Estimating Forest Cover and Carbon Stock Loss in Ethiopia (2000-2020) Using Geospatial Analysis and Remote Sensing Data

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Abstract: The loss of forest cover and the associated carbon stock depletion have become critical environmental concerns globally. In Ethiopia, a country known for its rich biodiversity and significant forest resources, understanding the extent of forest loss and carbon emissions is crucial for effective conservation and sustainable land management. This study aims to estimate forest cover and carbon stock loss in Ethiopia between 2000 and 2020 using a combination of data sources and methods. **Material and Methods:** In this study, we utilized multiple data sources and implemented various analysis techniques to estimate forest cover loss and carbon emissions in Ethiopia between 2000 and 2020. To begin, we acquired the treecover2000 dataset, which provided information on tree canopy cover percentages for the year 2000 (GLAD, 2013). Additionally, we obtained the lossyear layer, which indicated the annual forest losses from 2001 to 2020, and the forestGHG layer, which provided estimates of greenhouse gas emissions resulting from forest disturbances (Hansen et al., 2013; Harris et al., 2021). To calculate the annual forest losses, we subtracted the lossyear values from the treecover2000 dataset, effectively determining the changes in forest cover over time. Concurrently, the forestGHG layer was overlaid with the lossyear layer to estimate the corresponding carbon emissions associated with the forest losses. Furthermore, we conducted a ranking analysis of the provinces based on total annual forest loss and total annual forest emissions. This allowed us to identify the regions experiencing the most significant deforestation and carbon emissions within Ethiopia. Additionally, we examined the proportional annual forest loss to assess the relative impact of deforestation across different provinces. To evaluate the temporal trends in forest loss and carbon emissions, we performed a Pearson correlation analysis. This analysis helped us determine the statistical significance of the linear trends observed during the 2000-2020 timeframe (Austin et al., 2017; Hansen et al., 2013; Pereira et al., 2018; Zarin et al., 2016). To ensure data compatibility and facilitate the analysis, we carried out pre-processing steps using GDAL and QGIS software. These steps included data formatting and geospatial operations to prepare the input layers for analysis. The main analysis was conducted using the Google Earth Engine platform, which provided efficient computational capabilities and enabled us to visualize the results effectively. **Results:** The analysis reveals an overall increasing trend in deforestation over the study period. Several years stand out as having particularly high levels of forest cover loss, indicating critical periods of degradation for Ethiopia's forests. Among the highest years of forest cover loss, 2014 stands out with a significant loss of 565,149,992.52 square meters. This indicates a substantial decline in forested areas during that year, highlighting the urgency of addressing deforestation and implementing conservation measures. Another notable year is 2017, which recorded a forest cover loss of 554,944,697.42 square meters. This high level of deforestation emphasizes the need for immediate action to halt the loss of valuable forest ecosystems and protect the biodiversity and ecological services they provide. Oromia Region emerges as the most affected region, exhibiting substantial forest cover and carbon stock loss over the study period. The extensive agricultural expansion, population growth, and infrastructure development in Oromia have contributed to significant deforestation. Large-scale land conversions for agriculture, including commercial farming and subsistence cultivation, have led to the clearing of vast forest areas. Consequently, the carbon stored in the vegetation and soil

within these forests has been released into the atmosphere as greenhouse gas emissions. The Southern Nations Nationalities and Peoples Region follows closely behind Oromia in terms of forest cover and carbon stock loss. This region also experiences high levels of deforestation due to agricultural expansion, particularly for cash crops such as coffee and tea. Additionally, the Southern Nations Nationalities and Peoples Region is characterized by significant forest-based economic activities, including logging and fuelwood collection, which contribute to further forest degradation and carbon emissions. Benishangul Gumuz Region ranks as the third most affected region in terms of deforestation and carbon emissions. This region is known for its extensive forest resources, including the dense forests along the Sudanese border. However, large-scale infrastructure projects, such as the construction of dams and roads, have led to significant forest clearance and degradation in Benishangul Gumuz. The establishment of agricultural plantations, particularly for cash crops like oil palm, has also contributed to the loss of forest cover and associated carbon emissions in this region. **Discussion:** These three regions - Oromia, Southern Nations Nationalities and Peoples, and Benishangul Gumuz - face complex challenges related to forest conservation and sustainable land management. The high population density, expanding agricultural activities, and economic development pressures exert significant pressure on the remaining forest areas. It is crucial for policymakers, local communities, and conservation organizations to prioritize efforts to mitigate deforestation, promote sustainable farming practices, and implement effective land-use planning strategies in these regions. Addressing the drivers of deforestation, such as agricultural expansion and infrastructure development, is essential for preserving the remaining forest ecosystems and their associated carbon stocks. Promoting alternative livelihood options, such as agroforestry and sustainable land management practices, can help alleviate the pressure on forests while providing economic opportunities for local communities. Furthermore, strengthening law enforcement and monitoring systems is crucial to curb illegal logging and unsustainable resource extraction in these regions. Community-based forest management initiatives, involving local communities in decision-making processes and benefiting from forest resources sustainably, can also contribute to forest conservation and carbon stock preservation. **Conclusion:** The findings emphasize the urgent need to address the drivers of deforestation in these regions and develop targeted conservation strategies. Understanding the specific dynamics and factors contributing to deforestation is crucial for implementing effective sustainable land management practices and mitigating further forest degradation and associated carbon emissions. In light of these results, it is recommended to shift away from traditional charcoal-based energy sources towards electric cooking and other sustainable alternatives. Promoting the adoption of clean energy solutions can help reduce the reliance on forest resources for cooking purposes, thereby contributing to forest conservation efforts. Furthermore, the implementation of sustainable land management practices, such as agroforestry and reforestation initiatives, can help restore and protect the remaining forest ecosystems. Engaging local communities, policymakers, and conservation organizations in collaborative efforts is vital for achieving successful conservation outcomes and preserving Ethiopia's valuable forests.

Keywords: forest cover, carbon stock loss, Ethiopia, deforestation, land degradation, greenhouse gas emissions, Oromia, Southern Nations Nationalities, Benishangul Gumuz, drivers, sustainable land management, conservation strategies, biodiversity preservation.