Phyto-sociological assessment, Biomass and Carbon Stock estimation of Sunehra Kadam Khandi sacred grove in Bharatpur, Rajasthan, India

Summer Internship submitted by

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For the partial fulfillment of the requirements for the reward of the degree of

B.Sc. (Hons) Forestry

Phyto-sociological assessment, Biomass and Carbon Stock estimation of Sunehra Kadam Khandi sacred grove in Bharatpur, Rajasthan, India

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ACKNOWLEDGMENT

I would like to extend my heartfelt gratitude to all the people and organisations who have helped me in any possible ways during my summer internship either directly or indirectly. First and foremost, I would like to thank my Internal Supervisor Dr. Upamanyu Hore for providing me with my first fieldwork opportunity.

I want to express my gratitude towards Ms. Radhika Bhagat and Ms. Rubina Rajan of Sacred Earth Trust for taking me as their intern. I also want to acknowledge and appreciate Mrs. Padmavati Dwivedi and Mr. Mohit Saini of Vanamali Project, and Mr. Debadityo Sinha of VIDHI Centre for Legal Policy. I would also like to extend a special thanks to Dr. Bobbymoore Konsamfor his valuable guidance throughout this internship. This study would never have materialized without the support of local people at Mata Ji Gaushala, Barsana and invaluable support, care and insights offered by village folks of Nagla Harnarayan, Nagla Harsukh and Kanwara who had preserved the sacred grove of Kadam Khandi for ages. Lastly, I would like to thank my family and friends for believing in me and Ishani Datta for being an amazing co-intern andfield partner.

My sincerest gratitude towards every member of Amity Institute of Forestry and Wildlife.

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ABSTRACT

The sacred grove of Sunehra Kadam Khandi in Bharatpur, Rajasthan is at least a 500-year- old community protected patch of forest confined between two hills. The study seems to be the first attempt at documenting the floral diversity of the sacred grove and assess it on standard phytosociological parameters to understand distribution of tree species. The sacred grove was found to be heavily infested with Prosopis juliflora (IVI-78.00)- an Invasive Alien Species (IAS) which was found to be competing with native species. Anogeissus pendula (109.69 Mg/ha) was found to have the highest total biomass among all the species and wasthe dominant species on hill slopes. Total carbon stock values calculated from this study (138.97 Mg C/ha) was within the range reported by other studies. In all, 856 tree individuals were sampled and GBH was measured for which 81 plots were drawn each of 10m*10m and 12 species were documented.

Keywords: Allometric equation, IVI, Prosopis juliflora, Invasive Alien Species, Flora of Rajasthan

INTRODUCTION

Sacred groves are natural sites which hold cultural and religious importance for communities living around it and hence have been naturally protected and preserved for ages by the virtue of a strong social fence through a set of unwritten rules of how to utilise the natural resources and ecosystem services offered by the sacred groves for sustenance but also at the same time deters them from over exploiting by attaching local beliefs which cannot be questioned. Sacred groves present an alternative conservation model where communities themselvescome forward to protect a patch of natural vegetation and the biodiversity it holds within withno external economic incentives to lure them to. Going against the current authoritarian protection practices of erecting natural fortresses at the crux of which lies the belief that ecosystems will only flourish when isolated from humans and a model where interaction between humans and other forms of life is classified as conflict which it is believed could be avoided by natural borders- the concept of sacred groves tends to challenge this notion where the underlying themes of eco-spirituality, sustainability, and a sense of being a small part of larger ecosystem govern people's actions and shape the parameters for resource utilization.

The origin of sacred groves has a strong correlation with expansion of agriculture when a need would have been felt to protect the forests for all the services, they provide from regulating services like pollination and controlling erosion to supporting services by managing watershed and soil formation, from all the uncountable provisioning services to themost strongly held and revered cultural services. Some estimates have predicted around 100,000- 150,000 sacred groves in India but as per C.P.R. Environment Education Centre, only 10,377 such groves have been documented. The highest been in Maharashtra with 2820 sacred groves, followed by Karnataka having 1476 and in third Tamil Nadu with 1275 sacred groves. Sacred groves come in varied shape and sizes from a bunch of trees to an area spanning hundreds of hectares. It is this versatility which adds even more importance to sacred grove as they provide safe recluse and might be playing crucial role in highly fracturedwildlife corridors in India. India has around 21.71% of its geographical area classified as forest but even with a network of 990 protected areas, it only protects 5.27% of its geographical land. Though sacred groves cover a miniscule part of India's vast geography, but these are some of the least disturbed patches of natural vegetation as logging is found to be mostly banned in these groves due to fear of angering the spirits/deities or gods who are believed to be residing in these groves. Just like in the Kadam Khandi of Sunehra in

Bharatpur, Rajasthan where people have this believe that even taking a twig from the grove would bring all sorts of hardships in their life and to this end use the grove to only graze their cattle and collect fruits if any.

In this 'Millennium of cities', with ever higher rates of internal migration (450 million internal migrants as per 2011 census) in India from rural parts to urban cities in search of employment to support their families back at home- this increasing struggle of finding one's place in fast moving capitalist economies is also impacting cultural, religious and social dynamics of Indian societies and threads to one's own culture and faith in religious beliefs is seen to be deteriorating. Here, sacred groves offer an opportunity to study how changing social dynamics impact conservation efforts on a village level, how it effects the 'social fence' which drives community action over individual needs and is economic incentivization the answer to all conservation problems which the ICDP (Integrated Conservation & Development Project) approach holds in high regard. To begin understanding thecomplexities of conservation and loopholes in current western conservation models where protected areas are seen as the cornerstones for biodiversity conservation with a top-down authoritarian approach- the study of sacred groves and documenting the rich biodiversity which they support should be the first step and how the community's perception tends to change with changing needs.

In this third decade of 21st century, when the brunt of climate change could be felt by everyone and people from myriad spheres are coming together to raise their concern to conserve biodiversity and forests for their role as major carbon sequestrator. As carbon dioxide which at present is at 412 parts per million-an all-time high, that's a 47% increase since the dawn of Industrial Age and 11% increase since the start of 3rd millennium. Forests take in CO2 from atmosphere and use photosynthesis to convert it into biomass. It's believed that forests sequester up to one fourth of the carbon released by anthropogenic activities. In India alone, the forests are estimated to stock 7204 million tonnes of carbon in them as per Forest Survey Report 2021. The studies on carbon stock potential of sacred groves are of great importance to put into light that regardless of their small size and lack of economic prospects on eco-tourism front due to absence of large charismatic wild animals- the two attributes which are deemed to be valuable in context of protecting a patch of naturalvegetation from falling to encroachment or diversion to non-forestry practices, the sacred groves could come to use in country's effort to increase carbon sequestration by increasing

and more importantly protecting the sacred old growth patches of green cover whether it be forests or grasslands or wetlands.

AIMS & OBJECTIVES

The main aim of this study is to understand the floral diversity and carbon sequestration potential of sacred groves to bolster their conservation programs.

Objectives covered:

(1) To study phytosociology of tree species.
(2) To estimate biomass and carbon stock of tree species of sampled sacred grove.

STUDY AREA

The sacred grove of Sunehra Kadam Khandi falls under Kaman Tehsil in Bharatpur district of Rajasthan. Bharatpur is also known as the Eastern Gate of Rajasthan and is part of larger Braj region. The two closest village to Kadam Khandi sacred grove which also share boundaries with it are Nagla Harnarayan and Nagla Harsukh. As the name suggests, the sacred grove was named Kadam Khandi because it was once dominated by the Krishna Kadam or True Kadam (*Mitragyna parvifolia*) which as per the local beliefs also happens to be one of the favourite trees of Lord Krishna and Radha. The grove of Kadam Khandi is held sacred as it is the place where revered saint Naga Baba went into samadhi after Lord Krishna and Radha came together to untangle his braids from the bushes of Heens (*Capparis sepiaria*). The area falls under semi-arid biogeographic zone and has Dry Tropical Thorn Forest.

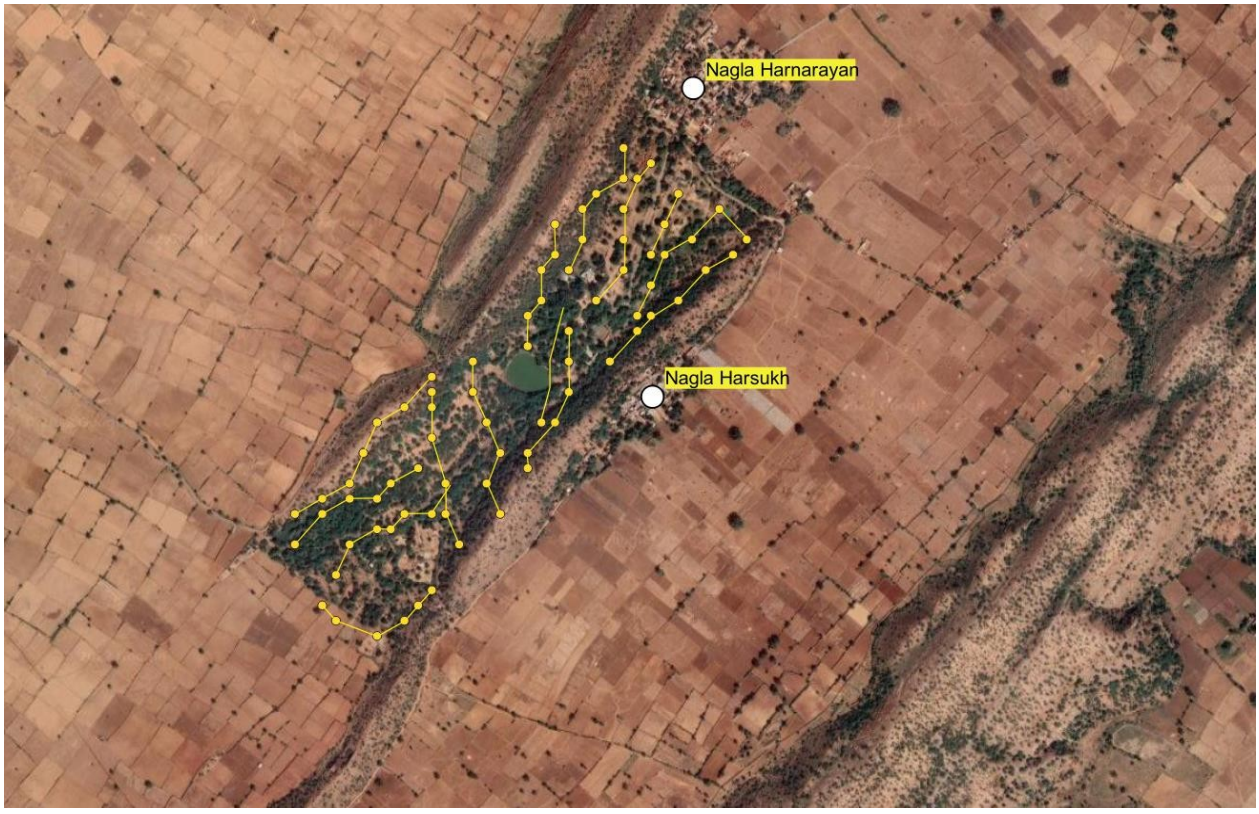


Figure 1: Google Earth Image representing the sacred grove of Kadam Khandi with all 14 transects and 81 sampling plots.

MATERIALS & METHODS

The area was sampled using Systematic Random sampling by drawing 300 m long transects on which were drawn 6 plots alternatively on both sides of the transect, each of 10*10m size- 60m apart from each other. In total, 81 plots were sampled covering nearly 10% of the Kadam Khandi sacred grove. All tree species within the plot which was taller than 1.37m wasmeasured for GBH using a diameter tape.

The Phyto-sociological parameters like frequency, density, abundance, A/F ratio, Total Basal Cover and IVI (Important Value Index) were calculated using standard formulas. Biomass and Carbon Stock was assessed using non-destructive methods. The tree girth at breast height GBH is the best variable available to measure the tree biomass. The above ground biomass of all recorded species was estimated using allometric equation proposed by Rawat and Singh, 1988 for Mixed Woody Species and works for a varied range of conditions in India.

$$\ln AGB = 0.349 + 1.316 * \ln(GBH)$$

The BGB was estimated using the following equation: (Brahma et al., 2021)

$$BGB = \exp[-1.085 + 0.9256 * \ln(AGB)]$$

Total TB was calculated as a sum of Above Ground biomass (AGB) and Below Ground Biomass (BGB).

$$TB = AGB + BGB$$

The carbon stock of a tree was estimated by multiplying the Total Biomass of a tree by a conversion factor of 0.48.

RESULTS

PHYTOSOCIOLOGY

A total of 856 individuals were recorded belonging from 7 orders, 9 families, 10 genera and 12 species.

KADAM KHANDI SACRED GROVE	
Number of Species	12
Number of Genera	10
Number of Families	9
Number of Orders	7

Table 1: Name of species, Family, Order and Common Name of all tree species in Kadam Khandi sacred grove.

Species	Family	Order	Common Name
Anogeissus pendula	Combretaceae	Myrtales	Dhok
Azadirachta indica	Meliaceae	Sapindales	Neem
Balanites roxburghii	Zygophyllaceae	Zygophyllales	Hingota
Capparis decidua	Capparaceae	Brassicales	Kareel
Capparis sepiaria	Capparaceae	Brassicales	Heens
Ficus racemosa	Moraceae	Rosales	Goolar
Holoptilia integrifolia	Ulmaceae	Rosales	Papri
Mitragyna parvifolia	Rubiaceae	Gentianales	True Kadam
Prosopis juliflora	Fabaceae	Fabales	Kavli Babool
Salvadora oleoides	Salvadoraceae	Brassicales	Doongar
Vachellia leucophloea	Fabaceae	Fabales	Ramja
Vachellia nilotica	Fabaceae	Fabales	Desi Babool

Among all the tree species, Prosopis juliflora had the highest IVI (78.00), followed by Anogeissus pendula with IVI (70.43) and Salvadora oleoides with IVI (58.29). Frequency among all tree species was highest for Prosopis juliflora (55.56%), followed again by Anogeissus pendula (41.98%) and Salvadora oleoides (23.46%). The density was highest for Prosopis juliflora (466.67 trees/hectare), followed by Anogeissus pendula (255.56 trees/hectare) and Balanites roxburghii with density of (76.54 trees/hectare). The abundance values were highest for Prosopis julifora (8.4), followed by Anogeissus pendula (6.09), and Balanites roxburghii (5.64).

Azadirachta indica (0.77) was found to be least dominant species followed by Ficus racemose with IVI (1.57) and Vachelia leucophloea with IVI (6.35). The lowest frequency of all trees was recorded for Azadirachta indica and Ficus racemose both with (1.23%) followed by Mitragyna parvifolia (3.70%). The least density was recorded for Azadirachta indica (1.23 trees/hectare), followed by Ficus racemose (2.47 trees/hectare) and Vachelia leucophloea with (6.17 trees/hectare). The abundance was lowest for both Azadirachta indica (1) and Vachelia leucophloea (1) followed by Ficus racemosa (2). The A/F ratio for all the 12 specieswas more than 0.05 indicating contagious distribution.

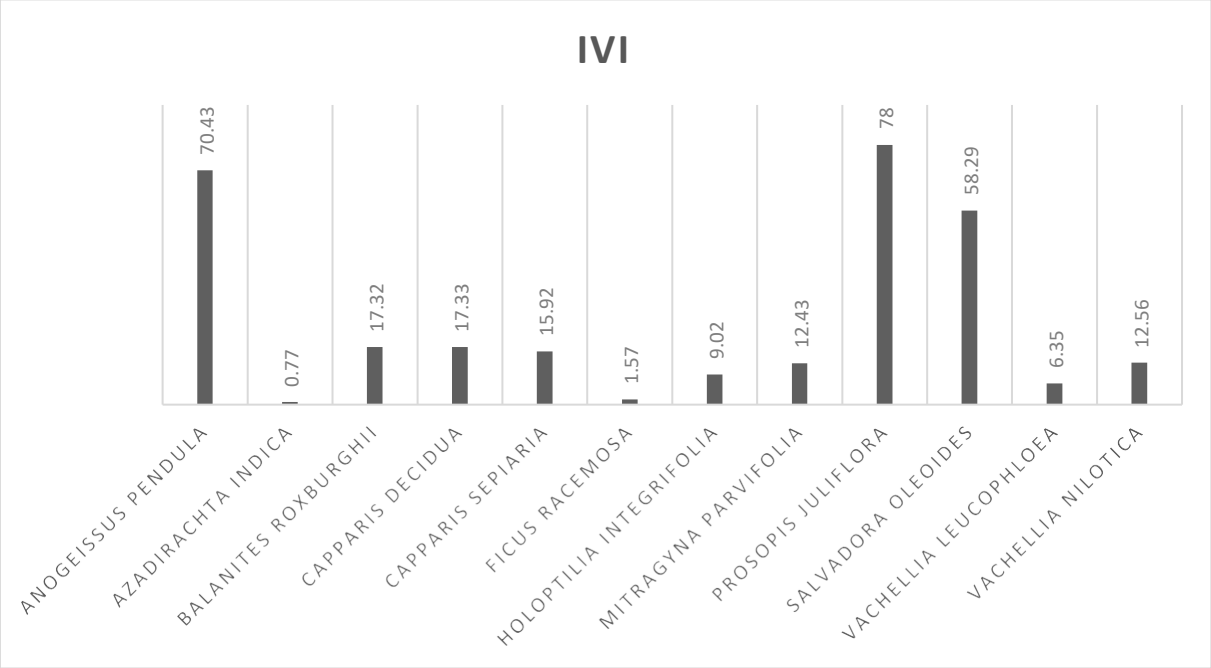


Figure 2: IVI of all the 12 tree species

Among the species documented, the highest Total Basal Cover was recorded for Salvadora oleoides (16.45 m^2/ha), followed by Anogeissus pendula (10.64 m^2/ha) and Mitrogyna parvifolia (3.88 m^2/ha) whereas the Azadirachta indica (0.02 m^2/ha) was found to have the lowest TBC, seconded by Capparis sepiaria (0.12 m^2/ha) and Ficus racemose (0.30 m^2/ha).

The overall Total Basal Cover was estimated to be 40.82 m^2/ha. The overall density was recorded as 1056.79 trees/hectare or 10.56 trees per 100 m^2.

Table 2: Frequency (%), Density (trees/hectare), A/F ratio, Total Basal Cover (m^2/ha) and IVI of all tree species in Kadam Khandi sacred grove.

Species					
Anogeissus pendula	41.98	255.56	0.15	10.64	70.43

Azadirachta indica	1.23	1.23	0.81	0.02	0.77
Balanites roxburghii	13.58	76.54	0.42	1.44	17.32
Capparis decidua	18.52	67.9	0.2	0.81	17.33
Capparis sepiaria	22.22	51.85	0.11	0.12	15.92
Ficus racemosa	1.23	2.47	1.62	0.3	1.57
Holoptilia integrifolia	8.64	19.75	0.26	1.22	9.02
Mitragyna parvifolia	3.7	12.35	0.9	3.88	12.43
Prosopis juliflora	55.56	466.67	0.15	2.89	78
Salvadora oleoides	23.46	71.6	0.13	16.45	58.29
Vachellia leucophloea	6.17	6.17	0.16	1.14	6.35
Vachellia nilotica	11.11	24.69	0.2	1.9	12.56
Total	**207.41**	**1056.79**	**0.2**	**40.82**	**300**

Table 3: Relative frequency, relative density, relative dominance and IVI of tree species in Kadam Khandi sacred grove.

Species	R.Frequency	R.Density	R.Dominance	IVI
Anogeissus pendula	20.24	24.18	26.01	70.43
Azadirachta indica	0.6	0.12	0.06	0.77
Balanites roxburghii	6.55	7.24	3.53	17.32
Capparis decidua	8.93	6.43	1.98	17.33
Capparis sepiaria	10.71	4.91	0.3	15.92
Ficus racemosa	0.6	0.23	0.74	1.57
Holoptilia integrifolia	4.17	1.87	2.98	9.02
Mitragyna parvifolia	1.79	1.17	9.48	12.43
Prosopis juliflora	26.79	44.16	7.06	78
Salvadora oleoides	11.31	6.78	40.21	58.29
Vachellia leucophloea	2.98	0.58	2.79	6.35
Vachellia nilotica	5.36	2.34	4.87	12.56
Total	**100**	**100**	**100**	**300**

Table 4: Mean of diameter, Girth at Breast Height (GBH), Basal Area and Total individuals of each tree species in Kadam Khandi sacred grove.

Species	Mean DBH(cm)	Mean GBH(cm)	Mean Basal Area (m^2)	Total Individual
Anogeissus pendula	21.05	66.14	0.042	207
Azadirachta indica	7.96	25	0.02	1
Balanites roxburghii	8.33	26.16	0.019	62
Capparis decidua	9.35	29.38	0.012	55
Capparis sepiaria	3.9	12.24	0.002	42

Ficus racemose	36.92	116	0.123	2
Holoptilia integrifolia	18.32	57.56	0.062	16
Mitragyna parvifolia	39.6	124.4	0.314	10
Prosopis juliflora	6.19	19.43	0.006	378
Salvadora oleoides	36.22	113.78	0.23	58
Vachellia leucophloea	44.5	139.8	0.185	5
Vachellia nilotica	23.78	74.7	0.077	20
			1.091	856

BIOMASS & CARBON STOCK

Among all the 12 species, the highest ABG biomass was recorded for Anogeissus pendula (93.66 mg/ha), followed by Salvadora oleoides (57.56 Mg/ha) and Prosopis juliflora(35.38 Mg/ha) whereas the lowest ABG biomass was recorded for Azadirachta indica (0.12 Mg/ha), followed by Ficus racemosa (1.88 Mg/ha) and Capparis sepiaria (2.09 Mg/ha).

The highest BGB among was recorded for Anogeissus pendula (16.04 Mg/ha), followed by Salvadora oleoides (10.53 Mg/ha) and Prosopis juliflora (6.46 Mg/ha) whereas the lowest BGB was recorded for Azadirachta indica (0.03 Mg/ha), followed by Ficus racemosa (0.37 Mg/ha) and Capparis sepiaria (0.46 Mg/ha).

But the highest TB was recorded in Anogeissus pendula (109.69 Mg/ha), followed by Salvadora oleoides (68.09 Mg/ha) and Prosopis juliflora (41.83 Mg/ha) whereas the least total biomass was recorded in Azadirachta indica (0.15 Mg/ha), followed by Ficus racemosa (2.25 Mg/ha) and Capparis sepiaria (2.56 Mg/ha).

The total biomass of all sampled trees was 289.52 Mg/hectare.

The total carbon stock was recorded to be highest in Anogeissus pendula (52.65 Mg C/ha), seconded by Salvadora oleoides (32.68 Mg C/ha) and Prosopis juliflora (20.08 Mg C/ha) whereas Azadirachta indica (0.07 Mg C/ha) had the least C stored in it, then it was Ficus racemosa (1.08 Mg C/ha) and Capparis sepiaria (1.23 Mg C/ha).

The total C of the sampled trees of Kadam Khandi sacred grove was 138.97 Mg/hectare.

Table 5: AGB(Mg/ha), BGB(Mg/ha), TB(Mg/ha) and Carbon stock (Mg C/ha) of all the species.

Species	AGB (Mg/ha)	BGB (Mg/ha)	TB (Mg/ha)	Carbon (Mg C/ha)
Anogeissus pendula	93.66	16.04	109.69	52.65
Azadirachta indica	0.12	0.03	0.15	0.07
Balanites roxburghii	8.73	1.71	10.44	5.01
Capparis decidua	9.05	1.81	10.85	5.21
Capparis sepiaria	2.09	0.46	2.56	1.23
Ficus racemose	1.88	0.37	2.25	1.08
Holoptilia integrifolia	6.6	1.36	7.96	3.82
Mitragyna parvifolia	12.63	2.37	15	7.2
Prosopis juliflora	35.38	6.46	41.83	20.08
Salvadora oleoides	57.56	10.53	68.09	32.68
Vachellia leucophloea	6.07	1.21	7.29	3.5
Vachellia nilotica	11.21	2.19	13.4	6.43
Total	244.98	44.54	289.52	138.97

DISCUSSION

FOREST STRUCTURE

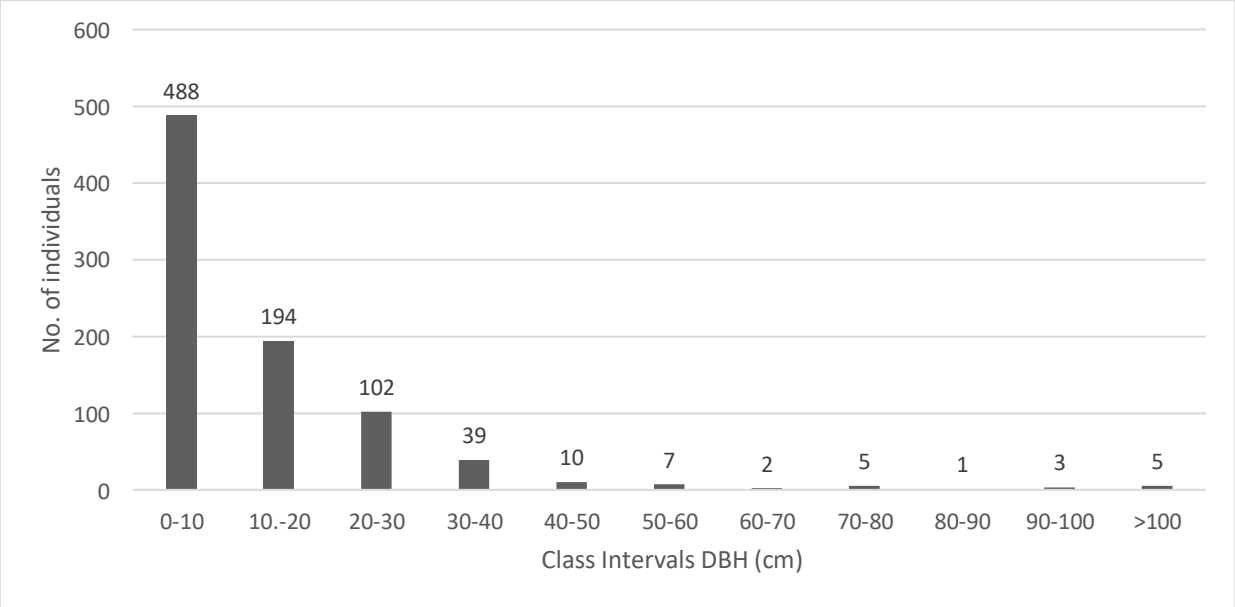


Figure 3: Histogram depicting DBH (cm) class intervals and corresponding number of individuals

Total number of tree individuals recorded from the sacred grove of Kadam Khandi belonging to 12 species are 856. Out of which Prosopis juliflora (378 individuals) and Anogeissus pendula (207 individuals) hold a mammoth share of 68.34%. Whereas there was only 1 individual recorded of Azadirachta indica near a newly established site inside the sacred

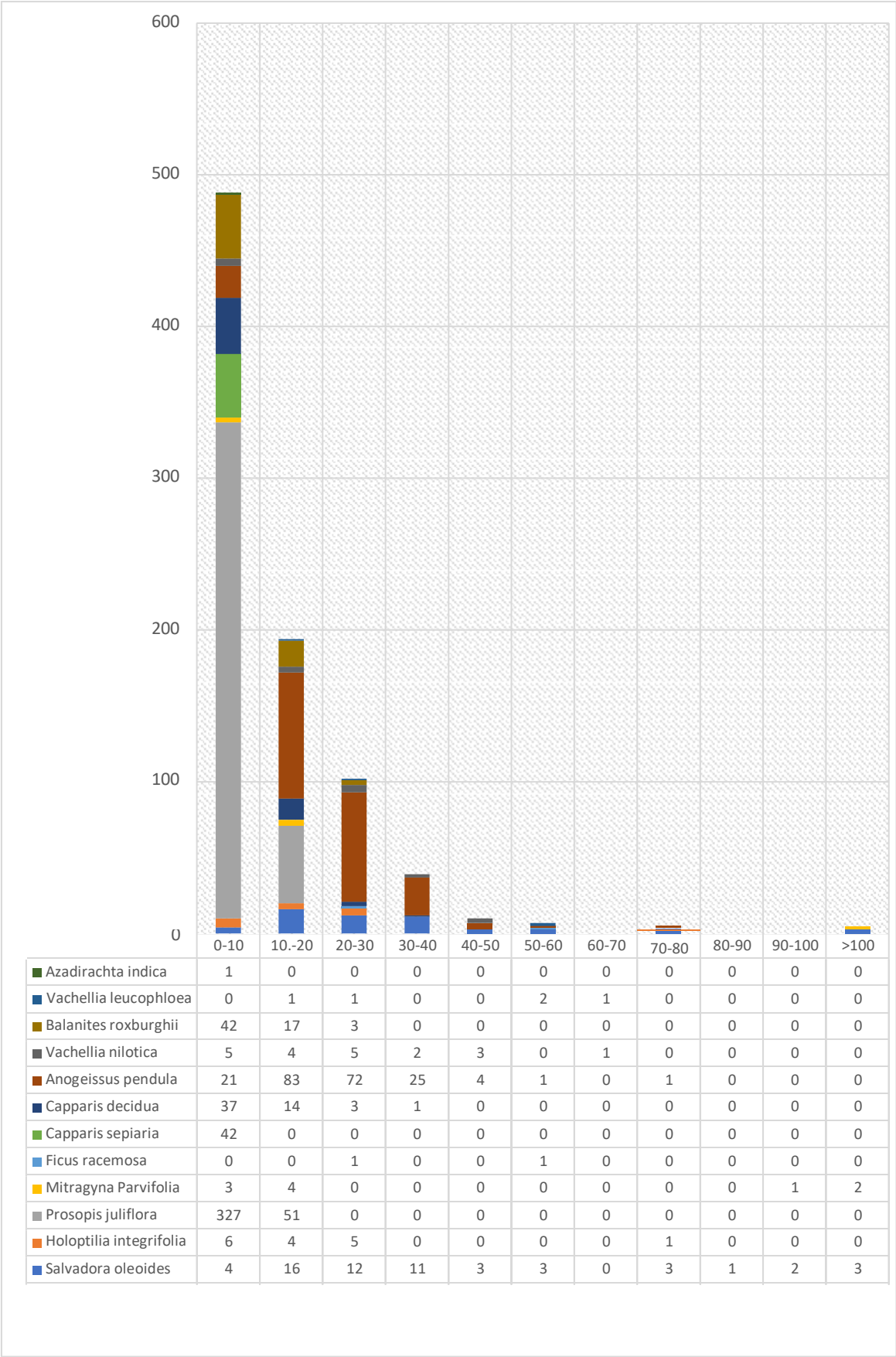
grove and 2 individuals of Ficus racemosa. Only 12 species were recorded from all the 81 sampling plots though tree species like Ficus religiosa, Ficus benghalensis, Prosopis cineraria, Crataeva sp. (1 ind.), Grewia tenax (1 ind.) were also observed outside the plot limits.

Diameter class distribution displayed a reverse J-shaped curve which aligns with the typical characteristic which is commonly found in a tropical forest. (Dar et al. 2019).

Out of total 856 tree individuals, 488 individuals (57%) fall in 0-10 cm DBH class interval and out of that 327 individuals (67%) belong to Prosopis juliflora. Under class interval 10-20cm, were 194 individuals (22%) of all the total and out of that 83 individuals (42.7%) belong to Anogeissus pendula. Only 5 individuals were found to have DBH more than 100 cm- 3 were of Salvadora oleoides and 2 were of Mitragyna parvifolia. Number of Prosopis juliflora individuals are high because of the multi stem nature of the species. It is the only species which is allowed to be cut down in the sacred grove first because it is an alien species and second and major reason is because of its invasive nature and near to no ecological services offered as the locals stated that the pods of this species are not preferred by livestock as it may cause bloating, the tree due to its allelopatheic nature reduces species diversity and soil fertility. Due to its low hanging canopy and sharp thorns, it doesn't even offer shade for humans or animals.

IVI (Importance Value Index) is a standard tool in forestry to measure ecological importance of different species in a forest. It is the sum of three important parameters which are Relative Frequency, Relative Density and Relative Dominance. This helps in portraying how a species is distributed as if they are cloistered in few locations or found all across the sampling sites. It also takes into account a species population by counting its density to assess its abundance or rarity and then it also measures how much area a species occupies relative to other species.

Prosopis juliflora has the highest IVI (78) but it is due to their high relative frequency (26.79) due to its invasive nature and high relative density (44.16) and it might be because of their multi- stemmed nature and in this study every stem forking below 1.37 m is considered as an individual tree, therefore, increasing the total count. Salvadora oleoides had the highest value for Relative Dominance (40.21) due to presence of old fully mature trees with mean GBH of 113.78 cm and also the tree individual with highest GBH (420 cm) in the entire sacred grove belongs to this species. Anogeissus pendula with IVI 70.43 had almost equal figures for all three relative parameters of frequency (20.24), desnity (24.18) and dominance (26.01).



	0-10	10.-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	>100
Azadirachta indica	1	0	0	0	0	0	0	0	0	0	0
Vachellia leucophloea	0	1	1	0	0	2	1	0	0	0	0
Balanites roxburghii	42	17	3	0	0	0	0	0	0	0	0
Vachellia nilotica	5	4	5	2	3	0	1	0	0	0	0
Anogeissus pendula	21	83	72	25	4	1	0	1	0	0	0
Capparis decidua	37	14	3	1	0	0	0	0	0	0	0
Capparis sepiaria	42	0	0	0	0	0	0	0	0	0	0
Ficus racemosa	0	0	1	0	0	1	0	0	0	0	0
Mitragyna Parvifolia	3	4	0	0	0	0	0	0	0	1	2
Prosopis juliflora	327	51	0	0	0	0	0	0	0	0	0
Holoptilia integrifolia	6	4	5	0	0	0	0	1	0	0	0
Salvadora oleoides	4	16	12	11	3	3	0	3	1	2	3

Figure 4: Distribution of total number of individuals of all species in DBH (cm) class intervals.

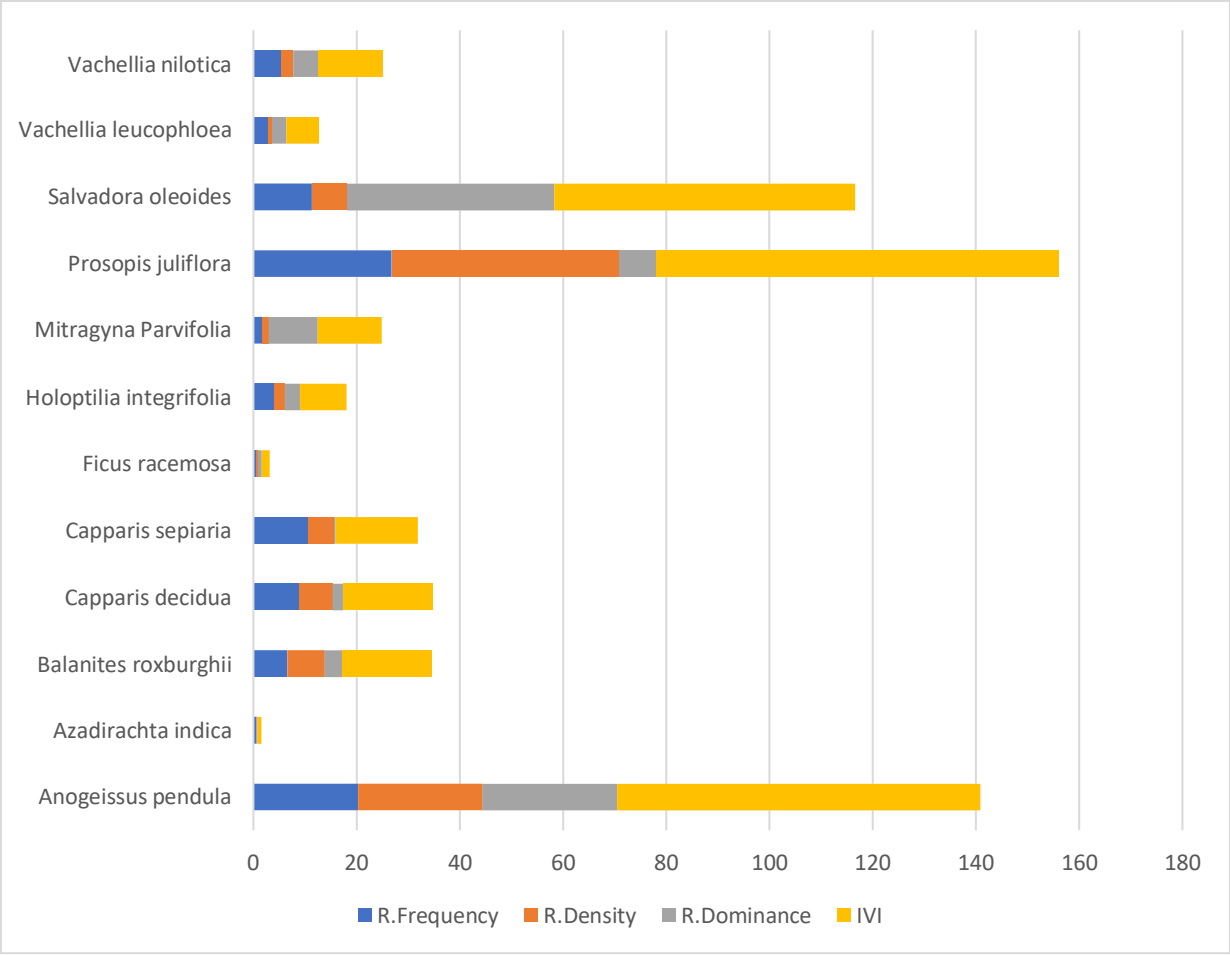


Figure 5: Stacked bar chart representing IVI scores as part of Relative Frequency, Relative Density and Relative Dominance.

TREE DENSITY

Tree density of a stand or a forest is a sum of tree densities of all the tree species present in a particular stand or forest. Density of a species is the ratio of total number of individuals of that species divided by the total number of sample plots. It can be of great use in understanding forest structure as it informs about the abundant and rare species and helps in defining the ecological services being provided. Tree density of the Kadam Khandi sacred grove was found to be 1056.79 trees per hectare. This density value is in within the range 702-1671.70 trees/ha as was recorded in a study conducted in tropical dry deciduous forest ofMadhya Pradesh (Joshi et al.2018), 345-4202 trees/ha in Sacred groves of Manipur (Khumbongmayum et al.2005) and is on the lower side of 663-3341 trees/ha as recorded

from Sacred groves of Kerela (Chandrashekara et al.1998). The density value falls short to the range 1206-2815 trees/ha recorded from Coromandel coast of India (Venkateswaran et al.2003). But the density value of Kadam Khandi sacred grove was higher than 995 trees/ha as recorded in a study from Rajasthan (J.I.Nirmalkumar et al.2011), was also above the range of 193-615 trees/ha as reported by (Salunkhe et al.2017) from their study done in Madhya Pradesh. It is also higher than the range 929-1018 trees/ha which is stated by (Rao et al.2011) as per their study done in Andhra Pradesh. The density was also much higher than the range of 75-675 trees/ha which was recorded in the sacred groves of Chhindwara district in Madhya Pradesh by (Dar et al.2019). The density observed in this study could be high due to the multi stemmed nature of Prosopis juliflora which among all the 12 species documented has the highest density 466.67 trees/ha and highest frequency (55.56%). All 378 stems of Prosopis juliflora were counted as separate individuals as they forked below the standard height of 1.37m. Out of 378 stems, 327 stems (86.5%) had DBH less than 10 cm whereas not a single stem was found to have DBH more than 30 cm. The density value might differ if multiple stems of Prosopis julifora having the same root system are counted as one single individual.

BASAL AREA

The basal area of Kadam Khandi scared grove was estimated to be 40.82 m^2/ha. This value sits on the upper side of 17-40 m^2/ha range suggested for dry forests of the world by (Murphyand Lugo, 1986). It's higher than 9 m^2/ha as reported by (Salunkhe et al.2017) from their study done in Madhya Pradesh; it is also more than 24.5 m^2/ha as reported by (Rao et al.2011) as per their study done in Andhra Pradesh. It's also way above the range 3.16-10.04 m^2/ha reported by (Sahu et al.2012) from sacred forest ecosystem in Eastern Ghats and 15.34 m^2/ha as suggested by (Pradhan et al.2016) from sacred forests of Western Odisha. The basal area value sits nicely in range of 6.8-54.1 m^2/ha as estimated by (Dar et al.2019) during their study on sacred groves in Chhindwara district of Madhya Pradesh. Though it is less than the reported values of 79.43-90.64 m^2/ha from Manipur's largest sacred grove (Waikhom et.al 2018) and sacred groves of central western ghats where a range of 62.09-82.84 m^2/ha was recorded. The basal area of current study is also less than 46.35 m^2/ha as reported from a study done in Rajasthan (J.I.Nirmalkumar et al.2011). Basal area of a tree is directly proportional to its Girth at Breast Height (GBH) therefore Basal area of a stand/grove or forest depends on the species composition, soil type, abiotic factors like rainfall, temperature etc. and biotic factors like faunal diversity, soil organisms and anthropogenic disturbances.

The basal cover of Kadam Khandi (40.82 m^2/ha) stands in middle of 8-74 m^2/ha range reported for the tropical forests of Central India this could be due to the protection it receives as a sacred grove which automatically activates an invisible 'social fence' forbidding logging or any such destructive activity within its boundaries. But the basal area also has the potentialto grow as currently the grove is infested with Prosopis juliflora (466.67 trees/ha) which due to its allelopathic nature hinders the growth of other trees, it also has one of the lowest basal areas (2.89 m^2/ha) and average biomass of all the species. It also does not fare well on carbon stock potential. On the other hand, native old growth trees like Salvadora oleoides (16.45 m^2/ha and 71.6 trees/ha) contributes to around 40.3% of the total basal cover of Kadam Khandi sacred grove, followed by Anogeissus pendula (10.64 m^2/ha and 255.56 trees/ha)- a rock loving, hardy tree which grows on hill slopes of Kadam Khandi contributes to 26.07% of total basal cover; together these two species cover around two thirds of the total basal cover.

BIOMASS AND CARBON STOCK

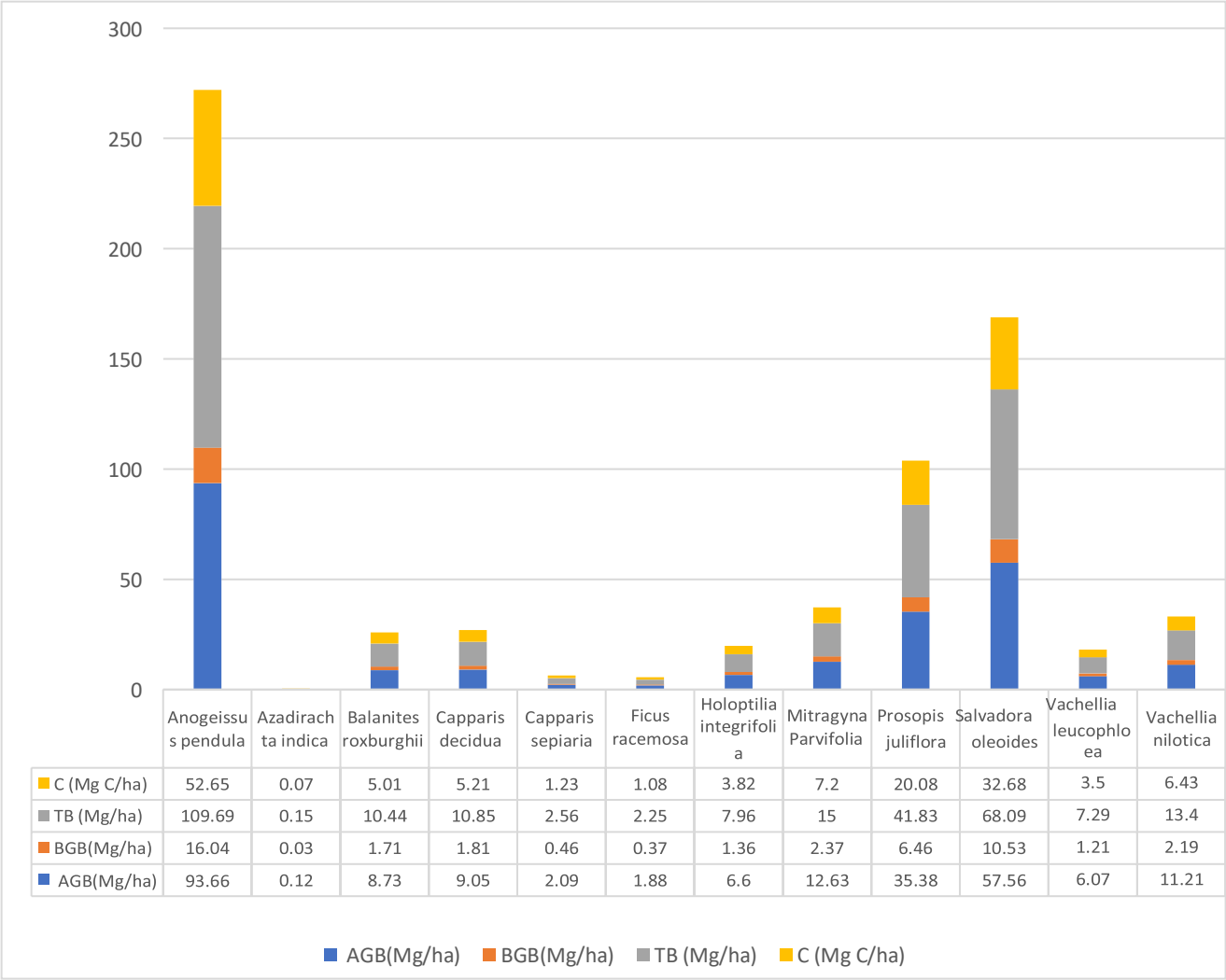
The total aboveground biomass of 244.98 Mg/ha and total below ground biomass of 44.54 Mg/ha was recorded for sacred grove of Kadam Khandi. Total biomass calculated was 289.52 Mg/ha. These values are in line with the range 34.9-409.8 Mg/ha reported from a study done in the sacred groves of Chhindwara district, Madhya Pradesh. (Dar et al. 2019) and in the range 13.96-514.5 Mg/ha suggested by (Sahu et al. 2016) for tropical dry forest of Eastern Ghats. The biomass result from this study also falls in the range 1.02-621.75 Mg/ha which was suggested for Indian forests for 2010 by (Rajshekhar et al. 2018). Though it was found to be on the lower side of range 290.8-455.9 Mg/ha which was estimated by (Behera et al. 2017) during their study in moist deciduous forest of Katerniaghat Wildlife Sanctuary, Uttar Pradesh. It was also lower than the range 963-1103.7 Mg/ha which was recorded from the largest sacred grove of Manipur. (Waikhom et al. 2018) The biomass value recorded in Kadam Khandi were higher than the range 58.4-102.7 Mg/ha recorded in tropical dry forests of Tamil Nadu (Sundarapandian et al. 2013), range 13-54 Mg/ha reported from Madhya Pradesh (Salunkhe et al. 2017). The AGB and BGB values match with the range 83.23-370.12 Mg/ha and 20.09-83.41 Mg/ha respectively which were recorded by (Joshi et al. 2018) in Madhya Pradesh.

Total carbon stock values calculated from this study (138.97 Mg C/ha) are in the range 48.97-214.97 Mg C/ha reported by (Joshi et al. 2018). The above ground carbon stock in the sacred

grove of Kadam Khandi was 117.59 Mg C/ha which is well within the range 14-123 Mg C/ha suggested by (Murphy and Lugo, 1986) for tropical deciduous forests. But the values were higher than reported by (Salunkhe et al. 2016) 6-26 Mg C/ha from Madhya Pradesh and from dry deciduous forests of Gurgaon district, Haryana (25.3-42.4 Mg C/ha).

Top three species (Anogeissus pendula, Salvadora oleoides and Prosopis juliflora) contributed 75.85 % of the total biomass stock of Kadam Khandi sacred grove.

The total biomass of the sacred grove was within the standard range suggested in various studies even when there is significant infestation of Prosopis juliflora. This could be due to its status as a sacred grove which preserves it from destructive utilisation of resources especially timber. Out of 12 species which were documented, the average GBH of 3 species (Vachellia leucophloea (139.8 cm), Mitragyna parvifolia (124.4), Salvadora oleoides (113.78 cm)) was found to be more than 100 and 3 species (Vachellia nilotica (74.7 cm), Anogeissus pendula (66.14 cm), Holoptilia integrifolia (57.56 cm)) had more than 50 cm GBH. This suggests towards presence of old growth trees which have benefitted from being considered sacred and therefore even the increasing human disturbances like metalled road which cuts the sacred grove into 2 parts, several newly erected wired establishments, movement of livestock from at least 3 surrounding villages, a school, omnipresent issue of plastic and invasion of Prosopis juliflora which contributes little to biomass and carbon stock but occupies largest part of sacred grove have not been able to significantly reduce the ecological services provided by Kadam Khandi sacred grove. These results reflect how sacred groves play a vital role as localcarbon sinks with higher average basal area and biomass stock. (Rao et al. 2011).



	Anogeissus pendula	Azadirachta indica	Balanites roxburghii	Capparis decidua	Capparis sepiaria	Ficus racemosa	Holoptilia integrifolia	Mitragyna Parvifolia	Prosopis juliflora	Salvadora oleoides	Vachellia leucophlo ea	Vachellia nilotica
C (Mg C/ha)	52.65	0.07	5.01	5.21	1.23	1.08	3.82	7.2	20.08	32.68	3.5	6.43
TB (Mg/ha)	109.69	0.15	10.44	10.85	2.56	2.25	7.96	15	41.83	68.09	7.29	13.4
BGB(Mg/ha)	16.04	0.03	1.71	1.81	0.46	0.37	1.36	2.37	6.46	10.53	1.21	2.19
AGB(Mg/ha)	93.66	0.12	8.73	9.05	2.09	1.88	6.6	12.63	35.38	57.56	6.07	11.21

Figure 6: Stacked column chart representing AGB, BGB, TB and Carbon stock in Kadam Khandi sacred grove.

CONCLUSION

The state of Rajasthan has 560 documented sacred groves, but none had been documented from the district of Bharatpur in which lies the Sunehra Kadam Khandi sacred grove. The sacred grove requires some positive interventions from management and conservation point of view. Some suggestions in this regard are:

1- The first positive step could be to notify the sacred grove and Sunehra Kadam Khandi so that it could be legally protected as per the provisions under Wildlife (Protection) Amendment Act, 2002 for 'Community Reserves'.
2- Prosopis juliflora (Kavli Babool)- the world-renowned Invasive Alien Species was the most dominant tree species with highest IVI value, highest frequency, highest density, highest abundance but one of the lowest average AGB among all the tree species. Hence, a community-based long-term approach should be adopted to slowly replace Prosopis juliflora with native tree species such as Salvadora oleoides, Mitragyna parvifolia, Holoptelia integerifolia, Capparis decidua, Balanites roxburghii and on the hill slopes Anogeissus pendula which offer a wide range of ecological services.
3- More studies are required to better understand the ecology of the trees found in this region and species specific allometric equation are needed to better assess the carbon stock potential of these hardy trees.
4- Multi seasonal studies are required for thorough documentation of flora in the sacred grove of Kadam Khandi including trees, shrubs, herbs and epiphytes.

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