

SUSTAINING FOREST ECOSYSTEM FOR ENHANCING CLIMATE STABILITY USING RS AND GIS

Wajid Ali Solangi¹, Habibullah Abbasi^{*1}, Abdul Haq Shaikh², Sher Muhammad Ghoto³,
Saeed Ahmed Pirani⁴, Riaz Ahmed Wagan⁴, Wasim Razaq Khan⁵

¹Centre for Environmental Science, University of Sindh Jamshoro,

²Divisional Forest and Planning Department

³Quaid-e-Awam University of Engineering, Science and Technology, Nawabshah Sindh Pakistan

⁴Forestry Research Education Sindh

⁴Forests Riverine & Inland Forests Sindh at Hyderabad

⁵Universiti Putra Malaysia

²habibullah.abbasi@usindh.edu.pk

²<https://orcid.org/0000-0001-9910-5002>

DOI: <https://doi.org/10.5281/zenodo.22657731>

Keywords

Forest, Soil fertility, NDVI, LST,
Loss of ignition (LOI).

Article History

Received: 01 July 2026

Accepted: 16 August 2026

Published: 08 September 2026

Copyright @Author

Corresponding Author: *

Habibullah Abbasi

Abstract

Forest conservation for sustainable ecosystem services, environmental protection, biodiversity conservation, and the continuous supply of goods and services is a key concern for planners, policymakers, and regulatory institutions. Afforestation or artificial plantation is considered an essential strategic solution. When it comes to environmental protection and ecosystem services. However, the sustainable management of these forest ecosystems remains at risk due to a lack of pre-planning and management strategies. The research study focuses on monitoring and analyzing spatio-temporal changes in vegetation cover and regional climate patterns, and soil assessment in response to the implementation of the conservation plan in the Khipro forest, a desert region. The objective of this study is to identify the key drivers of degradation and an implementation plan for forest conservation and improvement of soil fertility and health in a desert region for crop production. The results analyzed for forest cover change over time indicate control over forest degradation after a significant loss of vegetation cover by the end of 2025. Improved vegetation cover resulted in stable regional climate conditions and enhanced soil enrichment. Results for Normalized Difference Vegetation Index (NDVI) in correlation with soil enrichment indicate a positive correlation with Soil Organic Carbon (SOC). The correlation supports the research findings that soil health has improved over time by controlling key drivers of land use that degrade soil fertility and crop production.

1. INTRODUCTION

Artificial or plantation forests are extensively sustained and regulated forest types, with specific species, planted for wood production for industrial and domestic purposes, and Environmental protection (Labarre & Christophe, 2025; Tesfaye et al., 2025). Forest ecosystems play a key role in regulating the global carbon cycle, biodiversity, and climate change (Alhamd et al., 2025; Muhammad et al., 2024), capturing carbon from the atmosphere through photosynthesis and storing it in biomass and soil (Khan et al., 2021). These ecosystems are carbon pools threatened by the conversion of forest land to other land types (Almeida et al., 2025; Li et al., 2024). Deforestation leads to loss of ecosystem services and biodiversity, exacerbating climate change, water stress, soil loss, and negative impacts on socioeconomic development (Jong et al., 2025; Kumar et al., 2024; Qian et al., 2024).

Forest ecosystems provide numerous ecosystem services, both visible and invisible, that are valuable to communities and the quality of life (Ramachandra & Ahmed, 2025; Rita et al., 2023). These ecosystem services are at risk due to land transformation and unbalanced environmental management (Rovai et al., 2023). Anthropogenic activities, particularly land cover changes, lead to loss of soil quality (Murindangabo et al., 2023). Land use and land cover change and mismanagement lead to changes in regional climate patterns and loss of soil fertility as a result of the decline in SOC, which leads to compromised soil ecosystem services (Lamla, 2023). Monitoring soil quality in relation to vegetation cover and climate is essential, especially where land cover and forest cover change are common practices due to anthropogenic pressure. It indicates the environmental quality of the ecosystem by determining the carbon stock in the soil pools (Hoyos et al., 2025). Forest plantation is one of the most effective nature-based solutions to achieve the targeted temperature of 1.5 °C in strategic planning for climate resilience, sustainability (Esperon-rodriguez et al., 2025; M. Zhang et al., 2025), and soil enrichment. Arid

and semi-arid regions experience water shortage and climate challenges, leading to soil loss, which requires regular monitoring. Monitoring change in vegetation cover due to land cover change is a challenge, particularly in developing countries, due to a lack of advanced technology approaches, inefficient knowledge, and a lack of resource support for sampling the area on a large scale; however, remote sensing technology provides reliable, accurate, and cost-effective data for monitoring such a large area.

Traditional methods for field measurements are reliable and accurate for monitoring forest and vegetation cover in relation to climate; however, these approaches are far more expensive and time-consuming (Ali et al., 2018). Thus, remote sensing is the best alternative and approach for spatial and temporal analysis and environmental monitoring in a large area. Multiple RS techniques have been introduced for the estimation of change in vegetation cover. Therefore, remote sensing and vegetation indices are effective approaches in the field of ecosystem management and estimation of vegetation biomass quality (Garrouette et al., 2016). Several satellite-based vegetation indices have been introduced for forest biomass estimation, including Normalized Vegetation Index (NDVI), Soil-adjusted vegetation index (SAVI), and Enhanced vegetation index (EVI) are the most commonly used indices (Bordoloi et al., 2022).

On the other hand, for soil monitoring and assessment, SOM is one of the soil quality indicators universally used for soil assessment (Campus & Osmond, 2009; Kumala et al., 2023). Soil quality assessment is carried out using multiple techniques and quality indices; however, SOM and SOC are considered the most important factors, impacting physical, chemical, and biological properties of soil. Several methods have been used for soil SOC and SOM assessment, including the Walkley-Black (WB) method, the Tyurin method, the TDS method, and the loss of ignition (LOI) method. LOI is a suitable and reliable method because it is a cost-effective, quick, and simple method used for soil organic carbon carbonate (Cloete et al., 2025;

Heiri et al., 2001; Wright et al., 2008). This study uses the LOI method for laboratory assessment of soil samples to identify SOC and SOM properties.

Pakistan's natural resources, including forests, face conservation challenges due to capacity development, which leads to soil loss, affecting crop productivity on a massive scale. Continuous changes in forest cover and vegetation area influence ecosystem services; therefore, spatio-temporal change analysis and continuous monitoring are essential for the management and conservation of these resources. This study aims to evaluate spatiotemporal changes in vegetation cover, leading to changes in climate in the Khipro forest using multiple indices, including NDVI and LST. Furthermore, these indices were evaluated in correlation with soil organic carbon, as playing a major role in regulating soil quality. This study contributes to strengthening knowledge and understanding of how each environmental factor responds over time.

2. Material and Methods

2.1. Study Area

The Khipro Forest is an artificial forest, planted during the British colonial era in the early 20th century. It is situated in Sanghar District, Sindh, Pakistan (25°52'47" N, 69°19'22" E). The plantation aimed to prevent desertification, biodiversity conservation, and fulfill the demand for fuel-wood and lumber. Initially, it covered 24,000 acres. The forest ecosystem services, including wildlife habitats, supply green cover and regulate the local climate, because it is located in an arid to semi-arid region. The region experiences climatic variations in terms of temperature and rainfall. Temperature ranges from 20°C to 47°C, and rainfall ranges from 88mm to 133mm. Khipro is a vulnerable forest zone due to encroachments, water scarcity, and deforestation, impacting its biological services, which is a challenge for forest conservation. However, it plays an important role in the socioeconomic and environmental landscape of the area despite these obstacles.

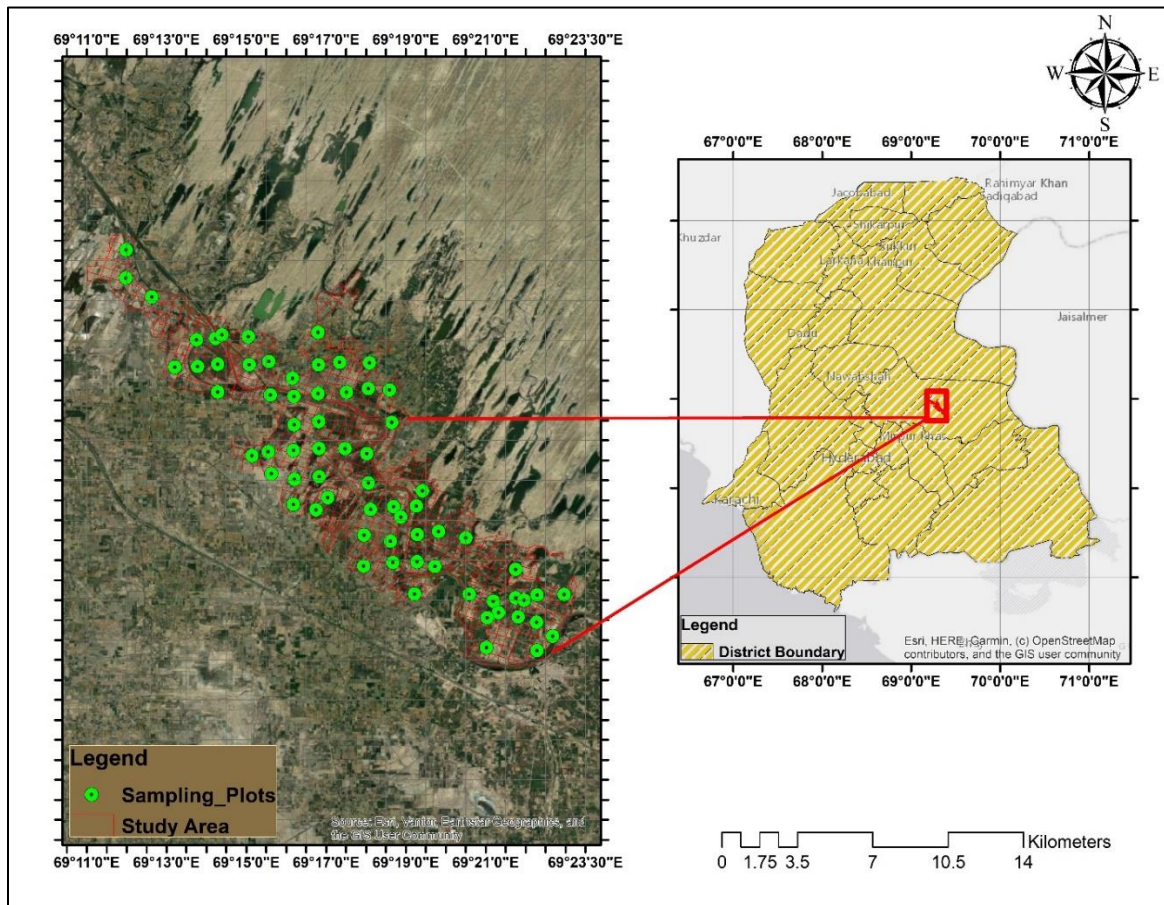


Fig 1. Study are location

2.2. Methodology

The research study calculated vegetation indices (VIs) and climate indices using satellite data sources for an accurate estimation. The vegetation index, including NDVI and climate index LST, was calculated with a decadal gap for the year (2000-2025). These indices provide insights into vegetation change resulting from environmental and climate change. Climate indices, including temperature and precipitation, were dynamically correlated with NDVI and soil parameters, including SOC and SOM. It helps to understand how variations in vegetation cover influence the climate and its ultimate impacts on soil quality. The integrated analysis helps to understand the dynamic interaction between forest cover and the climate. Furthermore, these indices were correlated with soil health and parameters to determine the role of vegetation

cover in contributing to soil health and enrichment. The soil sample were analyzed using the loss of ignition (LOI) method for the identification of SOC and SOM.

2.2.1. Soil Sampling and Analysis

A total of 75 soil samples were collected at a depth of 30 cm using a systematic soil sampling. For each soil sample point, four secondary sample points were selected for each plot to determine the soil characteristics. The samples were preserved and immediately moved to the laboratory. Before laboratory analysis, samples were air-dried at ambient temperature in a well-ventilated area. Non-soil constituents were removed, and the dried soil was passed through a 2mm sieve after crushing the soil material. After preprocessing, soil organic carbon and organic matter were determined using the Loss on

Ignition (LOI) method. In the first step, a clean, empty crucible was weighed and recorded as $W1$. 5 grams of soil were dried in an oven for 24 hours at a temperature of 105°C . The dried soil samples were heated at 550°C in a muffle furnace for four hours. During this process, soil organic matter is burnt off and weighted as $W2$. Finally, organic matter for each sample was calculated using equation 4,

$$SOM\% = \frac{W1-W2}{W1} \times 100 \quad (4)$$

The SOC values were calculated by dividing SOM by 1.724 (Bernardini et al., 2025). The equation is given below (5), and the classification of organic carbon and organic matter is given in Table 1.

$$SOC\% = \frac{SOM\%}{1.724} \quad (5)$$

Table 1: Classification for Soil organic carbon and soil organic matter

S. No	Class	Rating for Organic Matter	Rating for Organic Carbon
1	Very Low	<1	-
2	Low	1.0-2.0	<0.40
3	Moderate	2.01-3	0.40-75
4	High	3.01-5	>0.75
5	Very high	>5	-

2.2.2. Normalized Difference Vegetation Index (NDVI)

The Normalized Difference Vegetation Index (NDVI) is one of the indices used for biomass. It minimizes atmospheric and surface factors impacting enhanced green vegetation signals (X. Zhang & Ni-meister, 2014). It is the most commonly used vegetation index because of high NIR radiation and low red band reflectance. The NDVI quantifies the greenness and plant condition within forests or vegetated land (Anuar et al., 2023). NDVI is calculated using the equation;

$$NDVI = \frac{NIR-RED}{NIR+RED} \quad (1)$$

2.2.3. Land Surface Temperature

Land surface temperature is one of the major climatic factors that indicate climate conditions in response to the land use type and activities in the region. The selected factor was considered to correlate with land use cover change, especially vegetation cover over time. The temporal changes

identify impacts on climate due to the incline or decline of vegetation cover. The land surface temperature for Landsat 8 and 9 was calculated using the following steps.

Step1: Conversion of top of atmosphere (TOA) radiance using equation 2.

$$L\lambda = ML \times Q_{cal} + AL - O_i \quad (2)$$

Step2: Conversion of Top of Atmosphere brightness temperature in Kelvin using equation 3,

$$BT = \frac{K_2}{1n\left(\frac{K_1}{L\lambda} + 1\right)} - 272.15 \quad (3)$$

Where,

$L\lambda$ is TOA spectral radiance ($\text{watts/m}^2 \times \text{sr} \times \mu\text{m}$), ML represent the radiance of multiplicative band number, Q_{cal} is the pixel values that is quantized and standard, AL represents radiance add band and O_i is the correction values of band 10 which is 0.29. BT is the brightness for the top of atmosphere, K_1 and K_2 indicate constant band numbers.

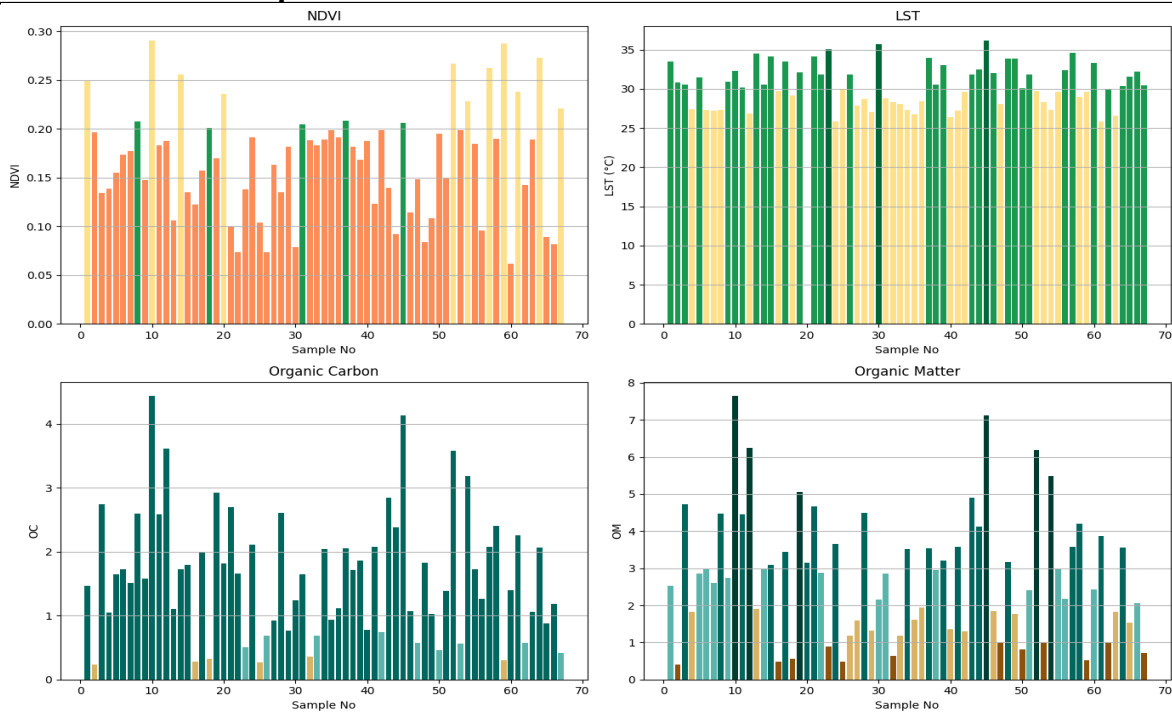


Fig 2. NDVI, LST, SOC, and SOM values for each Soil sample collected.

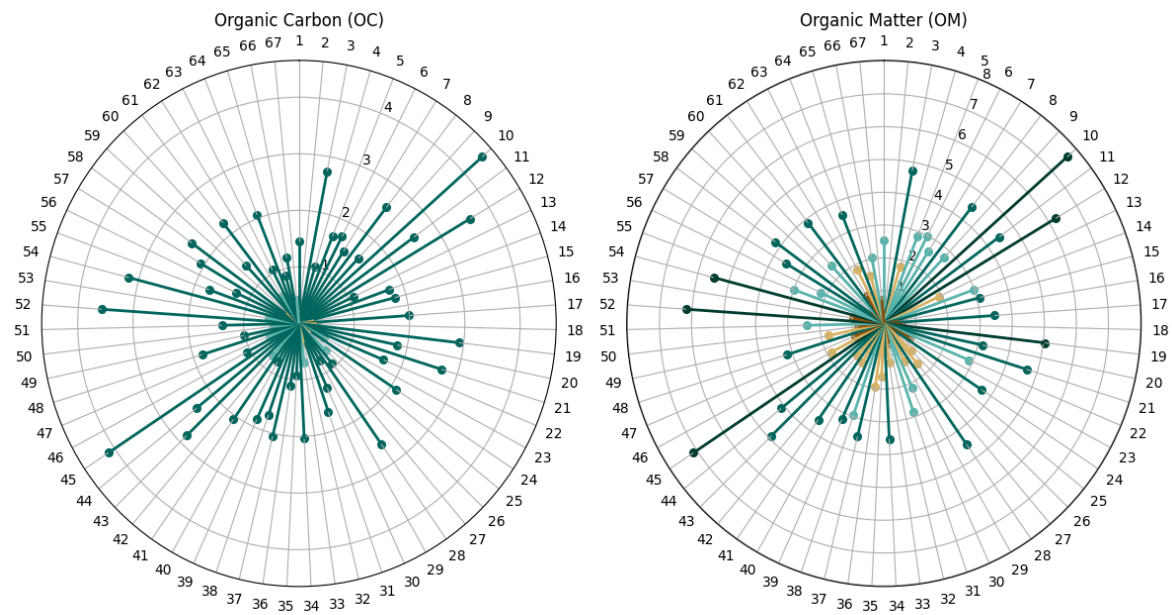


Fig 3. Dynamic of SOC and SOM for each soil sample.

3. Results and Discussions

3.1. Spatial-Temporal Change in NDVI and LST

The variations in temperature can be observed, with changes in vegetation cover and vegetation health. NDVI values ranging from -0.23 to 0.67, with temperature 23.6 °C to 33.3 °C in 1990, which increased from 25.40 °C to 36.8 °C and 27.9 °C to 38 °C in 2000 and 2010, respectively,

as a result of a decline in vegetation cover. The NDVI values range from -0.19 to 0.64 and from -0.05 to 0.48 in (2000 and 2010), respectively. The temperature decreased in 2020 and 2025 due to an increase in vegetation cover. The NDVI and temperature values range from -0.8 to 0.50, -0.05 to 0.54, 24.40 °C to 35.9 °C, and 24.4 °C to 36 °C in 2020 and 2025, respectively. Figure 4 and 5 show spatiotemporal change of NDVI and LST, respectively.

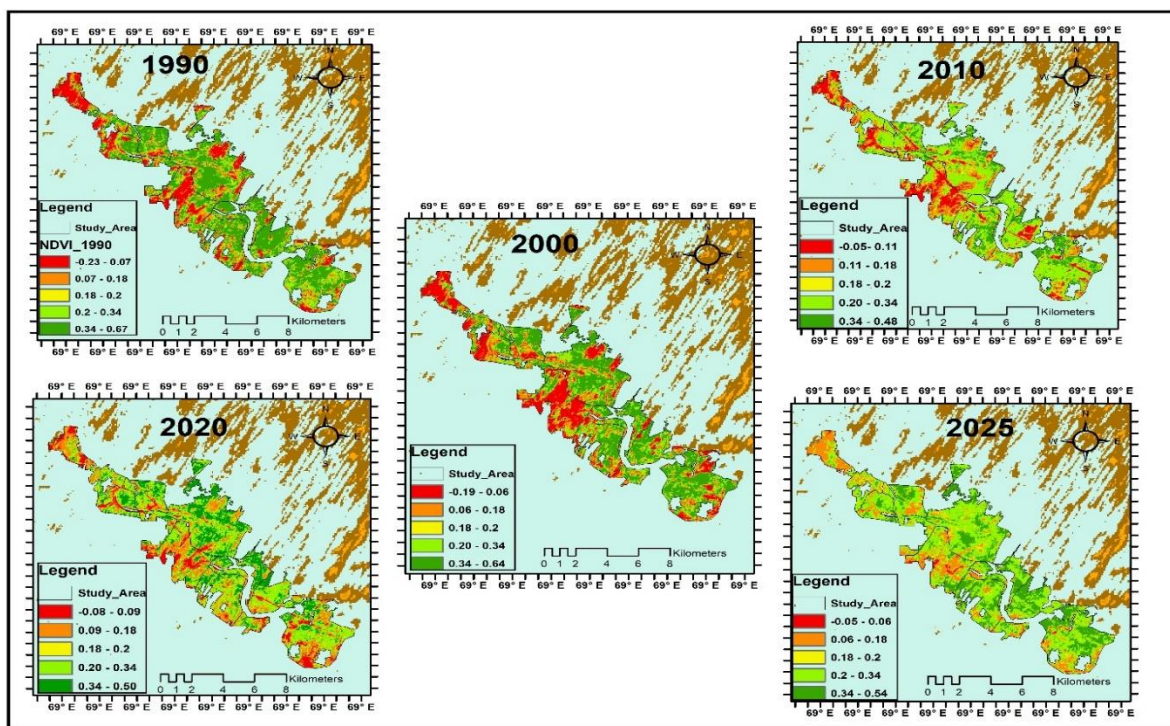


Figure 4. Spatitemporal change for NDVI.

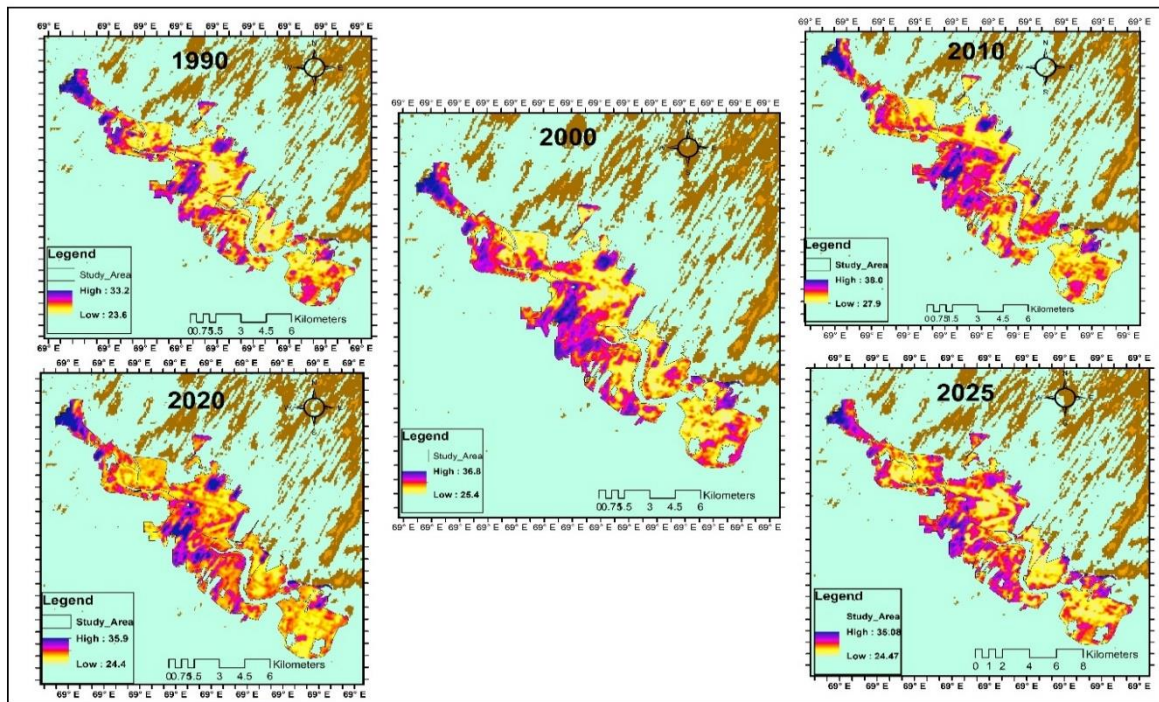


Figure 5. Spatitemporal change for LST.

3.2. Soil Organic Carbon

Soil organic carbon stored depends on number of environmental factors, such as vegetation cover, soil texture, water holding capacity, and regional climate (Kumala et al., 2023). The analyzed samples for soil organic carbon were classified as low, ranging from >0.40 . Moderate class values range from 0.40 to 0.75, and high class values are classified as >0.75 . The results indicate that 59 of the samples, with 78%, have organic carbon higher than 0.75, 10 of the total samples, with 13.3%, are moderate, and 6 samples, constituting 8% of the total samples, have low organic carbon.

3.3. Soil Organic Matter

The soil organic matter represents the soil fertility status, which differs from soil features, such as

rock and other non-soil types. It enhances soil structure, soil fertility, moisture content, soil nutrients, and soil runoff control (Ravikumar & Somashekar, 2013). The soil organic matter was classified as very low, ranging <1 , low 1.01-2.0, Moderate 2.01-3.0, High 3.01-5, and very high >5 . The classified sample results indicate 23 samples with 30% exhibit higher values, 16 samples are moderate, and 16 samples are low values with 21%, respectively. 13 samples, constituting 17%, and 7 samples with 9% of the total samples are very low, and very high, respectively. Figure 6 shows percentage for classified SOC and SOM and class distribution for each soil sample.

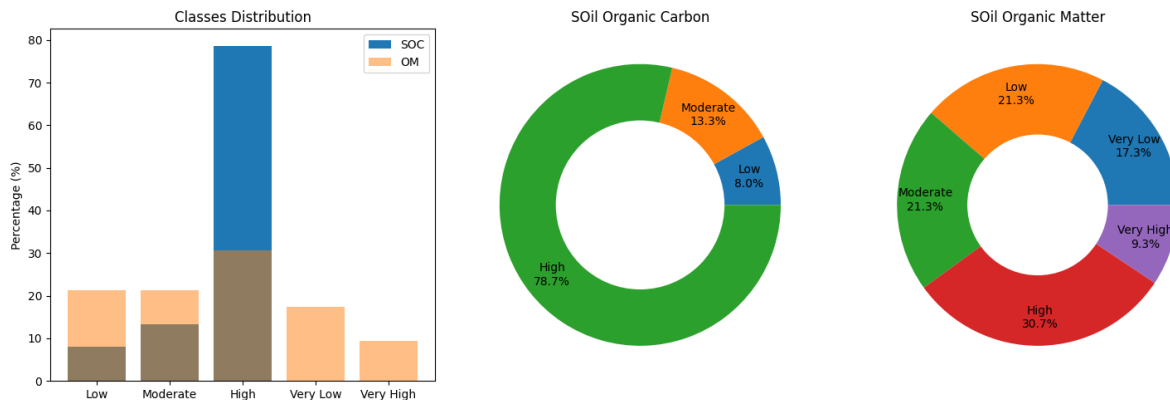


Figure 6 (a). Classified SOC and SOM percentage.

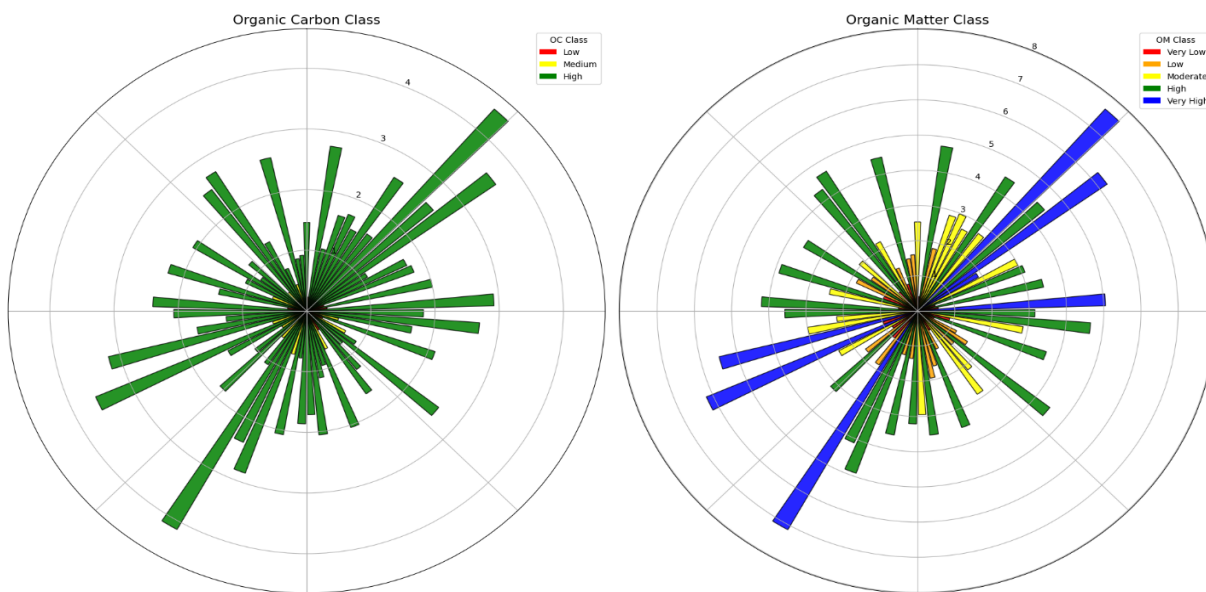


Figure 6 (b) soil class distribution for each sample.

3.4. Dynamics of NDVI, LST, SOC, and SOM

Understanding the dynamics of NDVI, LST, SOC, and SOM is crucial because these are strongly correlated, which helps decision-making and policy implementation. NDVI indicates spatial vegetation density within the region, which directly influences organic residue into the soil, hence enhancing soil fertility due to SOC and SOM accumulation. Conversely, elevated LST leads to sparse vegetation cover and reduced soil moisture, which ultimately leads to reduced SOC and SOM. Therefore, spatiotemporal variations for these factors reflect the combined effect on physical and chemical soil properties.

Results for each soil sample analyzed indicate that organic carbon and organic matter are positively correlated with NDVI and negatively correlated with LST. Figure 8 clearly represents the dynamic correlation among these variables, where soils exhibit higher organic carbon and organic matter, with improved NDVI and lower LST. Soils exhibiting lower organic carbon and organic matter with higher LST. The correlation for each sample supports findings that soil health has improved over time by controlling key drivers of land use that degrade soil fertility and crop production.

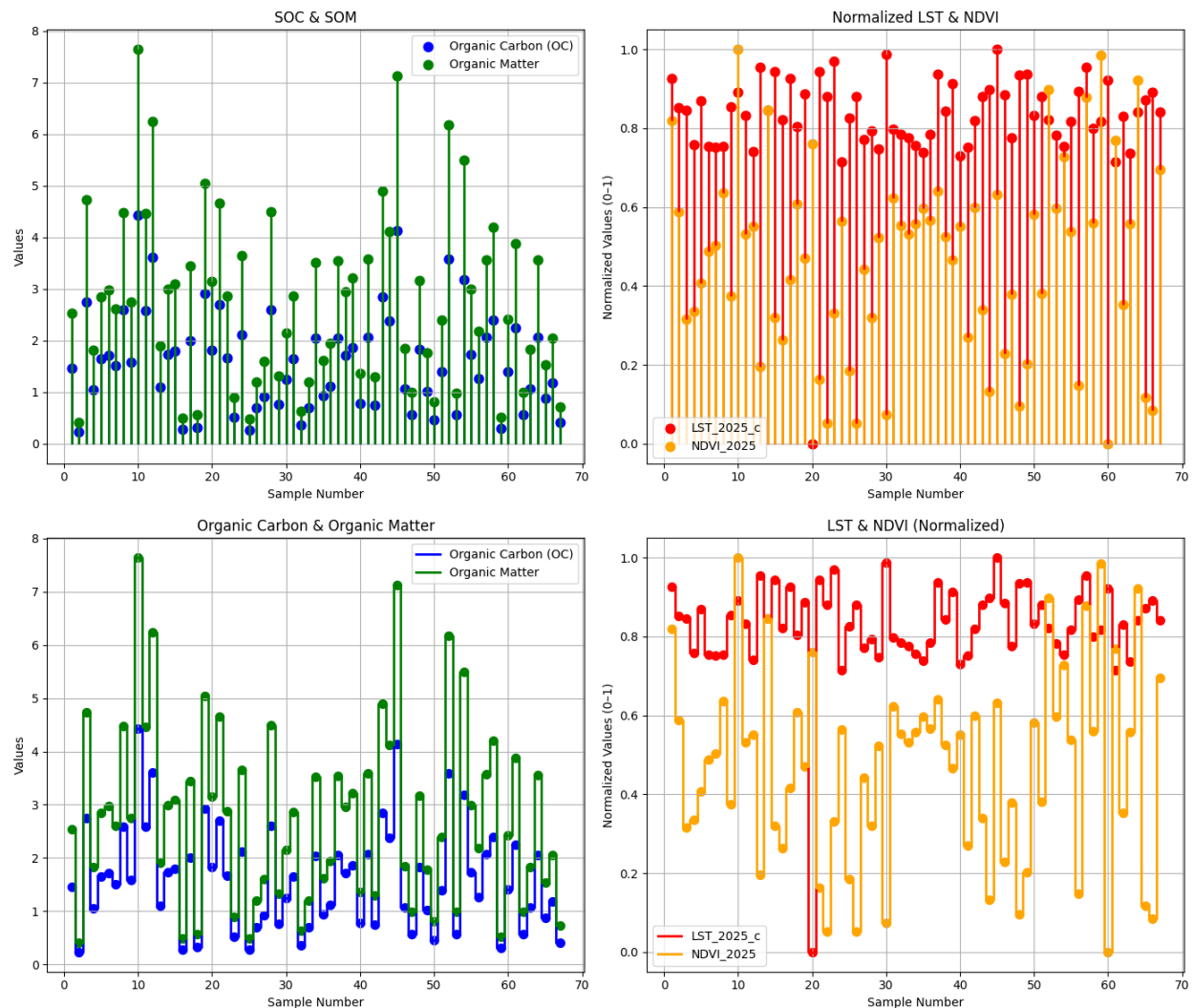


Figure 8. Dynamic correlation of NDVI and LST in relation to the SOC and SOM.

3.5. Annual Temporal Change in Climate Variables

The annual temporal data analysis was carried out to identify the overall trend within the region. The results indicate a slight change in annual average temperature; however, these changes are associated with variations in NDVI. The variations in NDVI cover, resulting from

deforestation drivers such as urban expansion and the cutting of fuel wood. An increasing trend in precipitation was observed, with decreasing temperatures. The overall trend is negatively correlated, which represents a clear insight into the climate of the study area. The improved precipitation events led to soil enrichment and fertility with improved vegetation cover.

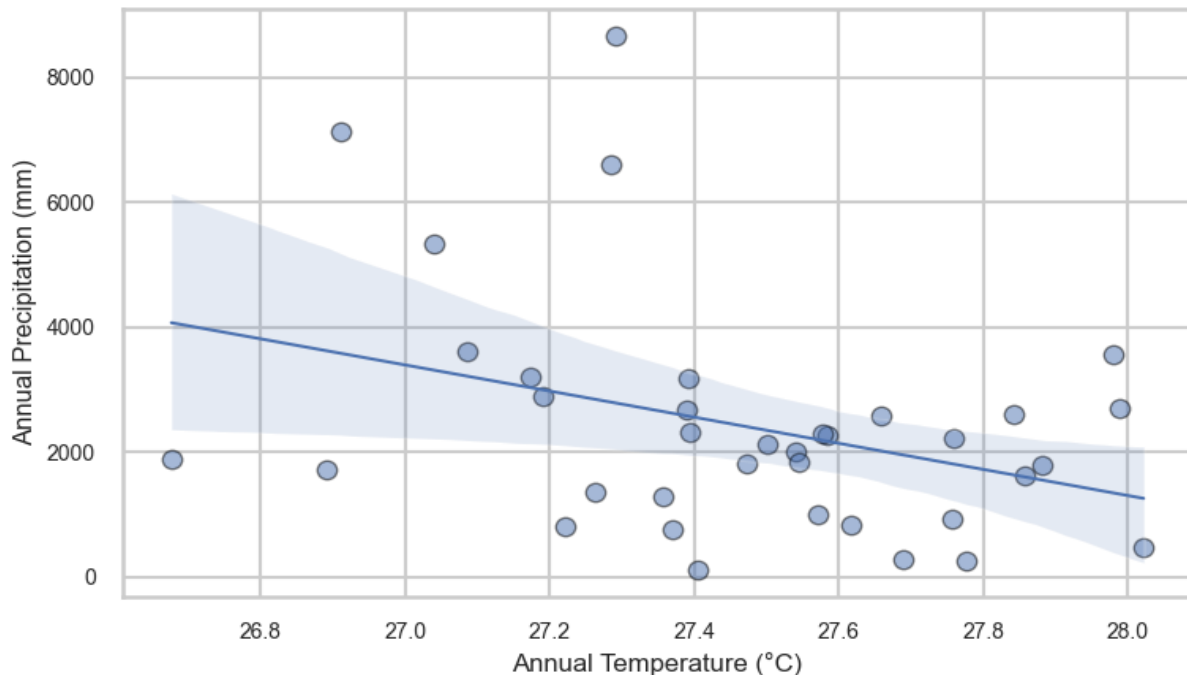


Figure 9. Correlation for annual temperature and precipitation

4. Conclusion

The soil analysis indicates a strong correlation of SOC and SOM with NDVI dynamics, which supports improved soil health as a result of the management plan. The spatiotemporal changes of NDVI, LST, and soil health in the study area are dynamic and show strong interactions. Each correlation provides insights into understanding how the mechanisms of the ecological system are interconnected. Changes in one factor lead to changes in others, helping to identify controlling factors for soil fertility and quality. The variations in NDVI highlight the significant role of vegetation cover in regulating land surface temperatures and soil quality. Areas with higher vegetation values and lower temperatures tend to exhibit higher SOC and SOM; furthermore, precipitation variability influences vegetation cover and soil carbon storage. Increased precipitation events contribute to improved vegetation cover and stabilize soil conditions, which enhance soil carbon storage and improve soil quality. Sustainable land management practices that promote vegetation cover can play a critical role in maintaining soil health and

fertility. It can also help to enhance carbon sequestration and long-term environmental stability.

Funding: The authors received no financial support for the research, authorship, or publication of this research.

Data Availability: Data will be provided upon reasonable request from the corresponding author.

Ethical Approval: Not Applicable

Consents to Participate: All authors confirm the participation and their contribution. They have approved the final submission of the manuscript.

REFERENCE

- Alhamd, L., Setijo, J., & Lintang, A. (2025). Trees , Forests and People Biomass and carbon sequestration in four sub-montane forest types : Insights from multiple-year monitoring data in Indonesia. *Trees, Forests and People*, 22(November), 101078. <https://doi.org/10.1016/j.tfp.2025.101078>

- Ali, A., Ullah, S., Bushra, S., Ahmad, N., & Ali, A. (2018). Aboveground Biomass, Remote Sensing, Sentinel-2A data, Vegetation indices oberirdische Biomasse, Fernerkundung, Sentinel-2A-Daten, Vegetations-Indizes. 93–117.
- Almeida, B., Monteiro, L., Tiengo, R., Gil, A., & Cabral, P. (2025). Remote Sensing Applications: Society and Environment Spatially explicit assessment of carbon storage and sequestration in forest ecosystems. *Remote Sensing Applications: Society and Environment*, 38, 101544. <https://doi.org/10.1016/j.rsase.2025.101544>
- Anuar, N. I., Khalid, N., Tahar, K. N., & Nisa, A. (2023). Analyze the Relationship Between Aboveground Biomass and NDVI Values Derived from UAV Multispectral Imagery Analyze the Relationship Between Aboveground Biomass and NDVI Values Derived from UAV Multispectral Imagery. <https://doi.org/10.1088/1755-1315/1240/1/012015>
- Bernardini, L. G., Bruni, E., Izquierdo-verdiguier, E., Keiblinger, K. M., Rosinger, C., & Bodner, G. (2025). Geoderma Benchmarking the benchmark: comparison of methods for soil health assessment. *Geoderma*, 464(March), 117619. <https://doi.org/10.1016/j.geoderma.2025.117619>
- Bordoloi, R., Das, B., Tripathi, O. P., Sahoo, U. K., Nath, A. J., Deb, S., Das, D. J., Gupta, A., Devi, N. B., Charturvedi, S. S., Tiwari, B. K., Paul, A., & Tajo, L. (2022). Environmental and Sustainability Indicators Satellite based integrated approaches to modelling spatial carbon stock and carbon sequestration potential of different land uses of Northeast India. *Environmental and Sustainability Indicators*, 13(December 2021), 100166. <https://doi.org/10.1016/j.indic.2021.100166>
- Campus, W., & Osmond, G. (2009). Review : soil biological properties as indicators of. 1–13. <https://doi.org/10.1111/ajgw.12034>
- Cloete, W. H., Preez, G., & Zijl, G. M. Van. (2025). Geoderma Regional The carbon credit conundrum: Which analytical method should be used for determining soil organic carbon content in South Africa? *Geoderma Regional*, 41(March), e00947. <https://doi.org/10.1016/j.geodrs.2025.e00947>
- Esperon-rodriguez, M., Gallagher, R. V., Russo, A., Power, S. A., Calaza-martinez, P., Capela, T., Cari, P., Eleuterio, A. A., Guo, Z., Lee, G., Masselot, P., McDonald, R. I., Yan, P., Yang, J., & Tjoelker, M. G. (2025). Global trends in urban forest irrigation: Environmental influences, challenges and opportunities for sustainable practices across 109 cities worldwide. 130(June).
- Garrouste, E. L., Hansen, A. J., & Lawrence, R. L. (2016). Using NDVI and EVI to Map Spatiotemporal Variation in the Biomass and Quality of Forage for Migratory Elk in the Greater Yellowstone Ecosystem. <https://doi.org/10.3390/rs8050404>
- Heiri, O., Lotter, A. F., & Lemcke, G. (2001). Loss on ignition as a method for estimating organic and carbonate content in sediments: reproducibility and comparability of results. 101–110.
- Hoyos, A., Juan, S., & Menjivar, C. (2025). Soil organic carbon in agricultural soils of an inter - Andean valley in Colombia : understanding the effects of environmental and geographic variables. <https://doi.org/10.1007/s10661-025-14123-1>

- Jong, J. De, Poorter, L., Jong, W. De, Bongers, F., Lohbeck, M., Veenendaal, E., Meave, J. A., Jakovac, C. C., Brancalion, P. H. S., Amissah, L., Martinez-ramos, M., Bartholomeus, H., Laurance, S. G. W., Hagan, W., & Decuyper, M. (2025). Land Use Policy Dissecting forest transition : Contribution of mature forests , second-growth forests and tree plantations to tree cover dynamics in the tropics. *Land Use Policy*, 153(November 2023), 107545. <https://doi.org/10.1016/j.landusepol.2025.107545>
- Khan, I. A., Khan, W. R., Ali, A., & Nazre, M. (2021). Assessment of Above-Ground Biomass in Pakistan Forest Ecosystem ' s Carbon Pool : A Review. 1–18.
- Kumala, A., Supriatna, S., & Damayanti, A. (2023). Model assessment of soil organic matter content by remote sensing in Bayah , Indonesia Model Assessment of Soil Organic Matter Content by Remote Sensing in Bayah , Indonesia. 020192(October 2018). <https://doi.org/10.1063/1.5064189>
- Kumar, S., Shruti, G., Gowhar, K., Suraj, M., Singh, K., Singh, S., & Sajan, B. (2024). Discover Geoscience Optimizing land use for climate mitigation using nature based solution (NBS) strategy: a study on afforestation potential and carbon. *Discover Geoscience*. <https://doi.org/10.1007/s44288-024-00046-w>
- Labarre, C., & Christophe, J. (2025). The impact of climate change , disturbance and forest management on ecosystem service distribution across Europe ' s largest plantation forest in the 21st century.
- Lamla, M. (2023). Spatial variation of soil physical and chemical components of Lamitan City , Basilan province , Bangsamoro autonomous region in Muslim Mindanao (BARMM), Philippines Article Info Received : 23-04-2023 Accepted : 18-05-2023 Page No : 789-795. 789–795.
- Li, L., Fu, M., Zhu, Y., Kang, H., & Wen, H. (2024). The current situation and trend of land ecological security evaluation from the perspective of global change. *Ecological Indicators*, 167(August), 112608. <https://doi.org/10.1016/j.ecolind.2024.112608>
- Muhammad, B., Rehman, A. U. R., Mumtaz, F., & Qun, Y. (2024). Estimation of above-ground biomass in dry temperate forests using Sentinel-2 data and random forest : a case study of the Swat area of Pakistan. October, 1–16. <https://doi.org/10.3389/fenvs.2024.1448648>
- Murindangabo, Y. T., Kopecký, M., Hoang, T. N., Bernas, J., & Parajuli, T. (2023). Comparative analysis of soil organic matter fractions , lability , stability ratios , and carbon management index in various land use types within bharatpur catchment , Chitwan District ,. *Carbon Balance and Management*, 1–16. <https://doi.org/10.1186/s13021-023-00241-1>
- Qian, J., Ji, C., Yang, J., Zhao, H., Wang, Y., Fu, L., & Liu, Q. (2024). The advantage of afforestation using native tree species to enhance soil quality in degraded forest ecosystems. *Scientific Reports*, 0123456789, 1–10. <https://doi.org/10.1038/s41598-024-71162-3>
- Ramachandra, T. V., & Ahmed, S. A. (2025). Insights into the linkages of forest structure dynamics with ecosystem services. 1–21.
- Ravikumar, P., & Somashekar, R. K. (2013). Evaluation of nutrient index using organic carbon , available P and available K concentrations as a measure of soil fertility in Varahi River basin , India. 3(4), 330–343.
- Rita, A., Cammerino, B., Ingaramo, M., Piacquadio, L., & Monteleone, M. (2023). Assessing and Mapping Forest Functions through a GIS-Based , Multi-Criteria Approach as a Participative Planning Tool: An Application Analysis.

- Rovai, M., Trinchetti, T., Monacci, F., & Andreoli, M. (2023). *Mapping Ecosystem Services Bundles for Spatial Planning with the AHP Technique : A Case Study in Tuscany (Italy)*.
- Tesfaye, F. T., Mengistu, D. A., & Gela, A. G. (2025). *Mapping forest age and species dynamics in yeraba plantation forest of northwest Ethiopia using hyperspectral signatures and spectral angle mapper. 5*.
- Wright, A. L., Wang, Y., Reddy, K. R., Wright, A. L., Wang, Y., & Loss, K. R. R. (2008). *Communications in Soil Science and Plant Analysis Loss - on - Ignition Method to Assess Soil Organic Carbon in Calcareous Everglades Wetlands Loss-on-Ignition Method to Assess Soil Organic. 3624*.
<https://doi.org/10.1080/00103620802432931>
- Zhang, M., Liu, S., Luo, X., Keenan, T. F., Fu, L., & Xiao, C. (2025). Incorporating site suitability and carbon sequestration of tree species into China ' s climate-adaptive forestation. *Science Bulletin*, 70(11), 1834–1845.
<https://doi.org/10.1016/j.scib.2025.03.035>
- Zhang, X., & Ni-meister, W. (2014). *Remote Sensing of Forest Biomass*.
<https://doi.org/10.1007/978-3-642-25047-7>