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Assessment of Carbon Sequestration to describe the conservation potential of sacred groves from Ratnagiri District, Maharashtra, India

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ABSTRACT

Sacred groves are widely recognised for their contributions to gene pool preservation and biodiversity conservation. Their capacity to provide crucial ecological services—particularly carbon sequestration should also be considered in the context of small, traditionally protected forest patches. This study evaluates the carbon sequestration potential of sacred groves in Ratnagiri District, Maharashtra, through tree stock assessments conducted via field surveys. Despite their small size, these groves show considerable carbon storage, reinforcing their ecological significance. By highlighting the sequestration value of small sacred groves, the research shows the necessity to explore small sacred groves for their carbon sequestration potential. The paper suggests sustainable conservation strategies that integrate carbon management with cultural and ecological stewardship, and calls for policy interventions that align conservation efforts with community welfare.

Keywords: *Sacred groves, Carbon Sequestration, sustainability, forest conservation, forest management*

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1. INTRODUCTION

Carbon emissions are a growing concern. Various anthropogenic activities are contributing to increased atmospheric carbon dioxide, which is one of the major Greenhouse gases that trap heat and is leading to a rise in global temperatures.

The IPCC AR6 Working Group III reports that global net anthropogenic greenhouse gas emissions reached 59 ± 6.6 Gt of CO_2-eq in 2019, the highest in recorded history.

Economic growth and population increase remain the strongest drivers of fossil fuel emissions, outpacing improvements in energy efficiency and carbon intensity.

The Kyoto Protocol recognised the trend of Carbon emissions and set binding targets for developed nations. During its second commitment period (2013–2020), participating countries achieved an average 22% reduction compared to 1990 levels—but global emissions continued to rise due to increased output from developing economies.

While many solutions in the areas of renewable energy, sustainability in the industries, and sustainable transport systems are being tried out, afforestation, reforestation and conservation of forests play an equally important role.

Here the carbon sequestration function performed by various ecosystems becomes a great part of the solutions

Carbon sequestration refers to the rate at which atmospheric carbon is absorbed and retained within an ecosystem. It represents a vital ecological function or service provided by the ecosystem.

The carbon sequestration through ecosystems, which has also been described as 'biological sequestration' by Parmeswari and Nayak (2025), is crucial to compensate for the emissions of Carbon in the age of rapid development.

Various ecosystems perform the function of carbon sequestration. While Mangroves are considered the best in performing this function, the carbon sequestration carried out by forests should not be ignored.

As per Kyoto Protocol's definition of forests, land is considered forested—and thus eligible for carbon accounting—if it spreads over an area of at least 0.05 to 1.0 hectares, supports tree species capable of reaching 2–5 meters in height, and maintains a crown cover between 10– 30%, depending on national definitions.

It should be noted that small forest patches are gaining importance in the carbon markets and are being considered in carbon accounting.

As per a report published by the Council on Energy, Environment and Water (CEEW) in 2025, Small plots are grouped into larger project clusters, allowing them to meet the minimum thresholds required for carbon credit verification and registration. - This aggregation helps overcome economies of scale, making monitoring, reporting, and verification (MRV) more cost-effective. This way, the farmer producer organisations (FPOs). This has opened up an opportunity to include the community forestry projects, agroforestry projects and other conservation efforts into the carbon markets. This also includes the culturally protected forests like Sacred Groves

Considering all these national and international efforts it is essential to study the carbon sequestration potential of sacred groves and put forth a model for the study.

The current paper tries to establish this model through a study of two sacred groves from Maharashtra.

2. MATERIALS AND METHODS:

Study Area

Two sacred groves located in Ratnagiri District, Maharashtra, were selected for this study. The groves are approximately 12 kilometres apart. One of them, encompassing an area of about 3.9 hectares, has been demarcated and protected with fencing, resulting in relatively minimal disturbance. This conservation effort was undertaken by the Social Forestry Department of Maharashtra.

The second grove, situated near the village of Nivoshi, has been fragmented by a road. A portion of the grove separated from the main tract is in degraded condition and has experienced further shrinkage due to encroaching agricultural activities. This grove currently covers an area of approximately 1.3 hectares. These sacred groves were selected to assess how conservation status influences carbon sequestration potential, species composition, and ecological integrity.

Mapping and area calculation:

The area polygons for both the forests were drawn by walking along the peripheries of both the sacred groves using GPS.

The KML files generated by GPS were used to draw area polygons and calculate the area using Google Earth.

Calculating the disturbed areas:

Area polygons gave only the total area of the sacred groves, but there were patches of destruction inside the forest. These patches were cleared for some activities. Area polygons for all these patches were made to calculate their area and they were subtracted from the total area of the grove.

Estimation of Carbon stock:

Field surveys were conducted to estimate the above-ground biomass of the trees from sacred groves. A plot method with a stratified random sampling approach was used for the surveys. To ensure the ecological representativeness, 15 plots of 10m*10m were established across the groves. This allowed for spatially distributed sampling across canopy types, disturbance gradients, and culturally significant zones, totalling 1000 m^2 of sampled area.

Diameter at breast height (GBH) was measured for the calculation of basal area. Height was calculated using the stick or pen method. The Carbon stock was estimated using the internationally accepted formula, as below:

Total Biomass=VOB×WD×BEF VOB = 1/3 πr2h (Volume over bark)

BEF = Exp{3.213 - 0.506*Ln(BV)} for BV < 190 t/ha (Biomass expansion factors)

BV = biomass of inventoried volume in t/ha, calculated as the product of VOB/ha (m3/ha) and wood density (t/m3)

WD = wood density of each species published By FAO 1997.However; for few species wood density data are not available. In these situations, 0.57 arithmetic mean for most common wood density values for tropical tree species will be taken (Reyes et al.1992).

BGB = exp (-1.0587 + 0.8836 x Ln AGB) (Belwo Ground Biomass) Total Forest Biomass=AGB+BGB

Dry mass of biomass contains 50% of its weight carbon. So multiplying total biomass density with 50% can give the C-stock estimation in the forest vegetation (Brown et al. 1989) this can be expressed in formula as: C-stock = Total biomass x50

3. RESULTS AND DISCUSSIONS:

The sacred grove of Chikhli, in spite of protection from the social forestry initiatives, shows area having destruction. Fig.

1 and Fig. 2 show the demarcation of the sacred grove and areas showing destruction. The areas have been cleared completely for various developmental activities. It needs to be noted that the areas like the temple and the funeral sites, which have been culturally significant for the residents, are also devoid of any trees. A small road that passes through the sacred grove is also without any vegetation.

Fig. 1: Area Calculation and calculation of disturbed areas in Chikhli Sacred Grove

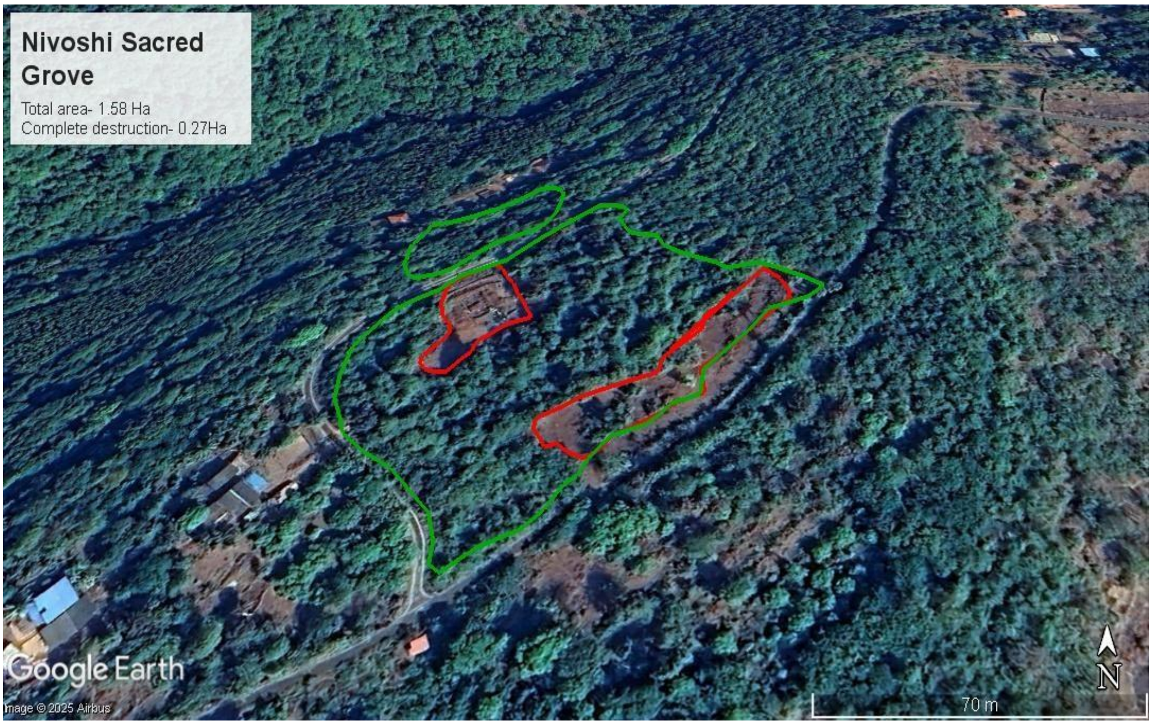

Fig. 2: Area Calculation and calculation of disturbed areas in Nivoshi Sacred Grove This reduced the overall area of Chikhli sacred grove to 3.9 Ha. 58 individuals of 18 species were recorded from the 15 sample plots. Table 1 shows the GBH data for the 58 tree individuals of Chikhli sacred grove.

Species Names	GBH in m
Mammea suriga	1.0668
Mammea suriga	0.7874
Mammea suriga	0.9144
Mammea suriga	0.889
Mammea suriga	1.1938
Mammea suriga	1.4732
Mammea suriga	0.9144
Mammea suriga	0.7112
Mammea suriga	0.6858
Mammea suriga	0.762
Mammea suriga	1.4986
Mammea suriga	0.7112
Mammea suriga	0.635
Mammea suriga	1.1176
Mammea suriga	1.0922
Mammea suriga	0.4699
Mammea suriga	0.3048
Mammea suriga	0.3048
Mammea suriga	0.3556
Mammea suriga	0.3302
Mammea suriga	0.127
Mammea suriga	1.0668
Mammea suriga	1.6002
Mammea suriga	0.7239
Mammea suriga	0.1905
Mammea suriga	0.5334
Mammea suriga	0.5842
Mammea suriga	1.3716

Species Names	GBH in m
Mammea suriga	0.3556
Mammea suriga	0.7366
Zanthoxylum rhetsa	0.8636
Terminalia bellirica	2.9972
Terminalia bellirica	0.9906
Careya arborea	1.2192
Careya arborea	0.6731
Holigarna grahmii	0.5588
Lagerstroemia macrocarpa	0.3429
Bridelia retusa	0.4064
Caryota urens	1.0922
Caryota urens	0.508
Albizia procera	1.0414
Mitragyna parviflora	0.8382
Mitragyna parviflora	1.0922
Holarrhena antidysenterica	0.2794
Garcinia indica	1.0668
Alstonia scholaris	0.762
Mammea suriga	0.9144
Mammea suriga	1.2446
Mammea suriga	1.6764
Mammea suriga	1.3462
Mammea suriga	1.0414
Mammea suriga	0.4826
Mammea suriga	0.508
Mammea suriga	0.1524
Mammea suriga	0.0762
Mammea suriga	0.1778

Table 1: GBH of Trees in the sample plots from Chikhli Sacred Grove

Out of the 18 tree species that were recorded in the sample plots of Chikhli Sacred grove, *Mammea suriga* was found to be the most abundant. It was the dominant canopy species in the sacred grove. It is Endemic to the Western Ghats, particularly the Konkan and northern Sahyadri regions.

Its prevalence in this grove aligns with regional patterns of floristic composition, where culturally protected forest patches often harbor locally abundant species with ethnobotanical significance. The species is also known for its fragrant flowers and medicinal properties. Its

dominance underscores the role of sacred groves in conserving endemic species and maintaining ecological continuity in fragmented landscapes. It is a slow-growing evergreen species and contributes to long-term biomass accumulation. Direct data of Carbon stock for this species is limited, but its canopy cover and growth properties make it important in carbon sequestration.

In sacred groves where anthropogenic disturbance is minimal, the dominance of such species enhances the grove's role as a micro-reservoir for carbon sequestration and biodiversity conservation.

From the quantitative data of trees, the total Carbon stock in the Chikhli Sacred Grove was found to be 311 tons, which differs greatly from the Sacred Groev of Nivoshi village, which has shown a Carbon Stock of 55 tons and is spread over an area of 1.3 Ha.

The sacred grove of Nivoshi is facing a great anthropogenic disturbance. A large area has been cleared for temple construction and other anthropogenic activities. 53 individuals were recorded from 10 sample plots. However the height and the GBH of the trees at Nivoshi were much smaller as compared to the Chikhli sacred grove, because of which the biomass estimated was much lesser as compared to the Chikhli Grove. *Ixora brachiate* was another species that showed dominance, along with *M. suriga*, in the Nivoshi Sacred Grove. The canopy layer was found to be very less as compared to the Chikhli Sacred grove.

4. CONCLUSION:

The ecological and carbon-sequestration potential of sacred groves, even those with modest size, is highlighted in this study. By comparing two groves, Chikhli (4 ha) and Nivoshi (1.3 ha), the results show a sharp difference in carbon stock: 311 tons in the preserved Chikhli grove and 55 tons in the disturbed Nivoshi grove. This discrepancy emphasizes how species composition, protection status, and human disturbance affect carbon storage.

The predominant canopy tree in Chikhli was discovered to be Mammea suriga, a slow-growing, evergreen species native to the Western Ghats that greatly increased the area's biomass and long-term carbon retention. The degraded grove of Nivoshi, on the other hand, was dominated by Ixora brachiata, a smaller understorey species, which reflected lower biomass accumulation and canopy cover.

Even though it is smaller, the Chikhli grove shows that cultural history, endemic species, and well-managed sacred woods can all act as micro-reservoirs of carbon. These results support the idea that sacred groves should be included in carbon accounting schemes as useful ecological units.

The methodology for Carbon stock estimation by field survey, given by international guidelines is easy to replicate and can be adopted by the communities for assessing the carbon stick estimation of several small sacred groves across multiple regions. This replicable model can reveal the data for multiple sacred groves and can be used for carbon accounting. It will also help to design policy strategies for conservation with community engagement. By combining community management, government protection, and incorporation into new carbon credit mechanisms, a multi-stakeholder approach is necessary to maintain and improve the carbon sequestration function of such groves. The potential of thousands of culturally protected forest patches might be unlocked by implementing this concept throughout the Western Ghats, making a significant contribution to ecological resilience and climate mitigation

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