH (Diameter at Breast Height) was calculated by measuring the tree's GBH at a height of roughly 1.32 meters above the ground by using the measuring tape. By dividing the actual girth of the tree species by (3.14), or GBH/3.14, the DBH of the tree species was determined.[12] GBH of 172 individuals of 16 tree species was measured.

Total Biomass (TB)

The total Biomass of trees is considered as the sum of the above and below grounds biomass.[13]

Method for measuring the Carbon Sequestration

Of the total biomass of trees, 72.5% is considered dry biomass14. Out of 72.5%, 50% of dry biomass is Carbon.[15] Wood volume (dry weight) can be used to calculate the carbon storage of tree species by multiplying it by 3.67 (Molecular weight of Carbon) which is considered the actual content of carbon in biomass.[16-17]

Result and Discussion

The selected sites show the flora diversity of Mundra taluka's Sacred grove. A total of 38 Plant species was recorded.

Table 1: Checklist of Sacred plants recorded in Mundra taluka sacred grove

Sr No.	Botanical Name	Family	Local Name	Habitat	Life Form
1	*Polyalthia longifolia* (Soon) Thw.	Annonaceae	Aasopalav	T	Ph
2	*Cocculus hirsutus* (L.) Diels.	Menispermaceae		C	Th
3	*Capparis decidua* (Forsk) Edgew.	Capparaceae	Kerdo	S	Ch
4	*Abutilon indicum* (L.) Sweet	Malvaceae	Kanski	H	Th
5	*Balanites aegyptiaca* (L.) Delile	Zygophyllaceae	Ingoriyo	T	Ph
6	*Azadirachta indica* A. Juss.	Meliaceae	Neem	T	Ph
7	*Moringa oleifera* Lam.	Moringaceae	Sargavo	T	Ph
8	*Ziziphus nummularia (Burm. f.) Wight & Arn.*	Rhamnaceae	Boradi	S	Th
9	*Crotalaria hebecarpa* (DC.) Rudd	Fabaceae	Hirta	H	Th
10	*Delonix regia* (Boj.) Raf		Gulmahor	T	Ph
11	*Indigofera linnaei* Ali			H	Th
12	*Pithecellobium dulce* (Roxb.) Benth		Mithi Ambali	T	Ph
13	*Pongamia pinnata* (L.) Pierre		Karanj	T	Th
14	*Tamarindus indicus* L.		khatiamli	T	Ph
15	*Senna auriculata* (L.) Roxb.	Caesalpiniaceae	Aaval	S	Th
16	*Acacia catechu* Willd.	Mimosaceae	Khair	T	Ph
17	*Acacia nilotica* (L.) Del.		Deshi bavl	T	Ph
18	*Prosopsis cineraria* (L.) Druce		Khijado	T	Ph
19	*Prosopsis juliflora* (Sw) DC		Gando Baval	S	Th
20	*Syzigium cumini* (L.) Skeels	Myrtaceae	Jambu	T	Ph
21	*Salvadora persica* L.	Salvadoraceae	Pilu	S	Ph
22	*Calotropis procera* (Ait.) R.Br.		Aakdo	S	Th
23	*Cordia myxa* L.	Boraginaceae	Lihari	T	Ph
24	*Ipomoea cairica* (L.) Sweet	Convolvulaceae		C	Th
25	*Rivea hypocrateriformis* Choisy		Fang	C	Ch
26	*Calotropis gigantea* (L.) Dryand.	Apocynaceae	Moto Aakado	S	Th
27	*Nerium oleander* L.		Lal Karen	S	Th
28	*Thevetia peruviana* (Pers.) Merrill		Karen Pili	S	Th
29	*Solanum virginianum* L.	Solanaceae	Bhoy-Ringani	H	Th
30	*Lepidagathis trinervis* Wall. Ex	Acanthaceae	Harancharo	H	Th
31	*Ocimum gratissimum* L.	Lamiaceae	Ram Tulsi	H	Th
32	*Ocimum tenuiflorum* L.		Tulsi	H	Th
33	*Achyranthes aspera*L. var. aspera	Amaranthaceae	Andhedi	H	Th

34	*Ficus bengalensis* L.	Moraceae	Vad	T	Ph
35	*Ficus religiosa* L.		Pipalo	T	Ph
36	*Aloe vera* (L.) Webb. & Berth	Liliaceae		H	Th
37	*Phoenix sylvestris* (L.) Roxb	Arecaceae		T	Ph
38	*Cynodon dactylon* (L.) Pers.	Poaceae	Doub Grass	H	Th

Table 2: Family-wise genera and species recorded in the Mundra Taluka sacred grove

Sr. Nos.	Name of Family	Total Genera	Total Species
1	Fabaceae	5	5
2	Mimosaceae	2	4
3	Caesalpiniaceae	2	2
4	Convolvulaceae	2	2
5	Apocynaceae	3	3
6	Lamiaceae	1	2
7	Moraceae	1	2
8	Annonaceae	1	1
9	Asclepiadaceae	1	1
10	Menispermaceae	1	1
11	Capparaceae	1	1
12	Malvaceae	1	1
13	Zygophyllaceae	1	1
14	Meliaceae	1	1
15	Moringaceae	1	1
16	Rhamnaceae	1	1
17	Myrtaceae	1	1
18	Salvadoraceae	1	1
19	Boraginaceae	1	1
20	Solanaceae	1	1
21	Acanthaceae	1	1
22	Amaranthaceae	1	1
23	Liliaceae	1	1
24	Arecaceae	1	1
25	Poaceae	1	1

Among 25 families, Fabaceae was the most dominant family i.e., 5 Species, followed by Mimosaceae (4 species), Apocynaceae (3 species), Caesalpiniaceae, Asclepiadaceae, Convolvulaceae and (2 species).

Table 3: Dominant genera in the Mundra Mundra sacred grove

Sr.No.	Genera	Family	No. of Species
1	Accacia	Mimosaceae	2
2	Prosopsis	Mimosaceae	2
3	Ocimum	Lamiaceae	2
4	Ficus	Moraceae	2

Among 33 genera, *Accacia, Ocimum Ficus, and Prosopsis* (2 species) were the most dominant genera respectively.

Table 4: Sacred groves, their village of occurrence and the area occupied.

Sr. No.	Name of Sacred Groves	Name of Village	Area in ha
1	*Shree Hanuman*	Mota Knadgra	0.01
2	*Shree Ganesay Dev*		0.05
3	*Shree Hanuman*	Navinal	0.01
4	*Yaksh Mahadev*		1.2
5	*Jay Suradada Aashat*	Zarpara	0.01
6	*Limdavala Khetarpar Dada*		3
7	*Somat Dada*	Mota Kapaya	0.03
8	*Jay Shree Khetarpar Dada*	Baroie	2.3
9	*Surapura*		0.01
10	*Ya Patan Pak Sarit*		0.02
11	*Chetan Shree Hanuman*	Mangra	0.01
12	*Aashapura Mataji*		0.01
13	*Ya Vali Dargah*		1.5
14	*Khetarpar Dada*		0.01
15	*Khetarpar Dada*	Bhorara	0.01
16	*Khetarpar Dada*	Ratadiya	0.02
17	*Ya Vali*	Viraniya	0.05
18	*Yaksh*		0.001
19	*Ramdev Pir*		0.01
20	*Ramdev Pir*	Vanki	0.0001
21	*Khetarpar Dada*	Pragpar-II	0.01
22	*Madadpir and Khetarpar dada*	Goersama	0.1
23	*Shree Gaman Ganeshaydev*		0.01
24	*Ganpatidada*	Luni	0.1
25	*Yaksh Mahadev*	Vadala	2
26	*Shree Khetarpar dada Kantivala bapa*	Kundrodi	0.01
27	*Khetarpar Dada*	Bagada	0.03
28	*Ya Halisha and Goga pir*		0.03
29	*Hajrat ya Hussain Pir*		0.01
30	*Khetarpar Dada*	Fachaniya	0.001
31	*Khetarpar Dada*	Tunda	2.2
32	*Ya Imbraimsha Dargah*		0.003

There are 61 villages in Mundra taluka. Out of the total 61 villages, sacred groves were recorded from 18 villages. Sacred groves were absent in the remaining villages of Mundra taluka. A total of 32 sacred groves were recorded from 18 villages which cover approximately 12.77 hectares of land area. Maximum sacred groves were recorded in Mangra village, i.e., 4 Sacred groves, followed by Baroie village (3 Sacred groves), Viraniya village (3 Sacred groves), and Bagada village (3 Sacred groves) respectively.

Out of the total 12.77 hectares of land area covered by sacred groves. The maximum area was recorded in SGs of Zarpara village i.e., 3.01 hectares followed by Baroie village (2.33), Tunda village (2.203 hectares), Mangra village (1.53 hectares) and Navinal (1.21 hectares).

The Carbon sequestration of 172 individuals of 16 tree species was estimated through the standard method9. Out of the total 16 tree species. *Ficus benghalensis* L. is contributed to the maximum

carbon sequestration, i.e., 5.84 tones followed by *Azadirachta indica* A. Juss. (4.34 tons) *Syzigium cumini* (L.) Skeels (3.79 tons), *Acacia nilotica* (L.) Del. (2.72 tons), *Phoenix sylvestris* (L.) *Roxb*., (2.61 tons) *Balanites aegyptiaca* (L.) *Delile* (2.39 tons), *Polyalthia longifolia* (Soon) Thw. (2.2 tons) Lower carbon sequestration was recorded in *Pithecellobium dulce* (Roxb.) Benth (0.961 tones), *Prosopsis cineraria* (L.) Druce (0.907 tons), *Acacia catechu* Willd. (0.39 tons) and *Tamarinds indica* L. (0.173 tons).

Table 5: Carbon Sequestration of Tree Species

Sr. Nos.	Name of plant	Mean Above Ground Biomass (kilogram/ tree)	Mean Below Ground Biomass (kilogram/ tree)	Total Biomass (Kilogram /tree)	Mean Carbon in total species (kilogram /tree)	Mean Carbon in total species (in Tons)
1	*Ficus benghalensis* L.	3819.878	572.98	4392.86	5844.15	5.84
2	*Azadirachta indica* A. Juss.	3492.78	523.92	4016.70	4343.72	4.34
3	*Syzigium cumini* (L.) Skeels	2479.51	371.93	2851.44	3793.49	3.79
4	*Acacia nilotica* (L.) Del.	1780.55	267.13	2047.98	2724.59	2.72
5	*Phoenix sylvestris* (L.) Roxb.	1707.54	256.13	1963.67	2612.42	2.61
6	*Balanites aegyptiaca* (L.) Delile	1567.60	235.14	1802.74	2398.32	2.39
7	*Polyalthia longifolia* (Soon) Thw.	1437.89	215.68	1653.55	2199.84	2.2
8	*Pongamia pinnata* (L.) Pierre	907.93	136.19	1044.12	1389.08	1.39
9	*Delonix regia* (Boj.) Raf	756.96	113.54	870.50	1158.01	1.16
10	*Cordia myxa* L.	639.63	104.64	802.28	1067.33	1.07
11	*Moringa oleifera* Lam.	718.33	107.75	826.08	1099.01	1.01
12	*Ficus religiosa* L.	6570.09	985.51	7555.61	10051.79	1.0
13	*Pithecellobium dulce* (Roxb.) Benth	6279.09	941.86	7220.96	960.59	0.961
14	*Prosopsis cineraria* (L.) Druce	5931.55	889.77	6821.62	907.32	0.907
15	*Acacia catechu* Willd.	256.39	38.46	294.85	392.27	0.39
16	*Tamarindus indica* L.	11351.50	1702.72	13054.22	173001	0.173

Conclusion

During my research work total of 32 sacred groves were recorded from 18 villages of selected study sites. Which covers approximately 12.27 hectares of the land surface area. total 127 individuals of 16 tree species carbon sequestration measured. Out of the total 16 tree species, *Ficus benghalensis* L. was recorded with 5.84 tons of carbon storage in only 8 individuals while *Azadirachta indica* A. Juss. was recorded with 4.34 tons of carbon storage in 52 individuals. *Syzigium cumini* (L.) Skeels was recorded with 3.79 tons of carbon storage in only 12 individuals. This indicates carbon sequestration is not only dependent on the individual number's species. It depends on the Biomass of the species. A low number of individuals with high biomass can store more carbon than a high number of individuals with low Biomass.

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Conflict of Interest

There is no conflict of interests.

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