Problem Statement:

Studying the effects of deforestation and afforestation on carbon sequestration

Summary

To determine the effects of deforestation and afforestation on carbon sequestration, I used Net Primary Productivity (NPP) as a measure of carbon sequestration. NPP can be defined as the amount of carbon dioxide plants takes in during photosynthesis and accounts for carbon dioxide released by plants during respiration. I prepared NPP data products to compare results across two time periods and sites. A brief analysis revealed that mean NPP for Radhanagri WLS decreased from 162.04 g C m−2 per month in 2017 to 150.12 g C m−2 per month in 2022. A small decline in NPP values in Kali WLS was observed from 178. 24 g C m−2 per month in 2017 to 176.13 g C m−2 per month in 2022. A thorough analysis would be necessary to determine the significance of these values.

Study Site

The two study sites for which I produced NPP maps were Radhanagri Wildlife Sanctuary (WLS) (351 km^2), Maharashtra, India, and Kali WLS (1345.58 km^2), Karnataka, India. I prepared maps for years 2017 and 2022 to study temporal and spatial changes across these sites. These study sites are in the Western Ghats and contain tropical evergreen forests and moist deciduous forests. They sites face several anthropogenic threats such as mining, overgrazing, and habitat loss amongst others.

Methodology

Data

I acquired imagery from Landsat 8 OLI/TIRS from USGS Earth explorer. Table 1 provides more details about the imagery. Given the geography of the study sites, I carried out analysis for the post-monsoon season when trees re-grow foliage after shedding during a harsh summer.

Table 1. Details of imagery used in analysis

Site	Date of acquisition	Path, Row
Kali WLS, 2017	16 November 2017	146,50
Kali WLS, 2022	30 November 2022	146,50
Radhanagri WLS, 2017	23 November 2017	147,49
Radhanagri WLS, 2022	28 October 2022	147, 49

Analysis

I used the CASA model to calculate NPP, which incorporates "incorporates meteorology, environment, and soil factors to simulate the physiological process of vegetation absorbing photosynthetically available radiation and transforming it into organic carbon" (Chengyong Wu et al. 2022). The model can be described using the following formula

$NPP = 0.5 * SOL * FPAR * T_{\varepsilon 1} * T_{\varepsilon 2} * WSC * \varepsilon_{max}$

Table 2 provides a detailed description of the methods used to calculate the parameters. Bands 4,5,6, and 7 were used to calculate input parameters required to determine NPP.

Table 2. Calculation for input data for CASA model

Parameter	Method of Estimation
0.5	Constant – proportion of radiation that can be absorbed by plants
SOL	Total Solar Radiation – Average value for India used for analysis SOL = 578.1 (MJ m^{-2} per month)
FPAR	Fraction of absorbed photosynthetically active radiation FPAR = $\frac{(NDVI-NDVImin)\times(FPARmax-FPARmin)}{NDVImax-NDVImin}+FPARmin$ NDVI was calculated using red or band 4 (R) and near infrared or band 5 (NIR) bands of the imagery NDVI = $\frac{NIR-R}{NIR+R}$ $FPAR_{max}$ is a constant with a value of 0.95 $FPAR_{min}$ is a constant with a value of 0.001
$T_{\varepsilon 1}$	Temperature stress factor calculated using the formula $T_{\varepsilon 1} = 0.8 + 0.02 * Topt - 0.0005 Topt^2$ T_{opt} was set to 26.34 (Annual average temperature (in °Celsius) for region close to both study sites)
$T_{\varepsilon 2}$	Temperature stress factor calculated using the formula $T_{\varepsilon 2} = \frac{1.1814}{1+e^{0.2*(Topt-10-T)}} \times \frac{1}{1+e^{0.3*(-Topt-10+T)}}$ T_{opt} was set to 26.34 (Annual average temperature (in °Celsius) for region close to both study sites) T was set to 27 (monthly average temperature (in °Celsius) for November for region close to both study sites)
WSC	Water Stress Coefficient WSC = $0.5 + 0.5 * (1 - Nsimi)$ N_{SIMI} – normalized shortwave infrared soil moisture index $N_{SIMI} = \frac{SIMI-SIMImin}{SIMImax-SIMImin}$ SIMI – Shortwave infrared soil moisture index SIMI was calculated using shortwave infrared (SWIR)1 or band 6 and SWIR 2 or band 7 SIMI = $0.7071\sqrt{SWIR_1^2 + SWIR_2^2}$
ε_{max}	Maximum radiation conversion efficiency (gCMJ^{-1}) ε_{max} = 1.044 (Running et al. 2000)

Limitations

In this analysis, I used constants for SOL, $T_{\varepsilon 1}$, $T_{\varepsilon 2}$. However, these values vary geographically, and it would be appropriate to use pixel specific values to improve the overall model output. Given the paucity of time, an in-depth analysis of the prepared NPP products could not be carried out. However, other analyses such as those that carry out a multi-temporal analysis could provide more details about the trend of NPP in these study sites. In addition, studying the impact of climate warming and human activities on Net Primary Productivity (NPP) can provide valuable insights for comprehending carbon sequestration in the upcoming years.

References

Wu, C., Chen, K., You, X., He, D., Hu, L., Liu, B., Wang, R., Shi, Y., Li, C. and Liu, F., 2022. Improved CASA model based on satellite remote sensing data: Simulating net primary productivity of Qinghai Lake Basin alpine grassland. *Geoscientific Model Development*, *15*(17), pp.6919-6933.

Running, S.W., Thornton, P.E., Nemani, R. and Glassy, J.M., 2000. Global terrestrial gross and net primary productivity from the earth observing system. *Methods in ecosystem science*, pp.44-57.