

Carbon Stock Assessment of Law Kyntang Ryngkew Swer Sacred Grove, East Khasi Hills, Meghalaya: A GIS and NDVI-Based Approach

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Abstract

Sacred groves maintained by traditional indigenous laws in Northeast India act as crucial biodiversity havens and important carbon sinks. This research assessed the biomass and carbon storage of the Law Kyntang Ryngkew Swer Sacred Grove in the East Khasi Hills of Meghalaya by integrating systematic field surveys with remote sensing and geospatial methods. Fifteen quadrats measuring 38.4×38.4 m were set up to document species diversity, diameter at breast height, and tree height. Aboveground biomass (AGB) was estimated through the allometric equations from Chave et al. (2014) designed for humid tropical forests, while belowground biomass (BGB) was calculated using recognized biomass relationships. The carbon stock was determined using the IPCC (2021) conversion factor of 0.47. High-resolution LISS-IV imagery was analyzed to derive the Normalized Difference Vegetation Index (NDVI), which was then linked to biomass through regression modeling to create spatial carbon maps. The findings indicated significant carbon sequestration potential, with average values for AGB and BGB suggesting considerable aboveground and belowground reserves, and total carbon storage surpassing 100 Mg ha^{-1} . NDVI displayed a negative correlation with biomass as a result of canopy saturation in dense areas; nevertheless, calibrated models facilitated effective spatial mapping. The classified carbon distribution ($62\text{--}200 \text{ Mg ha}^{-1}$) revealed variability associated with vegetation density, slope, and aspect, with higher stocks found in less disturbed, well-oriented locations. The research highlights the ecological and climatic importance of sacred groves, advocating for their inclusion in REDD+ initiatives and community-led conservation efforts. It also illustrates the effectiveness of NDVI-GIS techniques for biomass mapping in smaller, culturally significant forests.

Keywords: Sacred groves; Biomass estimation; Carbon Stock; GIS; East Khasi Hills; Meghalaya

1. INTRODUCTION

Sacred groves are forest fragments that are traditionally preserved by indigenous communities based on cultural and spiritual beliefs. These groves, found across India and other regions of Asia and Africa, can range in size from less than a hectare to several hundred hectares and often serve as the last bastions of primary forest in otherwise degraded landscapes (Khumbongmayum et al., 2005). Their ecological significance is not only in safeguarding rare, endemic, and threatened species but also in sustaining hydrological cycles, soil stability, and local climate regulation.

Climate change, primarily caused by human-induced greenhouse gas emissions, stands as one of the most urgent environmental issues facing the globe in the 21st century (IPCC, 2021). Among terrestrial ecosystems, forests are vital in regulating atmospheric carbon dioxide (CO_2) levels by functioning as significant carbon sinks (Pan et al., 2011). The capacity of forests to sequester carbon stems from their ability to store it in living biomass, dead organic matter, and soils. Tropical forests, in particular, are estimated to hold around 55% of the global forest biomass carbon (FAO, 2021). Consequently, the protection and sustainable management of forested areas are essential for climate mitigation strategies and biodiversity conservation efforts. Within the framework of climate change mitigation, the significance of small, community-managed forest patches—such as sacred groves—has attracted growing academic interest (Gadgil & Vartak, 1976).

Worldwide, forests sequester approximately 662 gigatonnes (Gt) of carbon in both biomass and soils (FAO, 2021). Deforestation and forest degradation contribute to about 10% of global anthropogenic CO_2 emissions (IPCC, 2021). Safeguarding existing forests, rehabilitating degraded ones, and increasing the carbon stock of managed forests are acknowledged as crucial pathways for mitigation.

In India, sacred groves have served as a fundamental aspect of community-based forest governance for centuries (Gadgil & Vartak, 1976; Malhotra et al., 2007). Typically, these groves are dedicated to local deities or ancestral spirits, and traditional belief systems often impose strict prohibitions against resource

extraction, tree felling, or hunting within their confines (Kala, 2011). Such socio-cultural norms have historically minimized human interference, allowing these groves to function as *in situ* conservation areas. Evidence from various regions of India, including the Western Ghats, Rajasthan, and Northeast India, indicates that sacred groves possess high species diversity, including rare medicinal plants and ancient tree species (Prasad et al., 2016; Ray & Ramachandra, 2010; Khiewtam & Ramakrishnan, 1993).

Sacred groves also provide cultural ecosystem services by acting as centers for community rituals, local identity, and indigenous environmental knowledge systems (Nath et al., 2016). Nevertheless, pressures from urbanization, agricultural expansion, and cultural changes have resulted in the degradation of many groves (Khumbongmayum et al., 2005). Their legal acknowledgment and incorporation into formal conservation and climate policy frameworks remain insufficient.

Northeast India is situated within two global biodiversity hotspots—the Indo-Burma and the Eastern Himalaya—distinguished by high species richness, including many endemic flora and fauna (Myers et al., 2000). The state of Meghalaya, often called the “abode of clouds,” is particularly abundant in forest biodiversity, with around 42% of its geographical area covered by forests (FSI, 2021). The unique physiography, substantial rainfall, and diverse altitudinal gradients of Meghalaya have nurtured a variety of forest types, ranging from tropical evergreen forests to subtropical pine forests (Champion & Seth, 1968). Research conducted in Meghalaya’s sacred groves has mainly concentrated on floristic composition, ethnobotanical applications, and biodiversity conservation (Khiewtam & Ramakrishnan, 1993; Tiwari et al., 1998). However, few studies have systematically quantified their biomass and carbon storage potential through standardized field measurements combined with modern geospatial technologies.

The Law Kyntang Ryngkew Swer Sacred Grove stands out as one of the significant groves in the East Khasi Hills. Managed by the Swer village community, this grove remains predominantly undisturbed and serves as a representative case for evaluating carbon storage in community-protected forests. The grove features diverse topography, with slopes varying from 0.5° to 40°, and consists of mixed evergreen and semi-evergreen forests that are rich in botanical diversity. The soil profile is mainly clayey-loam, which supports dense tree growth with multi-tier canopies. Preliminary floristic surveys indicate the presence of ferns, orchids, and various endemic tree species, underscoring its significance as a biodiversity refuge. The lack of commercial logging and the enforcement of cultural taboos guarantee minimal human interference. Given its ecological integrity, the grove presents an excellent opportunity to utilize remote sensing and GIS tools to evaluate biomass and carbon stocks with a high level of reliability.

The carbon sequestration potential of sacred groves in Meghalaya has seldom been investigated in peer-reviewed studies. Although provided foundational ecological evaluations, including species diversity and habitat quality, quantitative assessments of biomass are still limited. Moreover, the majority of carbon estimation research in the area has concentrated on larger state-managed forests or shifting cultivation landscapes (Upadhyay et al., 2005; Tripathi et al., 2009). This has resulted in a significant gap in comprehending the contribution of small, community-managed forest patches to regional and national carbon budgets.

Furthermore, the few investigations that have attempted biomass estimations in sacred groves have relied exclusively on field sampling with restricted spatial extrapolation. Contemporary remote sensing technologies, such as NDVI-based modeling and GIS spatial mapping, have not yet been fully utilized in these scenarios, despite their established effectiveness in global forest carbon assessments (Lu et al., 2016; Myneni et al., 1994). The current study seeks to address both of these deficiencies by combining comprehensive field measurements with high-resolution satellite imagery to map and quantify the carbon storage capacity of the Law Kyntang Ryngkew Swer Sacred Grove.

The primary goal of this research is to assess the carbon sequestration capacity of the Law Kyntang Ryngkew Swer Sacred Grove through an integrated field and geospatial methodology. The key objectives of this research are (a) To measure the aboveground and belowground biomass along with the associated carbon stock of the Law Kyntang Ryngkew Swer Sacred Grove, systematic field inventory methods, allometric equations, and IPCC (2006) conversion standards will be utilized. (b) To create a model and visualize the spatial distribution of biomass and carbon within the grove, NDVI-based regression analysis and GIS techniques will be employed, aiming to evaluate its contribution to biodiversity conservation and climate change mitigation.

2. Study Area

The research was carried out in the Law Kyntang Ryngkew Swer Sacred Grove, located in the East Khasi Hills district of Meghalaya, Northeast India, an area celebrated for its remarkable biodiversity and ecological health. Meghalaya is part of the Indo-Burma and Eastern Himalaya global biodiversity hotspots (Myers et al., 2000), hosting a significant number of endemic and rare. The state maintains around 42% forest cover (FSI, 2021), which includes a variety of vegetation types, from tropical evergreen forests to montane and bamboo forests (Chandrashekhara et al., 1998). Sacred groves are vital ecological and cultural forest fragments preserved by local communities in India for centuries. In Meghalaya, particularly among the Khasi tribe, sacred groves such as Law Kyntang Ryngkew Swer are protected through traditional regulations and religious beliefs, resulting in minimal human interference and substantial ecological integrity (Tiwari et al., 1998). While their role in biodiversity conservation has been extensively documented, the potential for carbon sequestration within these sacred forests remains underexplored. This study addresses this gap by employing field-based biomass assessments, NDVI analysis, and GIS-based spatial mapping to evaluate the biomass and carbon stock of a specific grove.

Law Kyntang Ryngkew Swer, often referred to as the Sacred Grove Ryngkew Swer, is situated in the East Khasi Hills District of Meghalaya, specifically in Swer village, which falls under the Hima Sohra Syiemship. Covering an area of 11.07 hectares, the grove is geographically positioned between 25°25'00" to 25°25'13" N latitude and 91°47'28" to 91°47'47" E longitude, standing at an elevation of roughly 1946 meters above sea level (Forest Resources Survey Division Climate Change, 2024). This region is characterized by rugged, dissected plateaus with elevations ranging from 300 m to 1,900 m, with steep slopes exceeding 35°, and a humid subtropical to temperate climate that receives over 2,000 mm of rainfall annually, primarily during the monsoon season (Yates et al., 2005). The soils in the area are mostly lateritic and clay-loam, acidic and moderately fertile, conducive to the growth of rich, multi-layered tropical and subtropical forests that display high plant variety, including *Shorea robusta*, *Castanopsis indica*, orchids, and ferns (FSI, 2021). Sacred groves, known locally as Law Kyntang, are forest patches that are culturally preserved and managed under traditional Khasi customary laws, promoting minimal human disturbance and providing considerable contributions to biodiversity conservation and ecosystem resilience in altered landscapes (Gadgil & Vartak, 1976; Tiwari et al., 1998; Khiewtam & Ramakrishnan, 1993).

The forest is primarily a closed-canopy type and is rich in ferns, shrubs, herbs, climbers, and epiphytic orchids, indicating that it is a mature and relatively undisturbed ecosystem (Khumbongmayum et al., 2005; Huete et al., 2002). The management of the grove is overseen by village institutions, highlighting the ecological, cultural, and climate mitigation significance of sacred groves throughout Meghalaya, positioning it as an ideal site for evaluating spatial patterns of biomass and carbon stocks through both field and geospatial approaches (Kala, 2011; Pan et al., 2011; FAO, 2021).

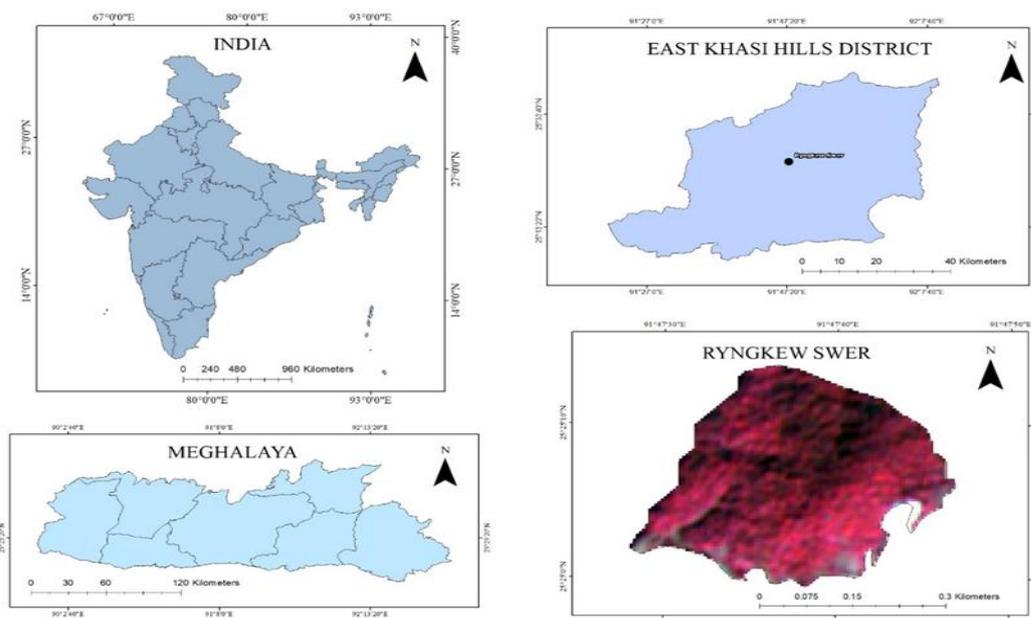


Fig:1. Location of the study area.

Furthermore, this research advances conservation strategies by providing foundational data to support integrating sacred groves into national and international climate initiatives such as REDD+ (Reducing

Emissions from Deforestation and Forest Degradation). By highlighting the carbon sequestration services of community-managed forests, the study elevates the role of indigenous knowledge systems combined with geospatial science in achieving biodiversity conservation and climate resilience (Gadgil et al., 1976).

3. DATABASE AND METHODOLOGY

This study combined high-resolution remote sensing data, GIS-based spatial analysis, and field inventory measurements to quantify aboveground biomass (AGB), belowground biomass (BGB), and carbon stocks in the Law Kyntang Ryngkew Swer Sacred Grove, East Khasi Hills, Meghalaya, India. The integrated approach ensured both spatial and ecological accuracy in estimating the grove's carbon sequestration potential.

3.1 Database

3.1.1 Secondary Data Sources

- Spatial mapping and distribution analysis for the East Khasi Hills district utilised multiple geospatial datasets (Table 1), including an Elevation Map, Supervised Classification Map, Rainfall Map, Sacred Groves Map, and proximity analysis of groves to settlements.
- Elevation data (30 m resolution) were obtained from the Shuttle Radar Topography Mission (SRTM) via USGS Earth Explorer (<https://earthexplorer.usgs.gov/>).
- Forest cover and land use/land cover (LULC) maps were produced using Landsat 8 imagery.
- Rainfall data for 2021–2024 were sourced from the Climate Research Unit (CRU), University of East Anglia.
- Sacred grove boundary data were digitised from high-resolution Google Earth Pro imagery.

Table 1: Source of data collection of East Khasi Hills District.

Factors	Data Source	Data Format	Resolution
Elevation	USGS EarthExplorer (https://earthexplorer.usgs.gov/)	Raster Data Format	30m
Forest Cover	Landsat 8		
Rainfall	Climate Research Unit		

For the sacred grove site, high-resolution LISS-IV imagery (5 m) was acquired from the Bhuvan-Bhoonidhi portal (ISRO-NRSC). These data (Table 2) were pre-processed for radiometric and geometric corrections in ArcGIS before vegetation indices (NDVI and SAVI) were computed to assess vegetation health and canopy density. DEM layers from Bhuvan were processed to derive slope, aspect, and elevation, which are relevant to biomass distribution analysis.

Official baseline forest inventory data – tree diameter at breast height (DBH), total height, and species composition – were obtained from the Office of the Divisional Forest Officer, Forest Resource Survey Division, Meghalaya, for validation of field measurements.

3.1.2 Primary Field Data

Field sampling was conducted within the grove to supplement and validate secondary data. Measurements included DBH (at 1.3 m height), total tree height, and species identification for all trees within designated sampling plots. Two plots from official datasets (Plot 40: 25°25'12" N, 91°47'41.9" E; Plot 42: 25°41'7.5" N, 91°79'5.3" E) were incorporated, along with two additional research plots established for methodological training and data enrichment. Total 15 plots were incorporated in the study area for sample collection.

Table 2: Source of Data Collection for Sacred Grove Law Kyntang Ryngkew Swer

Factors	Data Source	Data Format	Resolution
NDVI	LISS-4	Raster	5 m
SAVI	LISS-4	Raster	5 m
Slope	DEM (SRTM)	Raster	30 m
Aspect	DEM (SRTM)	Raster	30 m
LULC	ESRI	Raster / Vector	High

Factors	Data Source	Data Format	Resolution
DEM	SRTM	Raster	30 m
Grove Boundary	Google Earth Pro	KML / Shapefile	High (manual digitization)
Field Data (DBH, tree height, species)	Primary data from fieldwork conducted at study site	Tabular (Excel) / CSV	Point-level (GPS-based)

3.1.3 Software

Spatial data were processed using ArcGIS 10.8 for raster analysis (NDVI, SAVI, slope, aspect, LULC classification) and map production. Google Earth Pro was used for boundary delineation and site validation. Microsoft Excel facilitated plot-level biomass calculations, statistical analysis, and graphical representation. All datasets were projected to UTM WGS84 Zone 46N for spatial consistency.

3.2 Methodology

The methodological framework integrated GIS-based spatial analysis with field inventory data to generate spatially explicit estimates of biomass and carbon stocks (Fig : 2).

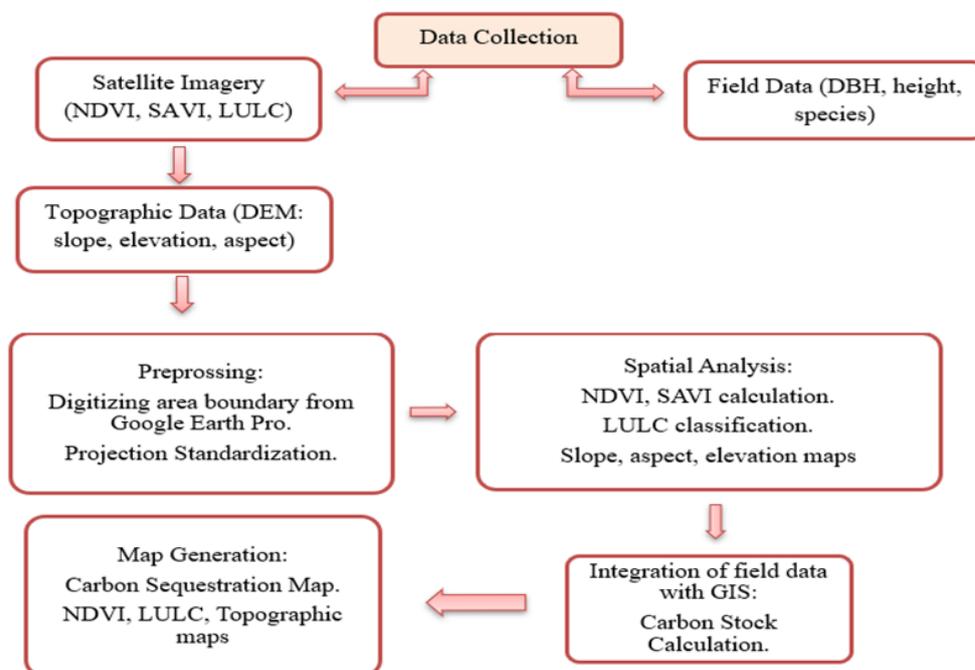


Fig: 2. Flowchart of data analysis.

3.2.1 Data Preparation and Processing

All datasets were standardised, corrected, clipped to the study area, and integrated within the ArcGIS environment. NDVI and SAVI were computed from LISS-IV imagery to highlight vegetation vigour. A supervised classification approach was applied for LULC mapping, validated against ground GPS data and Google Earth imagery.

3.2.2 Sampling Design

The grove covers 11.07 ha. A 20% sampling intensity was applied, producing a 2.214 ha surveyed area. Fifteen (15) square quadrats (38.4 m × 38.4 m; 1,476 m² each) were systematically distributed across the grove to capture topographic and canopy variability.

3.2.3 Field Measurements

In each quadrat, all trees with girth at breast height (GBH) ≥ 5 cm were measured for GBH and height. GBH was converted to DBH, which, along with tree height and wood density, was used for biomass estimation.

3.2.4 Biomass Estimation

AGB was estimated using the moist tropical forest allometric equation (Chave et al., 2005):

$$AGB = 0.0673 \times (\rho \cdot D^2 \cdot H)^{0.976} \quad (1)$$

Where:

$$\rho = \text{wood density (g/cm}^3\text{)}$$

$$D = \text{diameter at breast height (cm)}$$

H = tree height (m)

Carbon stock calculated as:

$$AGBC = 0.47 \times AGB \quad (2)$$

Belowground biomass (root biomass) is often estimated indirectly from AGB using a root-to-shoot ratio. Following IPCC (2021) guidelines for tropical forests

$$BGB = AGB \times 0.27 \quad (3)$$

Similarly, belowground biomass carbon is:

$$BGBC = BGB \times 0.47 \quad (4)$$

3.2.5 NDVI-Based Regression Modeling

NDVI values from each plot location were regressed against field-estimated AGB, BGB, AGB_C, and BGB_C to develop simple linear models. The models revealed negative slopes, likely reflecting NDVI saturation effects in dense tropical canopies (Myneni & Asrar, 1994; Huete et al., 2002). Final equations (Table 3) were applied to the NDVI raster in ArcGIS (Raster Calculator) to produce continuous biomass and carbon distribution maps.

3.2.6 Plot-Level Aggregation and Scaling

Plot biomass and carbon were summed, converted to per-hectare values (Mg ha^{-1}) using scaling factors, and averaged for grove-level estimates.

3.2.7 NDVI-Based Regression Modelling

NDVI values from each plot location were regressed against field-estimated AGB, BGB, AGB_C, and BGB_C to develop simple linear models. The models revealed negative slopes, likely reflecting NDVI saturation effects in dense tropical canopies (Myneni & Asrar, 1994; Huete et al., 2002). Final equations were applied to the NDVI raster in ArcGIS (Raster Calculator) to produce continuous biomass and carbon distribution maps.

3.2.8 Validation and Policy Relevance

Spatial outputs were cross-verified against official forestry data and field observations. Final maps and statistics were interpreted for their implications in biodiversity conservation, carbon management, and integration of sacred groves into REDD+ and climate mitigation strategies.

4. Result and Discussion

4.1 Spatial Distribution of Biomass and Carbon Stocks

The spatial distribution of biomass and carbon reserves was evaluated by converting NDVI pixel values through regression equations to create detailed spatial maps indicating above-ground biomass (AGB), below-ground biomass (BGB), above-ground carbon (AGBC), below-ground carbon (BGBC), and overall carbon stock. These maps effectively represented the variation in carbon storage across the study area (Fig: 3).

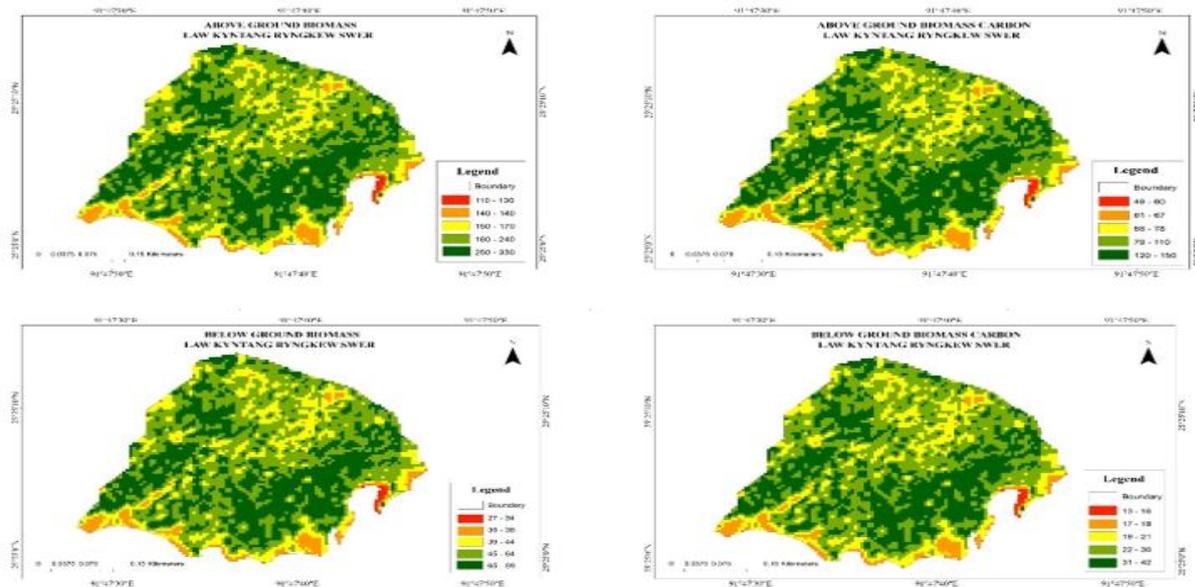


Fig. 3. Spatial distribution of biomass carbon in Law Kyntang Ryngkew Swer: (a) Aboveground Biomass (AGB), (b) Belowground Biomass (BGB), (c) Above ground Biomass Carbon (AGBC), (c) Belowground Biomass Carbon (BGBC).

For the purpose of analytical clarity, the total carbon stock was divided into five distinct categories based on Mg ha^{-1} ranges: 62–76, 77–85, 86–99, 100–140, and 150–200. The central and northern zones of the grove exhibit higher total carbon stock (dark green areas), suggesting dense vegetation cover and well-preserved forest patches that contribute significantly to carbon sequestration. These regions are crucial for maintaining ecological balance and mitigating carbon emissions. The spatial classification revealed specific carbon storage zones, with patterns closely associated with differences in vegetation density, topography, and human activities (Fig. 4).

Regions characterized by dense vegetation and favourable topographic conditions—like gentle slopes and riparian zones—were mainly classified into higher carbon stock categories ($100\text{--}200 \text{ Mg ha}^{-1}$). In contrast, areas experiencing substantial disturbance, such as agricultural development, pastureland, or deforestation, fell into the lower carbon stock classes ($62\text{--}85 \text{ Mg ha}^{-1}$). This spatial gradient illustrates the interconnected impacts of ecological productivity and land-use pressures on carbon accumulation.

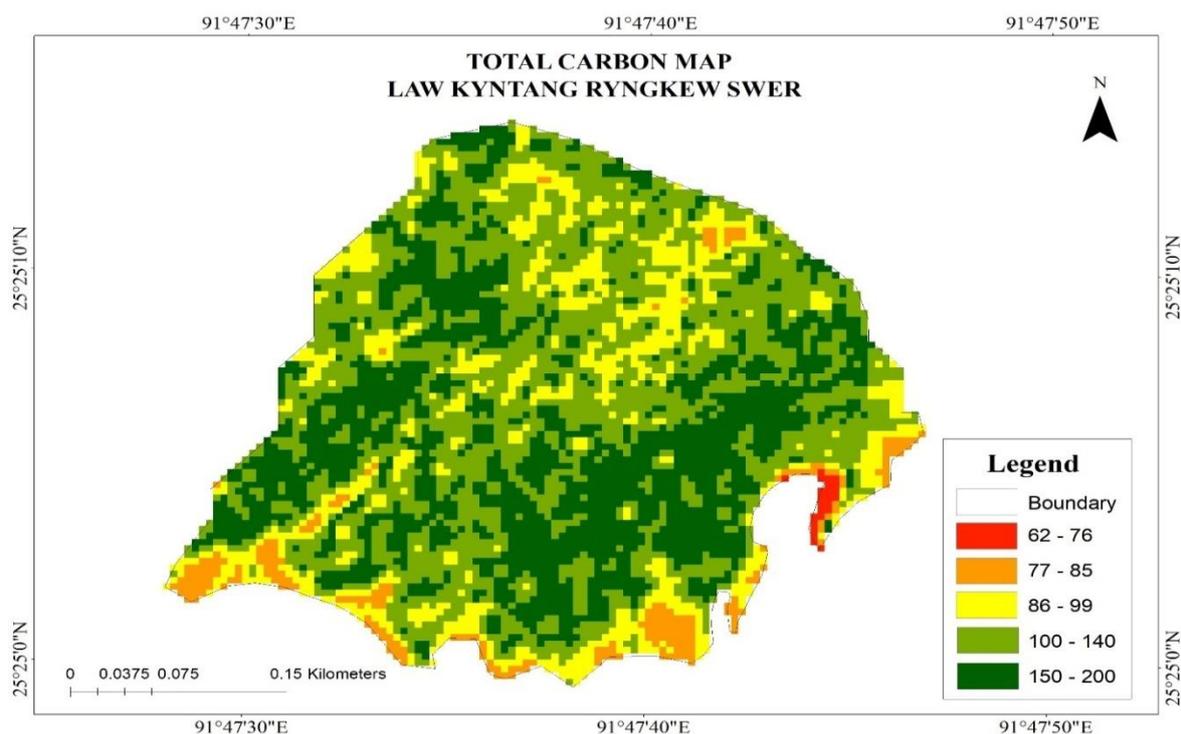


Fig. 4 . Total Carbon Map (Total $\text{C}_{\text{Mg/ha}}$) of Law Kyntang Ryngkew Swer.

4.2 Regression Modelling with NDVI

To spatially assess biomass and carbon reserves across the study area, regression modelling was performed using the Normalized Difference Vegetation Index (NDVI) as a predictor variable. NDVI, obtained from satellite remote sensing data, is a widely recognized vegetation index that responds to canopy health and density, with values ranging from -1 to +1. Elevated NDVI values generally suggest healthier and more robust vegetation and have been widely utilized as indicators for estimating vegetation productivity and biomass in forest ecosystems (Pettorelli et al., 2005).

In this research, NDVI was utilized as an indirect metric for essential forest biophysical parameters, including Aboveground Biomass (AGB), Belowground Biomass (BGB), their associated carbon equivalents (AGB_C and BGB_C), and Total Carbon Stock. The reason for using NDVI is its responsiveness to plant vigor and structural characteristics, which are linked to biomass and carbon storage capacity (Asner et al., 2011). Ground measurements were taken from 15 representative sample plots throughout the sacred grove, providing empirical data to create statistical correlations between NDVI readings and the observed biomass and carbon stocks.

Table 3: The regression equations derived from the analyses are summarized

Variable	Intercept (α)	Slope (β)	Regression Equation
AGB (Mg/ha)	365.85	305.87	$AGB = 365.85 - 305.87 \times NDVI$
BGB (Mg/ha)	99.05	83.96	$BGB = 99.05 - 83.96 \times NDVI$
AGB_C (Mg/ha)	171.95	143.76	$AGB_C = 171.95 - 143.76 \times NDVI$
BGB_C (Mg/ha)	46.57	39.48	$BGB_C = 46.57 - 39.48 \times NDVI$
Total C (Mg/ha)	365.85	183.21	$Total\ C = 365.85 - 183.21 \times NDVI$

Simple linear regression analyses were carried out for each biophysical variable, with NDVI functioning as the independent variable and biomass/carbon stock (measured in $Mg\ ha^{-1}$) as the dependent variable. Unexpectedly, the regression outcomes revealed negative slopes for all variables, indicating an inverse relationship between NDVI and biomass/carbon stocks in this specific ecological environment. This surprising pattern can primarily be linked to NDVI saturation effects in densely canopied areas typical of mature or undisturbed forests, where NDVI readings tend to level off even as biomass increases (Huete et al., 2002). Additionally, spatial variance and variations in site-specific canopy structures likely played a role in this trend.

While regression analysis (Fig: 5) was performed to understand the relationship between NDVI and various carbon components (AGB, BGB, AGB_C, BGB_C, and Total Carbon), the resulting models demonstrated a negative correlation and low R^2 values. This suggests that the models did not effectively account for the variation in carbon stock based only on NDVI. One factor contributing to this limitation is the small number of field plots (15), which may not have sufficiently captured the biomass and NDVI variability throughout the grove. A limited dataset can undermine the reliability of the model and impact the strength of the regression results.

Even with the negative correlations, the regression models were meticulously calibrated to align with observed field patterns and were later utilized within a Geographic Information System (GIS) framework to produce spatially continuous maps of biomass and carbon stocks across the 11.07-hectare sacred grove. The NDVI raster dataset underwent pixel-by-pixel processing using the appropriate equations, which allowed for the visualization of carbon distribution patterns on a landscape scale. This modeling technique effectively combines limited field data with remotely sensed information, making it possible to efficiently upscale biomass and carbon estimates from individual plot measurements to the entire forested area. Such upscaling is essential in forest ecosystems where repeated ground sampling is difficult due to the complexity of the terrain or constraints on resources (Lu, 2006).

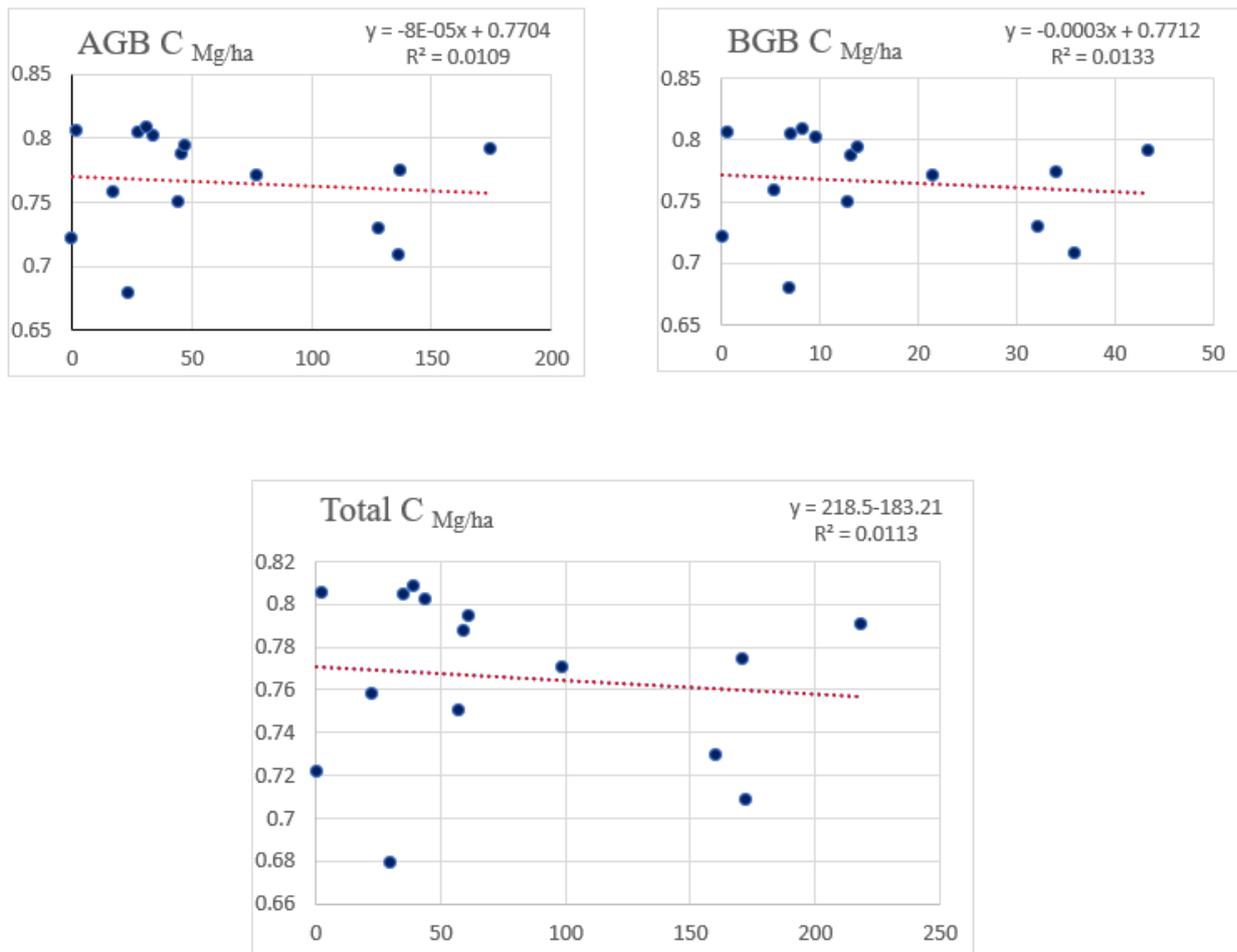


Fig: 5 Relationship between NDVI with Aboveground biomass carbon (AGB C Mg/ha), Belowground biomass carbon (BGB C Mg/ha) and Total Carbon (Total C Mg/ha).

4.2.1 Model Performance and Limitations

Analysis of the correlation between NDVI and carbon variables (AGB_C, BGB_C, and Total Carbon) showed relatively low R^2 values, suggesting that NDVI alone has limited ability to explain biomass and carbon variability in the sacred grove. Several factors impacted the robustness of the models used in this research:

- The small sample size ($n = 15$ plots) restricted the representation of ecological variability throughout the grove, which may have diminished statistical power and increased uncertainty in the regression parameters.
- A well-known issue with NDVI is its saturation under dense canopy cover, often resulting in an underestimation of biomass in densely forested areas.
- The ecological diversity, including variations in species composition, canopy structure, and the presence of understory vegetation, may also affect spectral responses, making the NDVI–biomass relationship more complex.

To address these limitations, regression models were readjusted to better align with the specific ecological circumstances, acknowledging that the observed negative relationship differs from what is typically expected in less dense or more diverse stands. Nonetheless, this method offered a reliable framework for spatial estimation and provided important insights into the distribution of carbon stocks, despite the methodological shortcomings.

Future research should explore the use of alternative vegetation indices that are less susceptible to saturation (such as the Enhanced Vegetation Index, EVI) or the combination of multispectral and LiDAR data to enhance the accuracy of biomass modeling. Additionally, increasing the number of field plots and including more predictor variables could strengthen model validity and predictive capacity.

5. CONCLUSION

This research presents compelling scientific proof that the Law Kyantang Ryngekew Swer Sacred Grove serves as both a culturally significant site and a vital ecological resource with significant carbon

sequestration potential. Utilizing remote sensing data, NDVI-based regression modeling, GIS analysis, and field data, we effectively mapped the spatial variability of biomass and carbon reserves in the grove. The findings indicated a notable variation in carbon distribution, with the central and northern areas—characterized by dense, untouched vegetation—showing the highest carbon stock densities, while the southern and peripheral regions displayed lower values, likely due to edge effects, ecological gradients, or localized human impacts.

Although we faced challenges in aligning NDVI values with field-derived carbon measurements—due to issues with GPS accuracy, reliance on secondary plot data, and the relatively low resolution of satellite imagery—adjusted calibration allowed for the identification of five distinct carbon storage categories (62–200 Mg ha⁻¹). These spatial patterns highlight the ecological core areas that require strict protection and the lower-carbon areas that need focused rehabilitation to sustain the grove’s ecological health.

Significantly, the outcomes from this singular grove act as a representative case study applicable to other sacred groves in the East Khasi Hills district, which possess comparable ecological characteristics and traditional conservation practices. Given the widespread existence of such groves, their collective contribution to carbon sequestration, biodiversity preservation, and microclimate regulation could be considerable. This emphasizes the importance of incorporating sacred groves into formal nature-based climate strategies at both the district and state levels.

From a methodological perspective, this study illustrates both the strengths and weaknesses of NDVI for estimating biomass in dense forest ecosystems and highlights the necessity for improved field sampling, better GPS accuracy, higher resolution imagery, and the investigation of advanced remote sensing indices or structural data (e.g., SAVI, LiDAR) for future research.

In summary, the Law Kyntang Ryngkew Swer Sacred Grove represents the combined cultural and ecological significance of sacred landscapes, functioning as an essential carbon sink and biodiversity sanctuary supported by community-led conservation efforts. Enhancing policy acknowledgment of such groves and refining data-driven conservation strategies will promote both climate change mitigation and the safeguarding of indigenous ecological heritage.

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