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ORIGINAL ARTICLE

Spatial analysis and change detection of carbon sequestration mapping using different satellite image processing

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ABSTRACT
Carbon emissions are an inevitable issue and are of growing importance for society as a result of modernization and urbanization. Soils, oceans, forests, and the atmosphere are all sources of carbon storage. They act as sources or sinks at different times and emit more carbon than they absorb. Carbon sinks remove carbon dioxide (CO_2) from the environment through a process known as carbon sequestration. On a larger scale, trees are more effective at storing carbon than crops are, while crops serve a purpose on a smaller scale. Carbon is stored in the tissues of green plants using atmospheric carbon dioxide (CO_2) produced during photosynthesis. Satellite data can be used to calculate ground biomass, seasonal productivity, and carbon sequestration. The carbon cycle and vegetation can both be monitored using global remote sensing technologies. This study includes open and closed shrubs, agricultural land, large-scale healthy vegetation patterns, and biomass. It pays a way to quickly access the value of biomass and carbon sequestration. In giving major significance to carbon sequestration, it is essential to take crops into account when simulating a region's carbon balance because they can function as modest carbon sinks.
Keywords: *Carbon sequestration, geospatial imaging, MODIS dataset, net primary productivity, remote sensing*

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INTRODUCTION

Global warming, which is the most dreaded problem on the planet, is partly brought on by carbon emissions from numerous sources. The atmosphere currently includes a lot of greenhouse gases as a result of human activities including urbanization, deforestation, and the burning of fossil fuels over the last century [1]. One of the most frequent greenhouse gas emissions, CO_2, which also contributes to climate change, sea levels rising, draughts, and deforestation, is what causes global warming [2]. The Atmosphere, seas, soils, and forests are all sources of carbon [3]. Biomass is measured in situ after being estimated for each plant type. The value of vegetation for sequestering carbon over a larger region in terms of biomass can be promptly and effectively evaluated using remotely sensed satellite data [4]. To global warming, the phenomenon of carbon sequestration includes storing CO_2 or other kinds of carbon. With the help of chemical, biological, or physical methods, CO_2 is eliminated from the atmosphere [5]. CO_2 is one type of greenhouse gas. Burning fossil fuels and other anthropogenic factors can be reduced by carbon sequestration, which prevents the atmospheric accumulation of greenhouse gases. A carbon sink is a reservoir that collects and holds chemical substances containing carbon. To remove CO_2 from the atmosphere, carbon sinks absorb it. Algae bloom, soil surface Forests areas and oceans are examples of natural sinks [6]. It is important to measure carbon sequestration using a precise, accurate, and cost-effective method. So, we can employ established methods like remote sensing and Information Systems to provide a more effective remedy in this circumstance [7]. Although the study of earth's surface predictive or diagnostic characteristics have usually received relatively little attention, satellite data has been used to develop methods for measuring biomass production as well as carbon content [8]. Several metric tons of CO_2 are held in biological materials all over the earth. Natural processes convert this organic material into fuel sources like peat, gasoline, coal, diesel, and wood. The CO_2 that has been collected is emitted into the atmosphere when fuel is burned [9]. CO_2 is once again stored, but less quickly than at the moment. Sinks take in the gas that is emitted and holds it for a longer time. The lithosphere, hydrosphere, atmosphere, and biosphere all contain carbon [8]. There are many conventional methods for calculating carbon storage. Several of these methods are expensive, difficult to operate, and have limited coverage. It is challenging to precisely estimate and monitor carbon because of these limitations. Remote sensing can be utilized to get around these measurement and monitoring restrictions [10]. Establishing permanent sample plots is one criterion for carbon sequestration that can be met with the use of remote sensing. An important source of data about plant biomass is the reflection of near-infrared (NIR), red and green wavelengths [11].

The main objective of this work is to estimate carbon sequestration using remote sensing product data from Gandhinagar district (Gujarat). Gandhinagar district is located on the west bank of the Sabarmati River in north-central-east Gujarat and serves as the state capital. During the summer, the river is mostly dry. The city covers a total area of 20,543 *km²*. The Gandhinagar district spans the latitudes of 23.2156°N and 72.6369°E. It stands at an average elevation of 81 *meters*. On land, Gandhinagar has a 54 percent green cover. The annual rainfall is around 803.4 *mm*[12], [13].

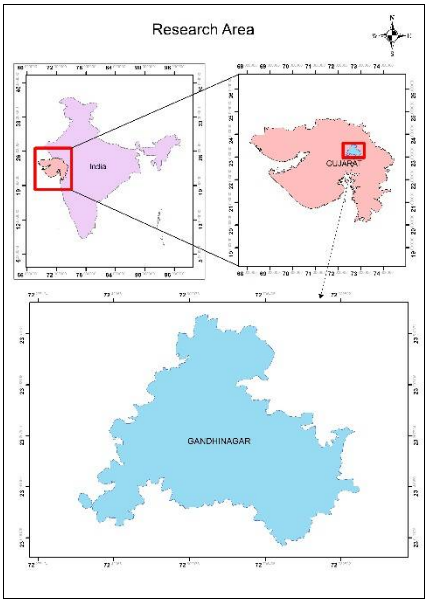

FIGURE 1 Study area located for the mapping of carbon sequestration. (*Source:* Figure 1 generated by the researcher).

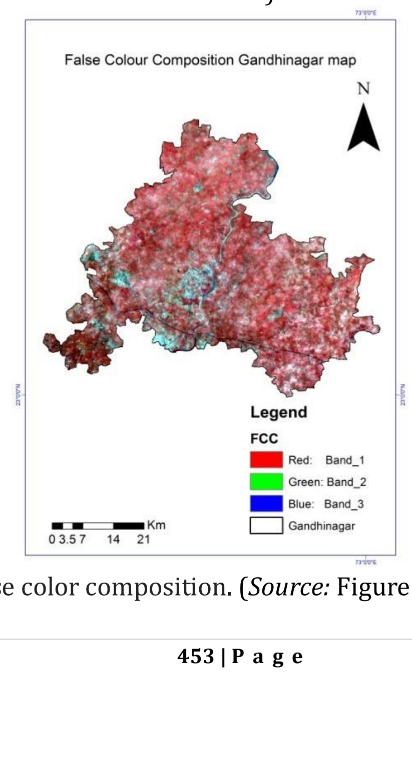

FIGURE 2 Satellite date for false color composition. (*Source:* Figure 2 generated by the researcher).

MATERIAL AND METHODS

Material

Moderate Resolution Imaging Spectroradiometers (MDOIS) are chosen for the investigation of its 500-*metre* spatial resolution. The MODIS sensor, which is installed on NASA's Terra satellite, has 36 wavelength channels and covers the visible electromagnetic spectra to thermal infrared spectra [14]. The very first seven 7 bands are primarily intended for remote sensing of terrestrial surfaces and include spatial resolutions of 250 *m* for Red (band 1), Near-infrared (band 2), and 500 *m* for bands 3 to 7. Bands 1 to 7 of MODIS were used to construct maps of the research areas [15]. For the years running 2021 and 2022, NASA provided the study area with MODIS data time series for the entire Gujarat region for January, June, and October. The software used to analyze the satellite imagery and geo-data was QGIS 3. Topographic maps at a resolution of 1:250000 were used in this inquiry [16], [17].

Methodology

According to the research methodology, the equation may accurately represent the increase in plant biomass's total primary output (NPP) [18]:

$$LUE.APAR = NPP$$

Where,

LUE=Light Use Efficiency factor

APAR=Absorbed Photo-synthetically Active Radiation

NPP=Net

Primary Production

The NDVI (normalized difference vegetation index), which utilizes the wavelength in the infrared (NIR) and red (RED) can be used to extract APAR and PAR from MODIS satellite data [19]–[21].

NIR – RED / NIR + RED = NDVI

(Near infrared – Red / near infrared + Red = Normalized Difference Vegetation Index)

NDVI ~ APAR / PAR

(Normalized Difference Vegetation Index ~ Absorbed Photosynthetically Active Radiation / Photosynthetically Active Radiation)

The rate of biomass production per time step, as given in the equation, is the measure of productivity

Normalized Difference Vegetation Index * Photosynthetically Active Radiation * Light Use Efficiency = Net Primary Productivity

(NDVI * PAR * LUE = NPP)

The vegetation acreage extraction process uses images from the MODIS Terra satellite with a 250-*metre* resolution. Six photographs are used in the method. Techniques for digital image processing are used on the satellite data. Using digital image processing software, satellite data is improved [22].

The winter season is depicted in the image for January, the summer season is depicted in June, and the monsoon season is depicted in October.

A mathematical formula for extracting the vegetation area and another parameter for NPP

Number of clusters' pixels * the image's resolution Square = Area (m^2)

Meter Area convert into a Hectare area

Area (m^2) / 10000 = Area (*ha*)

Since the MODIS satellite 250 *m* sensor was used to produce this image, the area (m^2) is equal to the value of the cluster of pixels multiplied by 250.

The algorithms used are mathematically represented. Theoretical computational methods for determining biomass using satellite data include the following:

$$NDVI*\mathrm{PAR}*LUE = \mathrm{Biomass}$$

For integrating simple leaf models of light absorption, stomata activity, light scattering, and photosynthesis, the FPAR Estimation approach is used. Using a strong mechanical foundation provided by the FPAR-Simple Ratio (SR) Vegetation Index correlation analysis, the correlations between FPAR and SR were determined for each kind of land cover. [18]:

$$FPAR_{SR} = \frac{(SR - SRmin)(FPAR\ max - FPARmin)}{SRmax - SRmin} + FPARmin$$

Where SRmin and SRmax are the SR values associated with 98% and 2% of the frequency analysis of the vegetation indices, respectively, and surface Reflection = (1 + NDVI)/ (1 – NDVI), we have FPARmax = 0.95 and FPARmin = 0.001. The SR-FPAR model refers to this equation.

The NDVI-FPAR model, a substitute model, is provided by the formula below.

$$FPAR_{NDVI} = \frac{(NDVI - NDVImin)(FPAR\,max - FPARmin)}{NDVImax - NDVImin} + FPARmin$$

NDVImax and NDVImin stand for the NDVI important information that accounts for 98% and 2%, respectively, of the NDVI summary data. The equation is known as the NDVI-FPAR model. An intermediate model that calculates the average FPAR from the SR-FPAR and NDVI-FPAR algorithms is shown below :[18].

$$FPAR = \frac{(FPAR(SR) - FPAR(NDVI)}{2}$$

The comparison between the estimated FPAR generated by the models and the ground-measured FPAR was done as previously mentioned. This study used this intermediary model to estimate the FPAR for 2021 and 2022. From 2021 to 2022, MODIS Vegetation indices were used to determine the 98% and 2% NDVI and related SR values for several vegetation types.

$$\varepsilon = \varepsilon^{\circ} * T1 * T2 * W \; (g/MJ)$$

Where $\varepsilon^{\circ} = 2.5$ *g/MJ* and

T1 and T2 link plant development to temperature adaption[22].

RESULTS

The Gandhinagar district is studied as the research area. The reported outcomes were displayed in Figures 4.3 and 4.4 as well as Table 4.1. In the current study, we computed the carbon sequestration rate and compared it to the study period of the years 2021 and 2022 using remote sensing and GIS. The estimated biomass of the vegetation for the winter, summer, and monsoon seasons of 2021 is 190177 *kg/ha*, 104360 *kg/ha*, and 127403 *kg/ha*, respectively. We estimated the district's vegetation biomass for the year 2022 to be 96160 *kg/ha* in the winter, 47491 *kg/ha* in the summer, and 89923 *kg/ha* during the monsoon season. The monsoon season is shown to have a higher projected value of carbon sequestration.

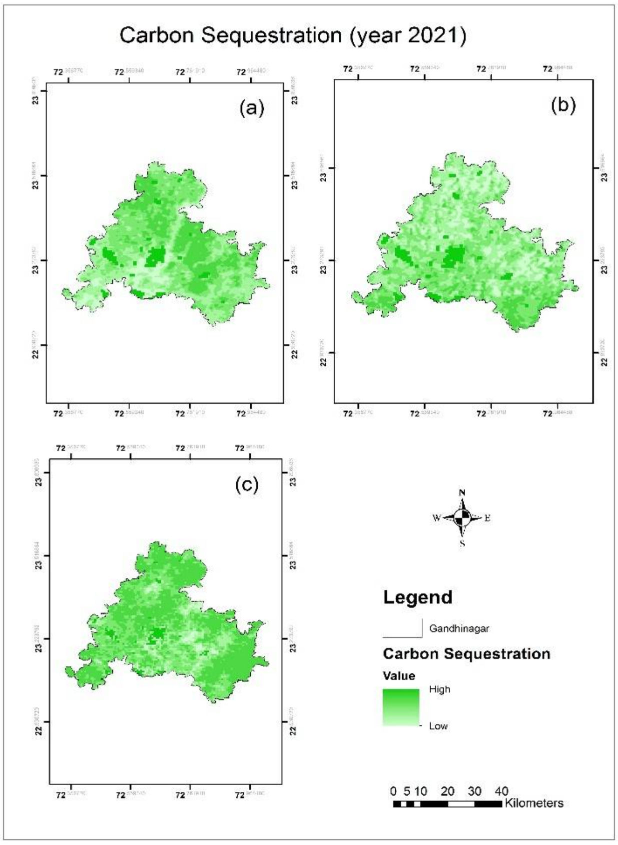

FIGURE 3 Changes in the amount of carbon within the premises of the research area for the time (a) January 2021 (b) June 2021 (c) October 2021. (*Source:* Figure 3 generated by the researcher).

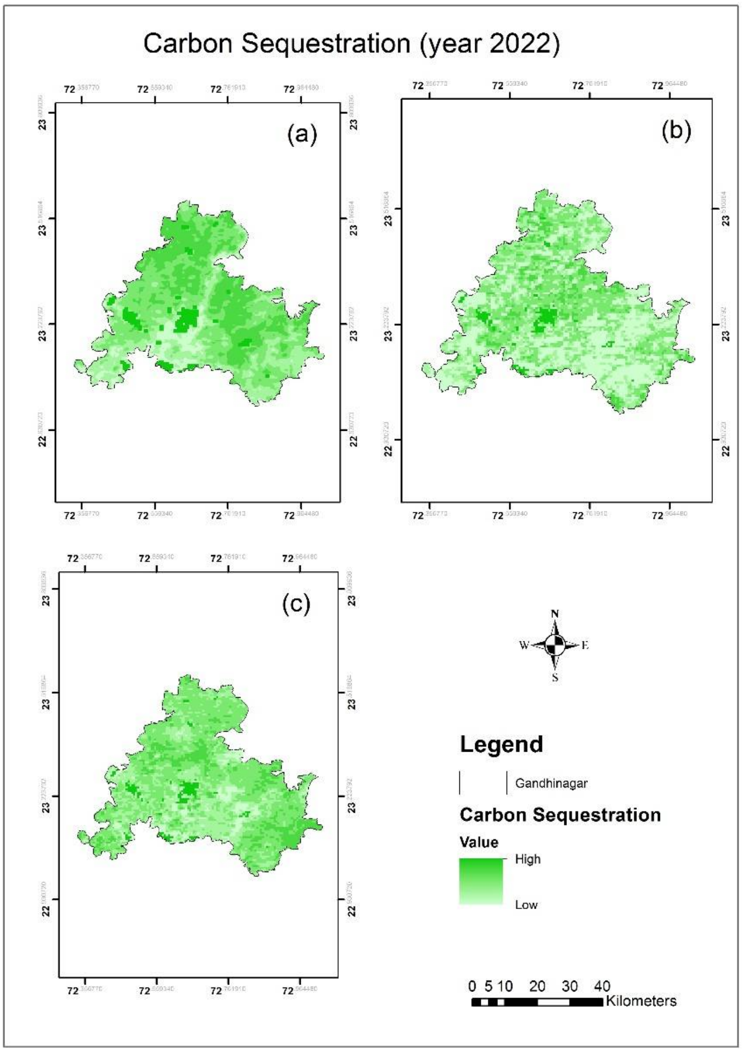

FIGURE 4 Changes in the amount of carbon within the premises of the research area for the time (a) January 2022 (b) June 2022 (c) October 2022. (*Source:* Figure 4 generated by the researcher).

TABLE 1: **Carbon sequestration data concerning time and study area*.**

Month	*kg/ha*	*tonne/ha*
Jan-21	190177	190.177
Jun-21	104360	104.36
Oct-21	127403	127.403
Jan-22	96160	96.16
Jun-22	47491	47.491
Oct-22	89923	89.923

* (*Source:* Aforementioned tabulation details generated by the researcher).

CONCLUSION

The current study imparts the assessment of remotely sensed data-based carbon quantification. We have analyzed results throughout the study of the research area with a one-time investment and built-in map-making capabilities. Even though it is clear that the research areas sequester a significant amount of carbon, the total amount of carbon sequestered in the study region was found to be 40969625 *t/ha*. There is a great deal of room for additional research on this topic. The environmental quality is enhanced and greenhouse gas emissions are decreased by agricultural carbon sequestration. So, the concept of carbon trading also has enormous financial potential.

The Indian economy is built on a foundation of agriculture [23]. A lot of agricultural land is available, but little is known about how effective it is as a carbon sink during the growing season. When all the elements

and traits are taken into account, it becomes abundantly evident that the current study on carbon sequestration has significant scientific value.
India in particular needs to become aware that there are other carbon sinks than the conventional ideas of forests and the ocean as a sink [18], [24]. We urgently need to expand carbon sinks as a substitute for forests to lessen the effects of global warming because the area covered by forests is rapidly disappearing.

AUTHOR CONTRIBUTIONS
All authors contributed to the study's conception and design. Material preparation, data collection, and analysis were performed by Prashantkumar B. Sathvara, J. Anuradha, Sandeep Tripathi, and R. Sanjeevi. The first draft of the manuscript was written by J. Anuradha and R. Sanjeevi and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

DECLARATION OF COMPETING INTEREST
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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REFERENCES
1. R. A. Houghton, (1996).“Converting Terrestrial Ecosystems from Sources to Sinks of Carbon,” *Ambio*, vol. 25, no. 4, pp. 267–272.
2. D. Arias, J. Calvo-Alvarado, D. de B. Richter, and A. Dohrenbusch, (2011). “Productivity, aboveground biomass, nutrient uptake and carbon content in fast-growing tree plantations of native and introduced species in the Southern Region of Costa Rica,” *Biomass and Bioenergy*, vol. 35, no. 5, pp. 1779–1788. doi: 10.1016/ j.biombioe.2011.01.009.
3. K. G. MacDicken, (1997) “A Guide to Monitoring Carbon Storage in Forestry and Agroforestry Projects,” p. 91.
4. A. Arya, S. Shalini Negi, J. C. Kathota, A. N. Patel, M. H. Kalubarme, and J. K. Garg, “Carbon Sequestration Analysis of dominant tree species using Geo-informatics Technology in Gujarat State (INDIA),” *International Journal of Environment and Geoinformatics*, vol. 4, no. 2, pp. 79–93, May 2017, doi: 10.30897/ijegeo.312517.
5. J. A. Anaya, E. Chuvieco, and A. Palacios-Orueta, “(2009). Above ground biomass assessment in Colombia: A remote sensing approach,” *Forest Ecology and Management*, vol. 257, no. 4, pp. 1237–1246. doi: 10.1016/ j.foreco. 2008.11.016.
6. P. J. Sellers *et al.*, (1995). “Remote sensing of the land surface for studies of global change: Models — algorithms — experiments,” *Remote Sensing of Environment*, vol. 51, no. 1, pp. 3–26. doi: 10.1016/0034-4257(94) 00061-Q.
7. S. Deng, Y. Shi, Y. Jin, and L. Wang, “A GIS-based approach for quantifying and mapping carbon sink and stock values of forest ecosystem: A case study,” *Energy Procedia*, vol. 5, pp. 1535–1545, 2011, doi: 10.1016/j.egypro.2011.03.263.
8. G. Bindu, P. Rajan, E. S. Jishnu, and K. Ajith Joseph, “Carbon stock assessment of mangroves using remote sensing and geographic information system,” *The Egyptian Journal of Remote Sensing and Space Science*, vol. 23, no. 1, pp. 1–9, Apr. 2020, doi: 10.1016/j.ejrs.2018.04.006.
9. S. N. Goward and K. E. Huemmrich, “Vegetation Canopy PAR Absorptance and the Normalized Dit erence Vegetation Index: An Assessment Using the SAIL Model,” p. 22, 1992.
10. D. K. Pareta and U. Pareta, (2011). “Forest Carbon Management Using Satellite Remote Sensing Techniques A Case Study Of Sagar District (M. P.),” *International Scientific Research Journal*, no. 4, p. 14, 20-22.
11. L. A. Frazão, J. C. Silva, and A. M. Silva-Olaya, “Introductory Chapter: CO_2 Sequestration,” in *CO2 Sequestration*, L. Almeida Frazão, A. Marcela Silva-Olaya, and J. Cota Silva, Eds., UNITED KINGDOM: IntechOpen, 2020. doi: 10.5772/intechopen.91747.
12. “Gandhinagar,” *Wikipedia*. Nov. 24, 2022. Accessed: Nov. 30, 2022. [Online]. Available: https://en.wikipedia.org/w/index.php?title=Gandhinagar&oldid=1123604897
13. “Gandhinagar - Wikipedia.” https://en.wikipedia.org/wiki/Gandhinagar (accessed Oct. 05, 2021).
14. P. Olofsson, L. Eklundh, F. Lagergren, P. Jönsson, and A. Lindroth, (2007).“Estimating net primary production for Scandinavian forests using data from Terra/MODIS,” *Advances in Space Research*, vol. 39, no. 1, pp. 125–130, doi: 10.1016/j.asr.2006.02.031.
15. M. Zhao, S. Running, F. A. Heinsch, and R. Nemani, (2010). “MODIS-Derived Terrestrial Primary Production,” in *Land Remote Sensing and Global Environmental Change*, B. Ramachandran, C. O. Justice, and M. J. Abrams, Eds., in Remote Sensing and Digital Image Processing, vol. 11. New York, NY: Springer New York, pp. 635–660. doi: 10.1007/978-1-4419-6749-7_28.

16. Q. K. Hassan, (2007). "Spatial mapping of growing degree days: an application of MODIS-based surface temperatures and enhanced vegetation index," *J. Appl. Remote Sens*, vol. 1, no. 1, p. 013511, doi: 10.1117/1.2740040.
17. J. Liu *et al.*, (2020). "Crop Yield Estimation in the Canadian Prairies Using Terra/MODIS-Derived Crop Metrics," *IEEE J. Sel. Top. Appl. Earth Observations Remote Sensing*, vol. 13, pp. 2685–2697. doi: 10.1109/JSTARS. 2020.2984158.
18. Q. Zhu *et al.*, (2017). "Remotely Sensed Estimation of Net Primary Productivity (NPP) and Its Spatial and Temporal Variations in the Greater Khingan Mountain Region, China," *Sustainability*, vol. 9, no. 7, p. 1213. doi: 10.3390/su9071213.
19. G. Asrar, M. Fuchs, E. T. Kanemasu, and J. L. Hatfield, (1984). "Estimating Absorbed Photosynthetic Radiation and Leaf Area Index from Spectral Reflectance in Wheat [1]," *Agronomy Journal*, vol. 76, no. 2, pp. 300–306. doi: 10.2134/agronj1984.00021962007600020029x.
20. R. Sanjeevi, Ankitkumar B. Rathod, Prashantkumar B. Sathvara, Aviral Tripathi, J. Anuradha, and Sandeep Tripathi, (2022)."Vegetational Cartography Analysis Utilizing Multi-Temporal Ndvi Data Series: A Case Study From Rajkot District (Gujarat), India," *Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/ Journal of Tianjin University Science and Technology*, vol. 55, no. 04:2022, pp. 490–497. doi: 10.17605/OSF.IO/UGJYM.
21. Ankitkumar B. Rathod, J. Anuradha, Prashantkumar B. Sathvara, Sandeep Tripathi, and R. Sanjeevi, (2023)."Vegetational Change Detection Using Machine Learning In Gis Technique: A Case Study From Jamnagar (Gujarat)," *journal of data acquisition and processing*, vol. 38, no. 1, p. 1046. doi: 10.5281/zenodo.7700655.
22. C. B. Field, J. T. Randerson, and C. M. Malmström, (1995). "Global net primary production: Combining ecology and remote sensing," *Remote Sensing of Environment*, vol. 51, no. 1, pp. 74–88.doi: 10.1016/0034-4257(94)00066-V.
23. L. Supriya Devi and P. S. Yadava, (2009). "Above ground biomass and net primary production of semi-evergreen tropical forest of Manipur, north-eastern India," *Journal of Forestry Research*, vol. 20, no. 2, pp. 151–155. doi: 10.1007/s11676-009-0026-y.
24. R. Sanjeevi, M. Haruna, S. Tripathi, B. Singh, and A. Jayaraman, (2017). "Impacts of Global Carbon Foot Print on the Marine Environment," *International Journal of Engineering Research and Technology*, vol. 5, pp. 51–54.