EO-based SDG Indicator Country Use Case

SDG Indicator/ Sub-indicator	**Target 15.3: End desertification and restore degraded land** **Indicator 15.3.1** - "Proportion of land that is degraded over the total land area."
Country or region	Colombia, Uganda, Portugal
Project Status *(mark with an x)*	_ being used in official SDG Indicator reporting **X** being verified or tested by country _ studying feasibility
Earth Observation Data Used *(include web links)*	- Sentinel-2 L2A
Additional/Other Data Used *(include web links)*	- Copernicus DEM input feature for LC classification - AgERA5 agrometeorological indicators used as input features for LC classification - ICOS Level 2 in-situ GPP for TIMESAT calibration - ESA CCI Biomass maps for AGB change calculations (e.g., 2010-2020).

Description of data access, processing, and analysis, including methodology that was developed, associated tools or applications, and how these are applied to compute SDG Indicator	The Good Practice Guidance for SDG indicator 15.3.1 involves three sub-indicators: (1) assessment of land cover and land cover changes; (2) analysis of land productivity and trends; and (3) Determination of carbon stocks values and changes. The **European Space Agency (ESA) Sentinels for Land Degradation Neutrality (SEN4LDN)** project aimed to develop and showcase a novel approach for improving both the spatial and temporal resolution of the data required for LD monitoring. (1) Trends in land cover between 2018 and 2023 are evaluated based on an automated algorithm to map land cover dynamics at 10 m resolution that combines deep learning and a pixel classifier on pre-processed Sentinel-2 imagery and ancillary input layers. Post-processing is performed to mitigate class fluctuations, resulting in consistent annual land cover maps. Land cover probabilities are used to generate land cover transition (probability) layers, that are further processed to discrete and continuous land cover degradation products. (2) To evaluate trends in land productivity, the seasonal accumulated production of green biomass is estimated from a Sentinel-2 derived vegetation index, which is an indicator for photosynthetic activity and overall ecosystem functionality. The performance of vegetation productivity is based on comparison of the local productivity to similar land units over a larger area. Discrete and continuous land productivity degradation maps are generated based on the combination of the former two. (3) The concept of carbon stocks in terms of LDN assessments is primarily related to the soil carbon pool and related changes. However, since soil organic carbon (SOC) stock change estimates from remote sensing are not readily available (yet), SEN4LDN explored the use of above-ground biomass (AGB) changes as a proxy for carbon stock changes to provide an estimate independent of the other two sub-indicators. Two research demonstration approaches were combined into a hybrid method to quantify trends in carbon stocks: a stock change approach based on ESA CCI biomass maps, and a gain-loss approach based on a carbon flux model. Sub-indicators (1) and (2) were validated. Land cover validation used national and global datasets with 70-90% accuracy. Land cover change was validated for Uganda collaborating with national experts while for Portugal and Colombia, a comparison with similar datasets was conducted (COSs and MapBiomass-Colombia respectively). Finally, the outputs of the trends in land cover and trends in land productivity sub-indicators are integrated to generate a product that allows to calculate the extent of land degradation for reporting on UN SDG indicator 15.3.1, expressed as the proportion (percentage) of land that is degraded over total land area. In SEN4LDN two methods were tested: (1) the so-called one-out-all-out in which a significant reduction or negative change in any one of the sub-indicators is considered to comprise land degradation, and (2) a continuous sub-indicator integration method that combines the continuous land cover degradation and land productivity degradation products into a continuous land degradation probability index. This allows for a more in-depth interpretation of the combined product, including an assessment of the magnitude or probability of degradation and improvement, and for an interpretation of possible contrasting sub-indicators.

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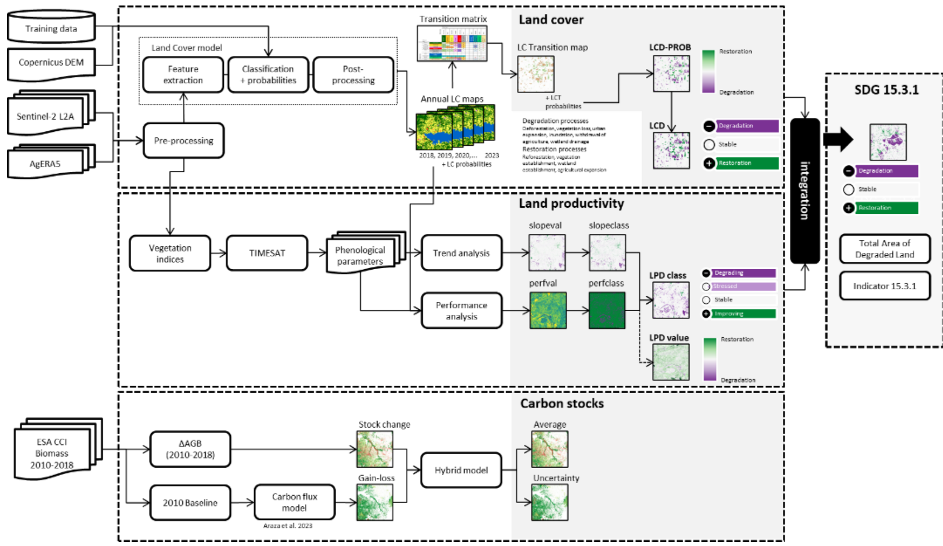
<td>Workflow</td>
<td>Please demonstrate the methodology workflow using a process flow diagram.

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<td>Lessons learned, any gaps, key issues and recommendations</td>
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- Artefacts over areas with persistent cloud cover, especially in high altitude lands and Tropical regions, both in LC mapping and evaluation of trends in productivity, are related to limited availability of Sentinel-2 observations. This can be mitigated through incorporation of Sentinel-1 imagery.
- Users highlighted the limited number of land cover (LC) classes and the necessity to differentiate between categories and further disaggregate LC classes (e.g., no distinction between natural tree cover and tree crops, between natural and managed grasslands, between native and non-native species, etc.). This issue stems from the compromise made in algorithm development to balance global applicability with local specificity.
- The land cover transition matrix that is used to categorize land cover class transitions into degradation and improvement transition classes should be customizable in on-demand workflows.
- The short time-series adds uncertainty to productivity trend estimation. The lack of historical high-resolution data with the same temporal revisit also limits the possibility to evaluate the productivity state sub-indicator.
- Performance estimation could be improved by using fine-grained bioclimatic zonation or ecosystem functional units.
- Close collaboration with national teams is needed to adapt and verify the indicator products.
- LCC maps of Colombia and Portugal were compared with existing similar change maps due to limited availability of reference data. Accuracy assessments on LCC using independent validation data is necessary to provide confidence in user applications.
- Uncertainties in the AGB models are linked to underrepresentation of ecozones and temporal gaps in data.
- The estimation of total carbon stocks requires the integration of both SOC and AGB methodologies, and we strongly advocate for significant research efforts in this area.

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Supporting material about this use case. *(include links, publications, etc.)*	National Demonstration Products are published on Zenodo: https://zenodo.org/records/14223153 https://zenodo.org/records/14230325 https://zenodo.org/records/14274476 https://zenodo.org/records/14283567 The Requirement Baseline, Algorithm Theoretical Baseline Document, Product User Guide and other public deliverables are made available on https://esa-sen4ldn.org/en/deliverables. GEE App to demonstrate results (was developed to be presented to the Early Adopters at the third round of living labs (November/2024). https://vitorsveg.users.earthengine.app/view/sen4ldn
Name(s) and email address of individual(s) involved in this effort. Please note the principal point(s) of contact (POCs).	Carolien Toté, VITO, carolien.tote@vito.be (POC) Marc Paganini, ESA, marc.paganini@esa.int (POC) Ruben Van De Kerchove, VITO, ruben.vandekerchove@vito.be (POC) Daniele Zanaga, VITO Giorgia Milli, VITO Lars Eklundh, University of Lund Zhanzhang Cai, University of Lund Katja Berger, GFZ, katja.berger@gfz.de Martin Herold, GFZ, herold@gfz.de Nandika Tsendbazar, Wageningen University Panpan Xu, Wageningen University Gabriel Daldegan, Conservation International