EARTH OBSERVATION FOR SDG TARGETS AND INDICATORS, LOT-1

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SUSTAINABLE FOREST MANAGEMENT

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1 Scope

This document compiles the materials submitted to the Discover Data journal by Springer Nature.

2 Data Note

Enhancing Forest Monitoring and Reporting with Earth Observation Data for SDG 15 Targets

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Abstract

Objectives:

Forests are vital for biodiversity and ecosystem services, yet deforestation and degradation continue at alarming rates, threatening sustainable forest management (SFM). Addressing SFM reporting gaps, especially in countries like Ethiopia and Vietnam, is essential for meeting global commitments such as the Paris Agreement and UN Sustainable Development Goals. This dataset collection enhances SFM reporting by identifying areas under unsustainable management or suitable for reforestation. Developed in collaboration with local partners, the datasets use high-quality geospatial and Earth Observation (EO) data to provide actionable insights for conservation and restoration.

Data description:

The datasets cover forest extent, gain, loss, condition, biomass, disturbances, landscape metrics, and risk assessments for soil erosion and landslides. The Forest Mask classifies forest and non-forest areas based on canopy cover, height, and land use, tracking changes like afforestation and deforestation. Forest Condition monitors vitality trends, while Above-Ground Biomass estimates biomass using NDVI data and regression models. Forest Disturbance detects true disturbances via change detection algorithms. Landscape Metrics assess forest structure and function for sustainable management. Erosion and Landslide Risk layers classify susceptibility based on terrain and environmental factors, aiding risk mitigation. All datasets are openly accessible for research and policy use.

Objective

Forests cover 31% of the global land area. While half of the global forest cover is relatively intact, more than one third is primary forest or naturally regenerated forest. Deforestation and forest degradation continue to take place at alarming rates, which contributes significantly to the ongoing loss of biodiversity [1]. The need for sustainable forest management (SFM) was recognized by the Paris Agreement (2015), embedded in the UN Agenda 2030 for Sustainable Development (2015) [2], and is addressed directly through the Sustainable Development Goal (SDG) 15 and its corresponding Targets 15.1.1 and 15.2.1 [3]. Therefore, countries must report on five different aspects of SFM: i) forest area annual net change rate; ii) above-ground biomass stock in forest; iii) proportion of forest area located within legally established protected areas; iv) proportion of forest area under a long-term forest management plan, and v) forest area under an independently verified forest management certification scheme [4]. The herein presented datasets and their corresponding methods aim to improve reporting on SFM for countries currently lacking resources like Ethiopia or Vietnam. We therefore developed several products making use of emerging high quality, geospatial and Earth Observation (EO) data to refine existing and develop new indicators which will close country specific gaps in terms of reporting capacities. These products include forest extent, forest gain and loss, forest condition, above ground biomass (AGB), forest landscape metrics, forest erosion and landslide risk. All developed products are freely available with their corresponding methods and were developed in close collaboration with local partners in Ethiopia and Vietnam. This close collaboration also ensured future usage of the developed products not only for reporting purposes but also e.g. for identifying forest areas under unsustainable management or areas suitable for forest regeneration reforestation.

Data description

The Forest Mask (Data file 1) classifies forest and non-forest areas based on a minimum forest size of 0.5 ha, height >5m, and >10% canopy cover, excluding predominantly agricultural and urban areas. Ethiopia's 2017 forest mask was created using calibrated Global Forest Change (GFC) data from the University of Maryland [5] and RapidEye data, with accuracy assessed via random points and optimal tree cover thresholds. The 2020 update integrates the 2017 mask forest gain and loss datasets (Data file 2).

The Forest Area Net Change (Data file 2) tracks positive (afforestation) and negative (deforestation) changes. Forest gain is identified using the global canopy height dataset [6], Sentinel-2 NDVI (Normalized Difference Vegetation Index) time series, and the 2020 global canopy height layer. Pixels with >5m tree height that were non-forest in 2017 represent gain. Forest loss is determined using negative NDVI trends.

The Forest Condition (Data file 3) evaluates forest vitality changes using Sentinel-2 time series, with a mean vitality benchmark to classify trends as increasing, decreasing, or stable.

AGB (Data file 4) estimates forest biomass (tons/ha) using a novel approach tailored to Ethiopia. Land cover classification by Friis et al. [7] was used to identify main forest biomes, with species-specific data on stand density and allometric equations derived from literature. Tree data (e.g., trunk diameter, height) from the Tallo database [8] informed regression models linking diameter at breast height (DBH) to tree height for biomass estimation. Biomass was estimated using the ETH Zurich's canopy height model (CHM) [6] and land cover classification, with regression models applied for allometry.

The Forest Disturbance (Data file 5) product detects forest changes using Sentinel-2 tiles, the 2015 Copernicus Global forest mask [9] and NDVI-based change detection. A pixel is classified as disturbed if a sustained disturbance is detected within a year. The dataset spans Vietnam from 2019 to mid-2024.

Forest Landscape Metrics (Dataset 1) quantify forest structure, function, and change using metrics such as area, shape, edge, core, isolation, and diversity. Computed via the "landscapemetrics" R package [10] and Copernicus Global forest mask [9], these metrics help understand and manage forest landscapes sustainably.

The Erosion Risk (Data files 6-8) product applies the RUSLE model to estimate mean annual soil loss (ton/ha/10000years) and classify it into five levels ("Very Low" to "Severe"). Inputs include Sentinel-2 imagery (Dec 2022–Jan 2024), rainfall erosivity (R factor) [11], soil erodibility (K factor) [12], topography (LS factor via Copernicus DEM) [13], and land cover (C factor via ESA WorldCover) [14]. Output resolution: 10m raster; minimum mapping unit: 0.5 ha (50 pixels).

The Landslide Risk (Data files 9-11) product uses LSI and AHP algorithms to reclassify susceptibility into five levels ("Very Low" to "Severe"). Variables include elevation, slope, aspect, hydrological network, land cover, and lithology. Inputs include lithology (global map) [15], topography (from Copernicus DEM), and land cover (ESA WorldCover). Output resolution: 30m raster; minimum mapping unit: 0.45 ha (5 pixels).

All erosion and landslide risk data files use UTM zone 48N and integrate Vietnam administrative data for averages [16].

Table 1. Overview of data files/data sets

Label	Name of data file/data set	File types (file extension)	Data repository and identifier (DOI or accession number)
Data file 1 [17]	NatDemo_Ethiopia_FM_ForestMask_2022_UTM37N (Forest Mask Ethiopia)	GeoTiff (.tif)	Zenodo (https://doi.org/10.5281/zenodo.14925376)
Data file 2 [18]	NatDemo_Ethiopia_FNC_ForestAreaNetChangeRate_2020_UTM37N (Forest Area Net Change Ethiopia)	GeoTiff (.tif)	Zenodo (https://doi.org/10.5281/zenodo.14925376)
Data file 3 [19]	NatDemo_Ethiopia_FCM_ForestConditionMonitoring_2022_UTM37N (Forest Condition Ethiopia)	GeoTiff (.tif)	Zenodo (https://doi.org/10.5281/zenodo.14925376)
Data file 4 [20]	NatDemo_Ethiopia_AGB_AboveGroundBiomass_2020_UTM37N (AGB Ethiopia)	GeoTiff (.tif)	Zenodo (https://doi.org/10.5281/zenodo.14925376)
Data file 5 [21]	NatDemo_Vietnam_FCM_ForestConditionMonitoring_Disturbance_WGS84 (Forest Disturbance Vietnam)	GeoTiff (.tif)	Zenodo (https://doi.org/10.5281/zenodo.14925376)
Data file 6 [22]	NatDemo_Vietnam_FER-ER_MeanSoilLoss_UTM48N (Soil erosion susceptibility calculated over Vietnam)	GeoTiff (.tif)	Zenodo (https://doi.org/10.5281/zenodo.14925376)
Data file 7 [23]	NatDemo_Vietnam_FER-ER_ErosionRisk_UTM48N (Soil erosion risk classification over Vietnam)	GeoTiff (.tif)	Zenodo (https://doi.org/10.5281/zenodo.14925376)
Data file 8 [24]	NatDemo_FER_ER_2022-24_Vietnam_WGS84 (Soil erosion susceptibility average calculated over Vietnam and the Vietnamese provinces and districts)	Shapefile Format (.cpg, .dbf, .prj, .sbn, .sbx, .shp, .shp.xml, .shx)	Zenodo (https://doi.org/10.5281/zenodo.14925376)

Data file 9 [25]	NatDemo_Vietnam_FER-LR-LandslideSusceptibility_UTM48N (Landslide susceptibility calculated over Vietnam)	GeoTiff (.tif)	Zenodo (https://doi.org/10.5281/zenodo.14925376)
Data file 10 [26]	NatDemo_Vietnam_FER-LR_LandslideRisk_UTM48N (Landslide risk classification over Vietnam)	GeoTiff (.tif)	Zenodo (https://doi.org/10.5281/zenodo.14925376)
Data file 11 [27]	NatDemo_FER_LR_2021_Vietnam_WGS84 (Landslide susceptibility average calculated over Vietnam and the Vietnamese provinces and districts)	Shapefile Format (.cpg, .dbf, .prj, .sbn, .sbx, .shp, .shp.xml, .shx)	Zenodo (https://doi.org/10.5281/zenodo.14925376)
Data set 1 [28]	NatDemo_Vietnam_FLM_ForestLandscapeMetrics_UTM48N (Forest Landscape metrics Vietnam)	GeoTiff (.tif)	Zenodo (https://doi.org/10.5281/zenodo.14925376)

Limitations

As typical for large scale remote sensing studies, it was not feasible to obtain ground truth data for the validation of these products. Additionally, satellite artifacts may introduce inaccuracies.

Forest Mask

The updated forest mask may contain small-scale commission errors due to inaccuracies in canopy height and NDVI reference datasets, influenced by cloud cover.

Forest Area Net Change

Uncertainties in forest gain stem from height inaccuracies in the global canopy height layer, leading to commission and omission errors. Cloud-influenced NDVI and NDVI trends may further affect classification accuracy.

Forest Condition

Cloud cover in certain areas limits the creation of cloud-free monthly composites, affecting accuracy.

AGB

Accuracy limitations of the AGB datasets mainly stem from inaccuracies of reference datasets like the canopy height dataset and the lack of in-situ data.

Forest Landscape Metrics

The forest mask from the Copernicus Land Service has an accuracy of no more than 80% on any continent, limiting the reliability of landscape metrics. Accurate results require an improved land cover classification baseline. The scale of landscapes, along with thematic content, resolution, spatial grain, and extent, significantly affects the interpretability of landscape metrics.

Forest Erosion Risk and Forest Landslide Risk

Visual inspection showed satisfactory thematic quality, with cross-comparison against ESDAC datasets [29], [30] enabling statistical evaluation for soil erosion. However, limitations include:

Local geometric/thematic inconsistencies in erosion risk due to heterogeneous Sentinel-2 imagery.

Visual artefacts from input layers, such as lithological class interfaces in landslide risk products.

Processing artefacts, especially in low-lying areas, tied to DEM accuracy.

Abbreviations

AGB – Above Ground Biomass

CHM – Canopy Height Model

DBH – Diameter at Breast Height

GFC – Global Forest Change

NDVI – Normalized Difference Vegetation Index

SDG – Sustainable Development Goal

SFM – Sustainable Forest Management

AHP: Analytical Hierarchical Process

DEM: Digital Elevation Model

EO: Earth observation

ESA: European Space Agency

ESDAC: European Soil Data Centre

LSI: Landslide Susceptibility Index

LULC: Land Use Land Cover

RUSLE: Revised Universal Soil Loss Equation

SDG: Sustainable Development Goals

UTM: Universal Transverse Mercator

Declarations

Acknowledgments

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Author contributions

Dzhaner Emin, Dr. Maximilian Schwarz, and Henri Giraud conceived the project and the main conceptual framework. Dr. Jose Cortez Resendiz, Lukas Aschenbrenner, Bastien Coriat, Oscar David Rafael Narvaez Luces, Rémi Braun, Thomas Ledauphin, Bartlomiej Roskoschny, and Andrés Andrade Velásquez handled the technical details and performed the analysis across all products. Andrés Andrade Velásquez led the manuscript preparation, with input and critical feedback from all authors.

Competing interests

The authors have no financial or proprietary interests in any material discussed in this article.

Data availability

The data described in this Data Note can be freely and openly accessed on Zenodo under https://doi.org/10.5281/zenodo.14925376. Please see table 1 and references [17-28] for details and links to the data.

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3 Cover Letter for submission to Journal

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February 24, 2025

Editor-in-Chief

Discover Data

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Dear Dr. Chawla,

I am pleased to submit our manuscript, titled "Enhancing Forest Monitoring and Reporting with Earth Observation Data for SDG 15 Targets", for consideration as a Data Note entry in Discover Data. Our study addresses the critical challenge of sustainable forest management (SFM) reporting by leveraging high-quality geospatial and Earth Observation (EO) data to improve monitoring and reporting capacities. Given the increasing urgency to meet global commitments such as the Paris Agreement and the United Nations Sustainable Development Goals (SDGs), our research offers innovative datasets that directly support the assessment and implementation of SDG 15 Targets.

In this work, we developed multiple geospatial datasets that enhance reporting capabilities for key forest indicators, including forest extent, forest gain and loss, biomass estimation, forest condition, disturbance detection, and risk assessments for soil erosion and landslides. Our findings provide an actionable framework for policymakers and conservationists, aiding in the identification of forest areas under unsustainable management and regions suitable for reforestation. These openly accessible datasets not only bridge critical data gaps but also foster collaboration with local stakeholders to ensure long-term utilization and impact.

The readership of Discover Data would greatly benefit from our work, as it aligns with the journal's focus on data science applications and open data methodologies. Our study contributes to the broader discourse on data acquisition, processing, and analysis for environmental sustainability by integrating various geospatial and EO datasets—such as Sentinel-2 imagery, canopy height models, and biogeographic data—while applying advanced methodologies like change detection algorithms, NDVI time-series analysis, and regression models for biomass estimation. These approaches enhance the quality and accuracy of forest-related datasets. Furthermore, our datasets help identify trends in deforestation, degradation, and potential areas for conservation or reforestation, supporting evidence-based decision-making. Given the journal's commitment to research that advances the United Nations Sustainable Development Goals, our study provides valuable insights and openly available datasets that contribute directly to achieving SDG 15 targets.

We confirm that this manuscript has not been published elsewhere and is not under consideration by another journal. All authors have approved the manuscript and agree with its submission to Discover Data. There are no related manuscripts currently under consideration in any other Springer Nature publication, and we have not had prior discussions with a Springer Nature editor regarding this work.

Thank you for considering our manuscript for publication. We look forward to your positive response and are happy to provide any further information if needed.

Sincerely,

Andrés Andrade Velásquez

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4 Confirmation of submission

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Title
Enhancing Forest Monitoring and Reporting with Earth Observation Data for SDG 15 Targets

Type
Data Note

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Submission ID
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