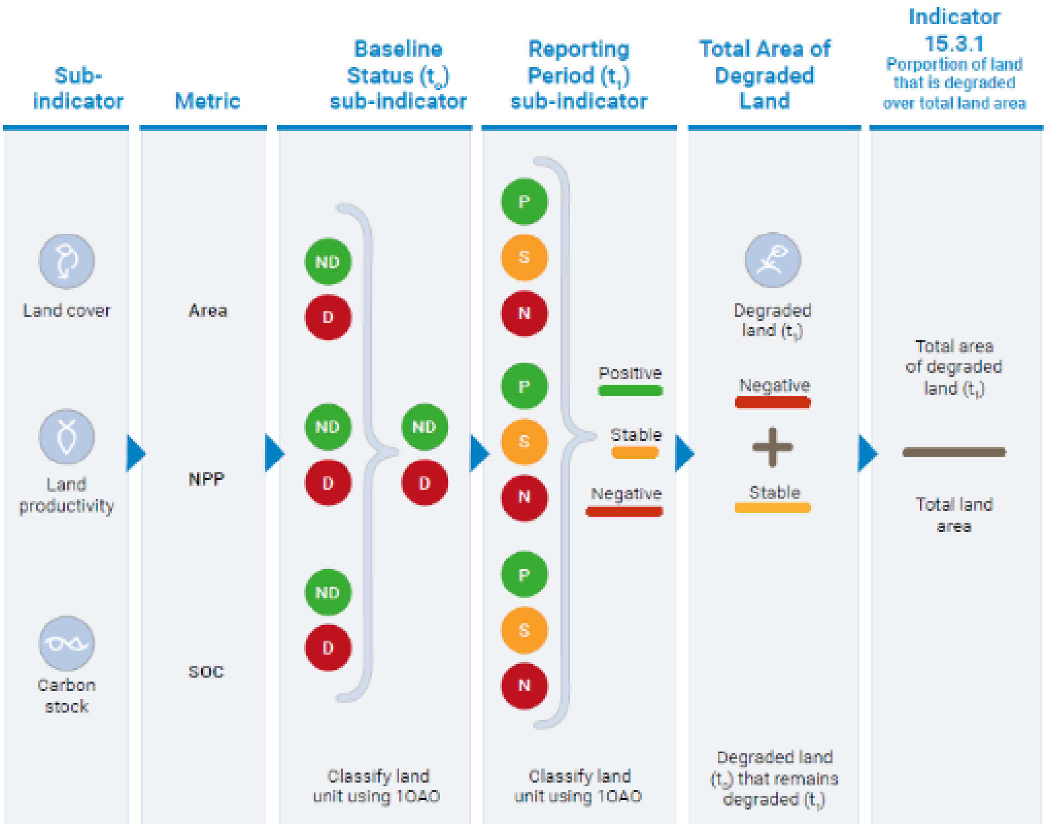
Satellite Data Requirements for SDG Indicator 15.3.1

Version 1.0 Published (31/08/2022)
with contributions from Neil Sims and Flora Kerblat (CSIRO), Uta Heiden (DLR), Brian O'Connor (UNCCD), Marc Paganini (ESA)

Indicator	**15.3.1** Proportion of land that is degraded over total land area.		
Target	15.3 By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world.		
Custodian	United Nations Convention to Combat Desertification (UNCCD)	Tier	I
Current approach and challenges	The UNCCD has defined three sub-indicators of SDG indicator 15.3.1: i) trends in land cover (Strategic Objective SO 1-1), trends in land productivity or functioning of the land (SO 1-2) and iii) trends in carbon stocks above and below ground (SO 1-3). With the Good Practice Guidance (GPG, Version 1.0, 2017 and Version 2.0, 2021), the UNCCD has established a universal methodology for reporting on SDG 15.3.1. **Approach:** Indicator 15.3.1 reports the proportion of land that is degraded over total land area. Land degradation is defined as "*the reduction or loss of the biological or economic productivity and complexity of rain fed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from a combination of pressures, including land use and management practices*" (UNCCD, 1994). The total proportion of land that is degraded over total land area is given by: $$P_n = \frac{A(degraded)_n}{\sum_i^m A(Total)}$$ where Pn is the proportion of land that is degraded over total land area; $A(Degraded)_n$ is the total area degraded in the year of monitoring *n* (ha) and *A(Total)* is the total area within the national boundary (ha). The indicator is a binary degraded/not degraded quantification based on the assessment of changes in three sub-indicators: Land cover and land cover change, land productivity and carbon stock above and below ground. These sub-indicators, representing proxies of the capacity of the land to deliver ecosystem services, were adopted by the UNCCD in 2013 as part of its monitoring and evaluation approach. The changes are assessed and depicted as (i) positive or improving, (ii) negative or declining, or (iii) stable or unchanging. Based on the evaluation of the changes, the proportion of land that is degraded over total land area (%) is calculated following a "One out all out" (1OAO) principle. That is, if any one of the sub-indicators indicates degradation (either a decrease or negative change in relation to the baseline period, or no change in an area previously identified as degraded) for a particular land unit, that area is considered to be degraded in the relevant reporting period (see below).		



Land Cover:

The sub-indicator describes the changes in the distribution of vegetation types, and human-impacted infrastructure, and reflects the use of land resources (i.e., soil, water, and biodiversity) for agriculture, forestry, human settlements and other purposes. The land cover classes should be exhaustive and mutually exclusive, with the entire country's land area being attributed to a set of land cover classes.

There is an international standard for land cover which includes the Land Cover Meta Language (LCML), a common reference structure (statistical standard) for the comparison and integration of data for any generic land cover classification system. LCML is also used for defining land cover and ecosystem functional units used in the System of Environmental-Economic Accounting (SEEA), and closely linked to the Intergovernmental Panel on Climate Change (IPCC) classification on land cover/land use. The IPCC land use change legend suggests six main classes (forest land, grassland, cropland, wetlands, settlements, and other lands including bare soil, snow and glaciers, and water bodies) which should be considered as a minimum set. To classify the changes and decide whether land degradation occurs from a land cover change perspective, a change matrix approach is applied (see below).

FINAL CLASS

ORIGINAL CLASS

IPCC Class	Forest Land	Grassland	Cropland	Wetlands	Settlements	Other Land
Forest Land	*Stable*	*Vegetation loss*	*Deforestation*	*Inundation*	*Deforestation*	*Vegetation loss*
Grassland	*Afforestation*	*Stable*	*Agricultural expansion*	*Inundation*	*Urban expansion*	*Vegetation loss*
Cropland	*Afforestation*	*Withdrawal of Agriculture*	*Stable*	*Inundation*	*Urban expansion*	*Vegetation loss*
Wetlands	*Woody Encroachment*	*Wetland drainage*	*Wetland drainage*	*Stable*	*Wetland drainage*	*Wetland drainage*
Settlements	*Afforestation*	*Vegetation establishment*	*Agricultural expansion*	*Wetland establishment*	*Stable*	*Withdrawal of Settlements*
Other Land	*Afforestation*	*Vegetation establishment*	*Agricultural expansion*	*Wetland establishment*	*Urban expansion*	*Stable*

Note: This sub-indicator is also expected to be used for reporting on SDG indicators 6.6.1, 11.3.1 and 15.1.1 to guarantee a consistency among the reporting (e.g., forest changes).

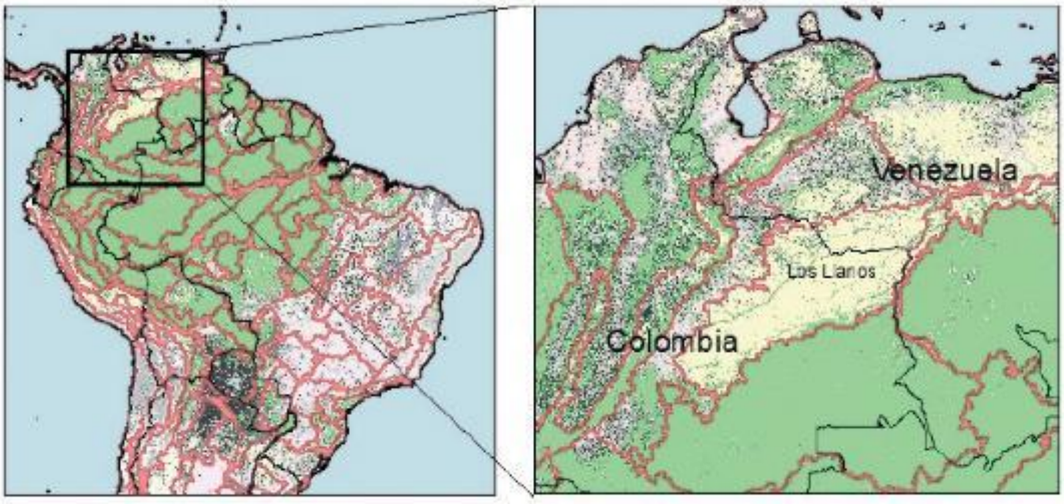
Note that the change matrix presented here and in the GPG is intended to be an example only and is not prescriptive in its identification of specific land cover transitions as degraded or not. While this example matrix is probably suitable in most countries, a transition from one land cover type to another may be considered degradation in one country or region, but not degradation in another. Version 2 of the GPG also presents change matrix for a notional 13-class land cover classification and provides more detail on the approach to identifying transitions that are degrading or not. This responds to a need from countries to be able to use a national land cover legend in defining key degradation process and for which provision has been made in the UNCCD reporting platform PRAIS.

Land productivity:

The sub-indicator refers to the total above-ground net primary production (NPP) defined as the energy fixated by plants minus their respiration which translates into the rate of biomass accumulation that delivers ecosystem services. The international standard for calculating NPP (gC/m²/day) from remotely sensed, multi-temporal surface reflectance data, accounting for the global range of climate and vegetation types, was established in 1999 by NASA for the MODIS sensor. The Land Productivity Dynamics (LPD) methodology and dataset, developed by the Joint Research Centre (JRC) of the European Commission (EC) and used in the UNCCD LDN Target Setting program, employs this international standard to calculate NPP time series trends and change analyses. The LPD dataset is based on a timeseries analysis of long-term changes and current efficiency levels of vegetative or standing biomass, providing 5 qualitative classes of land productivity trends over the period 2000-2019.

The GPG presents methods to calculate three metrics of the Productivity sub-indicator: **Trend**, which describes the *trajectory* of land productivity over the longer term; **State**, which represents the *level* of productivity in a land unit compared to the historical observations of productivity for that land unit over time, and **Performance**, which indicates the *level* of local plant productivity relative to other regions with similar productivity potential. Degradation in the Land Productivity sub-indicator is interpreted from the combination of metrics showing degradation (see below).

Changes to the recommended method for calculating Productivity Performance in GPG 2 now include the comparison of relative productivity between land units (usually pixels) within Land Cover/Ecosystem Functional Units (LCEU), which are areas with relatively homogenous environmental characteristics that control plant productivity potential such as land cover, soil type, climate conditions, elevation etc. The recommends a number of datasets that can be used to define the LCEUs, including the Global Agro-Environmental Stratification (GAES; Mücher et al. 2016), as shown below.



Carbon Stock:

In UNCCD decision 22/COP.11, Soil Organic Carbon (SOC) stock was adopted as the metric to be used with the understanding that this metric will be replaced by total terrestrial system carbon stocks once operational. SOC stock is an aggregator of above and below ground carbon cycling processes and is a meaningful indicator of soil structure and nutrient levels, which makes SOC a reasonable surrogate of total carbon stock. Version 2 of the GPG (2021) provides guidance on measuring the magnitude and significance of change that has been updated from the 2019 IPCC Refinement of the guidelines. The GPG also contains guidance on developing national SOC change analysis methods and describes data and analytics considerations in preparation for transition to a total carbon stock over time. Minimum data quality standards for SOC analysis are shown below (adapted in the GPG from the GEO Land Degradation Neutrality report, 2020).

Issue	Suggested standard	Comments
Cross-cutting		
Grid cell size	100 m	National SOC stocks should aim for a 100 m grid, but this will depend in part on the *in situ* data collection. Suggested standard **suitable.**
Temporal coverage	Specific to sub-indicator	National SOC stocks should aim for temporal coverage in line with global products. Suggested standard **suitable.**
Analysis ready data (ARD)	Use ARD	Knowing the processing lineage is more important and should be provided. Suggested standard **suitable.**
Sub-indicator specific		
SOC data uncertainty	Pixel based	Datasets should aim for pixel level uncertainty. Suggested to **further consultation required.**
Soil inventory update period	10 years	Ambitious standard, probably more of a goal to strive for. Specific time period depends on local rates of change, the change methods used and local conditions. Suggested standard **suitable.**

Baseline and reporting period:

The baseline period against which change in the extent of degradation is assessed is the 16 years from 1 January 2000 to 31 December 2015. The GPG provides guidance on how to calculate the extent of degradation in each of the three sub-indicators during the baseline period. All changes are assessed relative to the baseline value with a reporting interval of 4 years. Countries are responsible for submitting national reports to UNCCD. According to the reporting platform PRAIS[3] of the UNCCD a total of 149 countries have reported in 2018 making this one of the most reported SDG Indicators.

	At the time of writing, there are no datasets providing consistent interpretations of Land Cover or SOC stock from 1 January 2000 to the present date at a sufficiently high spatial resolution to be used consistently in areas such as small islands. The ESA CCI-LC dataset provides annual land cover information in 22 classes from 1992 to the present day at 300m resolution. Finer resolution and more frequent assessments would greatly improve the utility of these datasets as a basis to assess the impacts of land use changes and assess LDN. The UN custodian Agencies and GEO are aware of capacity building being a constant challenge for countries that need help, and CEOS can assess requests and possibly offer support with identifying, accessing, and using the most relevant data for their national reporting requirements. **Challenges:** The indicator was classified as TIER-I in December 2018 meaning that "Indicator is conceptually clear, has an internationally established methodology and standards are available, and data are regularly produced by countries for at least 50 per cent of countries and of the population in every region where the indicator is relevant". The key challenges in the calculation of Indicator 15.3.1 are the lack of consistent global land cover and land cover change datasets available over the baseline and reporting periods, the diversity of EO methods for measuring NPP and their calibration to physical measures of production and productivity, and the difficulty in measuring carbon and validating maps of SOC stock. The sub-indicators described for Indicator 15.3.1 are a minimum set, and they may not fully capture the complexity of land degradation under some circumstances. Countries are strongly encouraged to use other relevant national or sub-national indicators, data and information to strengthen their interpretation of degradation in their countries. The rather coarse spatial resolution (>100m) of the default EO products provided to countries may prevent detailed land degradation mapping in some geographies especially in arid regions where vegetation cover is sparse or non-existent. Other challenges include how to combine datasets of different spatial, spectral and temporal resolution over the baseline and reporting periods for a continuous time series, and the validation of national EO-based data products. There is also the need to develop an accurate, robust, and stable EO (or spatial) product showing carbon stocks above and below ground. Several countries reporting to the UNCCD on Indicator 15.3.1 have requested methods to calculate the severity or magnitude of degradation, rather than just the binary degraded/not degraded. While degradation severity measurement is more closely aligned to Land Degradation Neutrality (which is encapsulated in SDG Target 15.3), Chapter 7 in Version 2 of the GPG contains some guidance on assessing the magnitude of degradation for each of the sub-indicators and metrics of the land productivity sub-indicator, which is the appropriate scale for proper aggregation up to the Indicator scale. These recommendations have not yet been implemented. Countries in the Arab world have indicated to the UN the lack of accurate productivity assessment tools for their region. The vegetation index approach described in the GPG uses changes in vegetation greenness and biomass to infer changes in plant productivity. This method is less effective in areas with very low vegetation cover, such as arid regions, and where the variation in greenness is not seasonal or very significant. Finding a land productivity dataset suitable for use in these regions would be valuable: it may be worth investigating the suitability of fractional cover products, such as those developed and used in Australia (TERN project: https://portal.tern.org.au/fractional-cover-modis-csiro-algorithm/21786), core product of the global Rangelands and Pasture Productivity (RAPP) community (https://map.geo-rapp.org/about). Several reporting countries have indicated a need to implement land cover transition matrices at sub-national scales to reflect differences in the ecology and land management practices between regions. This may be achieved by providing the opportunity to implement multiple matrices per country. For consistency, the extent over which a matrix applies could be defined by the LCEU zones used to assess productivity performance. This is being considered for implementation in Trends.Earth.

Consideration of EO:

The GPG deeply integrates EO into the methodology for measuring Indicator 15.3.1. The document provides guidance on how to use the global default EO datasets shown below, and to create national datasets for land cover and land productivity datasets from other EO data sources.

Sub-indicator	Default data provided for 2018 reporting	Alternatives
Land Cover	**ESA-CCI-LC**[43] 300m annual global from 1992 to 2019	**Copernicus CGLS-LC100 (Collection 3)**[44]100m annual global from 2015 to 2019
Land productivity	**JRC Land Productivity Dynamics (LPD)**[45]1km annual global from 1999-2013	**MODIS vegetation index (MOD31Q1, MYD13Q1)**[46] 250 m global, 16-day integration period since 2000 **Copernicus Global Land Service NDVI,**[47] 1km annual global since 1998.
SOC	**ISRIC SoilGrids250m**[48] 250 m global spatial predictions for selected soil properties at six standard depths	**ISRIC SoilGrids250m version 2** (de Sousa et al. 2020), updated global product at 250 m spatial resolution with spatial uncertainty. **FAO Global Soil Organic Carbon Map**[49], global and national maps of SOC stocks at 1 km spatial resolution; latest version 2019. *https://soilsrevealed.org/

Conservation International (CI) together with Lund University and NASA have developed the Trends.Earth platform, which implements the GPG methods for monitoring land degradation using EO in a desktop and cloud-based system[1]. Trends.Earth provides access to the default datasets provided by the UNCCD and also facilitates the use of other national EO datasets for calculating the sub-indicators and the Indicator as required. By incorporating a range of other spatial and EO datasets, and linking directly to the PRAIS reporting portal of the UNCCD[2] the toolbox enables the sub-indicators to be calculated and reported in the format required by the UNCCD.

Within the GEO LDN Initiative there has been a review of the minimum data quality standards suitable for use in calculating the sub-indicators of Indicator 15.3.1 and LDN, many of which relate to EO datasets. The Decision Trees are presented for each of the indicator and sub-indicators in Version 2 of the GPG[3]. The minimum data quality standards are listed, as shown below (Summary of the decisions and suggested standards resulting from the data providers and specialists consultation process). It is recognised that some of these attributes are aspiratoinal at this time.

Topic	Suggested provider outcome	Suggested value
Grid cell size	Minimum Data Quality Standard	100 m[7]
Temporal coverage	Minimum Data Quality Standard	Specific to sub-indicator[8]
Analysis Ready Data (ARD)	Minimum Data Quality Standard	Use ARD
Land cover classes	Minimum Data Quality Standard	User decision
LC change assessment	Minimum Data Quality Standard	Accuracy > 85%
Legend translation	Minimum Data Quality Standard	LCML
Productivity index	Minimum Data Quality Standard	NDVI
Climate calibration/normalisation	Minimum Data Quality Standard	Use uncalibrated data
Linking time series	Minimum Data Quality Standard	Linear regression
Harmonise and compare indices	Minimum Data Quality Standard	Report change
Growing season definition	Minimum Data Quality Standard	Proportional
SOC data uncertainty	Minimum Data Quality Standard	Pixel-based
Soil inventory update period	Minimum Data Quality Standard	10 years

[7] For each of the three sub-indicators if possible
[8] See Appendix A for details per sub-indicator [i.e. annual, tri-annual and in line with global products]

Satellite Observations	
Opportunities for EO	One of the most important applications of SDG indicator 15.3.1 is in its support of the Land Degradation Neutrality (LDN) program of the UNCCD. Achieving LDN requires information about the drivers of degradation, including climate effects and direct anthropogenic land use impacts, to guide the implementation of activities to prevent, reduce or remediate degradation. High resolution time series EO datasets used to derive land use information is an essential complement to data on land cover, productivity, and carbon stocks. Ideally, the land condition and land use information should also be linked to spatially explicit climate (potentially EO-based) and land planning information (likely vector data) in order to predict areas susceptible to degradation. With the appropriate processing, the Landsat 5 to 8 archive could provide information throughout the baseline period to derive annual land cover change information at a higher spatial resolution than is provided in the default datasets provided by the UNCCD. The challenges for assessing land productivity are somewhat greater because of the preference to observe vegetation at the time of peak biomass each year. This may not be possible in mid to high latitude and temperate regions, particularly where the peak growth period may coincide with persistent cloud cover, and observations at an alternative, less cloud covered anniversary period each year may also be used under those circumstances, as it is the change in productivity and not the productivity itself that is the subject of assessment. Significant development is required to improve the assessment of C stocks from EO data sources, and particularly to address the assessment of C stocks above and below ground
Satellite Data requirements	The CEOS sub-team on 15.3.1 (SDG ad hoc team) has analyzed data availability and listed satellite data requirements based on end users' needs. The document follows a template developed by the GEOGLAM (Group on Earth Observation Agriculture monitoring) Initiative as the basis of their analysis of satellite observation requirements. The CEOS SDG 15.3.1 team coordinated technical inputs and feedback received from various sources including Space agencies, and the wider GEO Land Degradation Neutrality community. This document analyzes satellite data supply available to measure this indicator, and support CEOS Space Agencies in better understanding the satellite requirements needed by countries to use EO data for SDG reporting or for inclusion in their national sustainable agendas. This spreadsheet informed this EO Support sheet document, by identifying observation gaps and finding solutions with Space agencies to overcome them and help countries report on SDG effectively using EO data. The "SDG Requirements for 15.3.1" table includes detailed requirements, simplified requirements (showing the key EO products and their characteristics for each of the 3 sub indicators), CEOS core missions (describing and classifying the 'main' global, open, free and sustained missions), and the Satellite Missions (updated, including a Detailed Satellite Missions and Instrument Summary).

[1] Trends.Earth was produced as part of the project "Enabling the use of global data sources to assess and monitor land degradation at multiple scales", funded by Global Environment Facility (GEF).

[2] https://prais.unccd.int/node/7

[3] the full report including decision trees is available here https://www.unccd.int/resources/manuals-and-guides/good-practice-guidance-sdg-indicator-1531-proportion-land-degraded

	How ?		When ?	Where ?		
SDG Requirement	Spatial Resolution	Measurement Type	Observation Frequency	Sampling Type	Comments	CEOS Mission Classes
SDG 15.3.1 Land Cover Change	10-100m (The agreed minimum standard for national data is 100m aiming at 30m)	Classification/ Change Detection	Annual	Global, National	[ESA-CCI-LC (300m) or SEEA-MODIS as global default. Another Copernicus Dynamic Land Cover (100m) also available.] In the last reporting cycle (2018), the global default data were ESA-CCI-LC at 300m resolution. (cf. Mattina et al. 2018) The agreed minimum standard for national land cover change data is 100m aiming at 30m . Data users expressed the need to have 10-30m resolution to generate reliable information for planning and decision-making processes to implement SDG 15.3. Many countries are already using national data at 30m resolution for LCC reporting. For small island developing states (SIDS), 300m and even 100m resolution is not sufficient - many SIDS depend on the global default data for reporting and would need a higher resolution. The standard for the classification scheme is that it is a user-decision but following specific rules, e.g. use hierarchical class structures, aggregate to the GPG listed reporting scheme, and attain internal consistency across dates. (cf. GEO-LDN Initiative 2020)	**1,2**
SDG 15.3.1 Land Productivity	10-100m (The agreed minimum standard for national data is 100m aiming at 30m)	Optical. NDVI is the agreed minimum standard. Depending on the circumstances, other indices may be used, e.g. EVI2 over high biomass lands, and MSAVI or SATVI for savannas and sparsely vegetated areas.	Weekly to Monthly (data used for reporting in 2018 were daily data aggregated to observations every 10 days)	Vegetation Mask	[MODIS or Copernicus NDVI (global) and higher resolution for (regional/national).] Global default data for the last reporting cycle (2018) were JRC LPD at 1km, and at 250m for SIDS. JRC LPD is an operational global 15-year (1999 to 2013) time series of daily SPOT-VGT NDVI images aggregated/composited to observation every 10 days (i.e. 540 observations overall for each pixel). (cf. Mattina et al. 2018) The agreed minimum standard for national land productivity data is 100m aiming at 30m. The national land productivity products should aim for a 3 year product (which is acknowledged as difficult) instead of the global 15-year product. (cf. GEO-LDN Initiative 2020)	**1,2**
SDG 15.3.1 Soil Organic Carbon	100-250m (The agreed minimum standard for national data is 100m, but this will depend in part on the in situ data collection.)	[Microwave In-situ soil inventories in combination with a land use factor (based on land cover change data) and ideally (but currently not available) a land management factor and an input factor.	Annual for LCC (in situ soil inventory should be updated every 10 years)	Global, National	[Harmonised World Soil Database (HWSD), ISRIC SoilGrids or FAO GSOC map global soil products.] Global default data for the last reporting cycle (2018) were annual ISRIC's Soil Grids at 250m for the baseline in combination with ESA-CCI-LC for estimated changes in SOC stocks. (cf. Mattina et al. 2018) The agreed minimum standard for national carbon (SOC) stocks is annual data at 100m, but this will depend in part on the in situ data collection. It is suggested that national soil monitoring organisations aim to create SOC datasets as part of a soil inventory that is updated every 10 years. (cf. GEO-LDN Initiative 2020)	**1,5**

Figure 1, Simplified requirements for 15.3.1 (showing the key EO products and their characteristics for each of the 3 sub indicators)

Note: the EO data requirements (EO Variables and satellite observation requirements) have been provided independently of the satellite data availability - which have also been analyzed and listed in the other sheets called "CEOS core missions" or "Satellite missions" as shown below.

The following spreadsheet complements the table by combining active CEOS land imaging missions that are free and open access (unrestricted), global coverage, and have a plan for sustained measurements into the future. This table helps SDG users to apply the satellite data from the CEOS core missions toward specific SDG data requirements now and into the future.

More information is available in the CEOS Mission, Instruments and Measurements (CEOS MIM) Database: http://database.eohandbook.com/ and the CEOS Data Policy Portal: http://ceos-cove.org/data_policy .

Mission Class	Mission	Instrument	Agency	Launch	Repeat or Revisit *	Swath	Resolution
	Optical - Coarse Resolution (>100m)						
1	Terra	MODIS	NASA	Dec 1999	1 day	2330 km	250, 500, 1000m
	Aqua	MODIS	NASA	May 2002	1 day	2330 km	250, 500, 1000m
	Suomi-NPP	VIIRS	NASA	Oct 2011	1 day	3000 km	375, 750m
	Sentinel-3A	OLCI	ESA	Feb 2016	4 days	1270 km	300m (OLCI), SLSTR: 500m (VNIR/SWIR)+1000m (TIR)
	Sentinel-3B	OLCI	ESA	Apr 2018	4 days	1270 km	300m (OLCI), SLSTR: 500m (VNIR/SWIR)+1000m (TIR)
	Proba-V	VGT-P	ESA/BELSPO	May 2013	1 day	2285 km	100, 300, 1000m (1km free, 100+300 free >1 month)
	Optical - Moderate Resolution (10 to 100m)						
2	Landsat-7	ETM+	NASA/USGS	Apr 1999	16 days	183 km	15m (PAN), 30m (VIS/SWIR), 60m (TIR)
	Landsat-8	OLI + TIRS	NASA/USGS	Feb 2013	16 days	183 km	15m (PAN), 30m (VIS/SWIR), 100m (TIR)
	Sentinel-2A	MSI	ESA	Jun 2015	10 days	290 km	10m (VNIR), 20m (SWIR)
	Sentinel-2B	MSI	ESA	Mar 2017	10 days	290 km	10m (VNIR), 20m (SWIR)
	CBERS-4	WFI-2, PAN, MUXCam, IRS	INPE/CAST	Dec 2014	5-26 days	120 to 866 km	5m (PAN), 10m, 20m, 64m (VIS/NIR), 40m (SWIR), 80m (TIR)
	HJ-1A	HSI	CRESDA/CAST	Sep 2008	31 days	50 km	100m
	Meteor-M N1	KMSS	ROSKOSMOS	Sep 2009	4 days	900 km	60 m, 120 m
	C-Band SAR						
3	Sentinel-1A	SAR	ESA	Apr 2014	12 days	80, 250, 400 km	9, 20 (IWS), 50 m
	Sentinel-1B	SAR	ESA	Apr 2016	12 days	80, 250, 400 km	9, 20 (IWS), 50 m
	L-Band SAR						
4	ALOS-2	PALSAR-2	JAXA	May 2014	14 days	25 to 490 km	10 to 100 m (only annual mosaics free)
	ALOS-4	PALSAR-3	JAXA	Planned 2020	14 days	25 to 490 km	10 to 100 m, **TBD Data Policy**
	NISAR	SAR	NASA, ISRO	Planned 2022	12 days	240 km	10m
	Soil Moisture						
5	SMOS	MIRAS (L-Band MW)	ESA	Nov 2009	1-2 days	1050 km	15 km
	SMAP	SMAP (L-Band MW)	NASA	Jan 2015	1-2 days	1000 km	10 km (active) to 40 km (passive)
	Radar Altimetry						
6	Sentinel-3A	SRAL	ESA/EUMETSAT/E	Feb 2016	27 days	Profiling	3 cm
	Sentinel-3B	SRAL	ESA/EUMETSAT/E	Apr 2018	27 days	Profiling	3 cm
	Jason-3	Poseidon Altimeter	EUMETSAT/NOAA	Jan 2016	10 days	300 km	3.4 cm
	Sentinel-6A Mich	Poseidon Altimeter	EUMETSAT/EC/ES	Planned 2020	10 days	300 km	3.2 cm
	Sentinel-6B Mich	Poseidon Altimeter	EUMETSAT/EC/ES	Planned 2025	10 days	300 km	3.2 cm
	HY-2A	ALT	NSOAS/CAST	Aug 2011	14 days	16 km	4 cm
	HY-2B	ALT	NSOAS/CAST	Oct 2018	14 days	16 km	4 cm

* Check CBERS-4 global coverage
* Check KMSS data access and global coverage (Russia)
* Check China mission coverage and data access

Figure 2: CEOS Land Imaging Satellite Mission list for SDGs

Version 2 of the GPG includes guidance to identify EO datasets with the required data quality standards as decision trees for each of the sub-indicators and the Indicator level. These decision trees avoid recommending specific datasets, which may not provide suitable coverage in a particular region, or may not be supported in perpetuity, or may be superseded by improved datasets over time. The decision trees refer readers to additional guidance on dataset selection, including elsewhere in the GPG. The Decision Tree for selecting datasets suitable for calculating the Land Productivity sub-indicator are from Section 4.2.4 of the GPG.

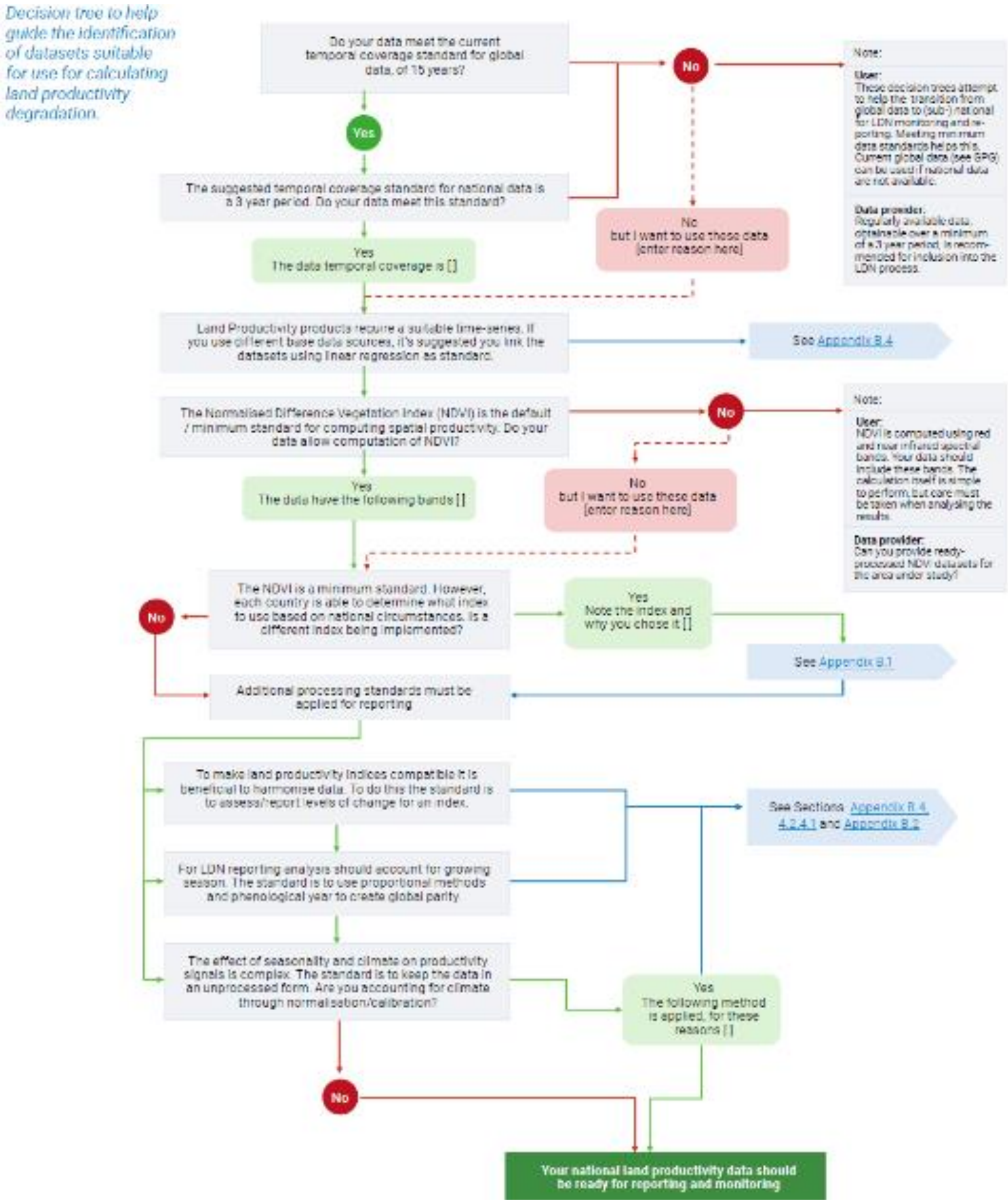


Figure 3: Decision Tree for selecting datasets suitable for calculating the Land Productivity sub-indicator (UNCCD Good Practice Guidance Version 2)

Satellite Data availability

By doing this data supply analysis, CEOS demonstrates that **coarse resolution satellite** data is already useful for monitoring land degradation over larger areas such as continental scale. However there remains a need for higher resolution data in regions such as in the Pacific or Caribbean, with a multitude of small island developing states, as well as regions with mountainous states.

ESA's Copernicus Sentinel-2 constellation now enables near-real-time monitoring of land cover and productivity at finer scales, however the capture frequency over some regions is relatively low, due to frequent cloud cover or lack of ground stations.

A major step forward would be to develop interoperable data products of relevance for the land surface, derived from Sentinel-2 and Landsat for example, dating back to the year 2000 so that the baseline can be recalculated with Sentinel-2 like data.

While access to high-resolution remote sensing imagery has improved dramatically in recent years, there is still a need for essential historical time series that are currently only available at coarse to medium resolution. Another constraint for higher resolution data is its cost (commercial providers), which countries are usually not ready to pay. The expectation is that the availability of high resolution, locally calibrated datasets will increase in future through programs such as the Copernicus Sentinels. National capacities to process, interpret and validate geospatial data still need to be enhanced in many countries.

EO Data Access

The Global default datasets for calculating each of the sub-indicators of Indicator 15.3.1 are shown below[4].

Sub-indicator	Default data provided for 2018 reporting	Alternatives
Land Cover	**ESA-CCI-LC**[43] 300m annual global from 1992 to 2019	**Copernicus CGLS-LC100 (Collection 3)**[44] 100m annual global from 2015 to 2019
Land productivity	**JRC Land Productivity Dynamics (LPD)**[45] 1km annual global from 1999-2013	**MODIS vegetation index (MOD31Q1, MYD13Q1)**[46] 250 m global, 16-day integration period since 2000 **Copernicus Global Land Service NDVI,**[47] 1km annual global since 1998.
SOC	**ISRIC SoilGrids250m**[48] 250 m global spatial predictions for selected soil properties at six standard depths	**ISRIC SoilGrids250m version 2** (de Sousa et al. 2020), updated global product at 250 m spatial resolution with spatial uncertainty. **FAO Global Soil Organic Carbon Map**[49], global and national maps of SOC stocks at 1 km spatial resolution; latest version 2019. *https://soilsrevealed.org/

43 https://climate.esa.int/en/projects/land-cover/
44 https://land.copernicus.eu/global/products/lc
45 https://wad.jrc.ec.europa.eu/landproductivity
46 https://modis.gsfc.nasa.gov/data/dataprod/mod13.php
47 https://land.copernicus.eu/global/products/ndvi
48 https://www.soilgrids.org/
49 http://www.fao.org/global-soil-partnership/pillars-action/4-information-and-data-new/global-soil-organic-carbon-gsoc-map/en/

Sentinel data can be accessed through the Data and Information Access Services (DIAS) or the Conventional Data Hubs (https://www.copernicus.eu/en/access-data)

Landsat data is available via the Earth Explorer website (https://earthexplorer.usgs.gov/).

These datasets (Level2A) may be accessible through cloud computing infrastructure such as Google Earth Engine, Amazon Web Service and Microsoft Planetary Computer. **Commercial satellite data** can be purchased through data providers and their reseller network.

Analysis Ready Data

CEOS Analysis Ready Data (CEOS-ARD) are satellite data that have been processed to a minimum set of requirements and organized into a form that allows immediate analysis with a minimum of additional user effort and interoperability both through time and with other datasets.

[4] Extracted from the GPG Document: https://www.unccd.int/resources/manuals-and-guides/good-practice-guidance-sdg-indicator-1531-proportion-land-degraded

	CEOS have also published ARD Standards for land applications (https://ceos.org/ard/), including links to ARD data access sites, which may enable countries to convert their national datasets to ARD standard. The availability of ARD is increasing through facilities including Digital Earth Australia (https://www.dea.ga.gov.au/), Digital Earth Africa (https://www.digitalearthafrica.org/) and proposed data cubes for other regions including in Latin America, or in the Pacific region (https://www.spc.int/DigitalEarthPacific).
EO-based global datasets	There is a range of global data products available to use for the indicator monitoring and reporting: *Land cover datasets:* • **ESA Climate Change Initiative Land Cover dataset:** Annual global land cover maps are available at 300m spatial resolution from 1992 to 2015. Land cover information is provided for 22 classes following the Land Cover Classification System (LCCS). Further regional classes are implemented allowing for a higher level of detail in the legend https://www.esa-landcover-cci.org/ • **Copernicus Dynamic Land Cover**: The dynamic land cover map provides a yearly global land cover map at 100m spatial resolution with an overall accuracy of higher than 85%. https://land.copernicus.eu/global/products/lc • **Pan-European Copernicus High Resolution Layers (HRL)**: HRL maps are available for imperviousness (2006, 2009, 2012, 2015, 2018), forest (2012, 2015, 2018), grasslands (2015, 2018), water and wetlands (2015, 2018) as well as small woody features for the year 2015 at 20m resolution https://land.copernicus.eu/pan-european/high-resolution-layers • A Summary of additional existing global, regional as well as national land cover data available is provided in the GPG (2017, Version 1.0). The GPG further states the accuracy, geographical coverage, spatial resolution, time periods available as well as thematic resolution. *Land productivity datasets:* • **JRC's Land Productivity Dynamics (LPD) dataset**[5]: The LPD dataset is based on an analysis of long-term changes and current efficiency levels of vegetative or standing biomass. The LPD dataset was derived from a 20-year time series (1999 to 2019) of global NDVI observations composited in 10-day intervals at a spatial resolution of 1 km. http://publications.jrc.ec.europa.eu/repository/handle/JRC80541 • **Copernicus Global Land Service products:** Several global datasets are available that allow for the assessment of vegetation condition including Fraction of Absorbed Photosynthetically Active Radiation (FAPAR), Fraction of green Vegetation Cover (FCover), Leaf Area Index (LAI), Normalized Difference Vegetation Index (NDVI), Vegetation Condition Index (VCI), and Vegetation Productivity Index (VPI) https://land.copernicus.eu/global/ • An overview for low or no-cost satellite sensors and data streams (e.g. PROBA-V, Vegetation, MODIS, etc.) utilized for land surface phenology studies is provided in the GPG (2017, version 1.0). *Soil Organic Carbon datasets:*

[5] The reference for the LPD should be: EC-JRC, 2021, based on Xavier Rotllan-Puig, Eva Ivits, Michael Cherlet, LPDynR: A new tool to calculate the land productivity dynamics indicator, Ecological Indicators, Volume 133, 2021, 108386, ISSN 1470-160X, https://doi.org/10.1016/j.ecolind.2021.108386.

	• **Harmonized World Soil Database (HWSD), Version 1.2**: The HWSD was produced by FAO, IIASA, ISRIC-World Soil Information, Institute of Soil Science, Chinese Academy of Sciences (ISSCAS), and the JRC. It is a 30 arc-second raster database that provides information on over 15000 different soil mapping units. http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/harmonized-world-soil-database-v12/en/ • **ISRIC's SoilGrids250m:** SoilGrids is a system for automated soil mapping based on state-of-the-art spatial predictions methods. It provides soil property and class maps of the world at 1 km / 250 m spatial resolutions produced using automated soil mapping based on machine learning algorithms. https://www.isric.org/explore/soilgrids • **Global Soil Organic Carbon Map v1.0**: The GSOC map was produced by the Global Soil Partnership (GSP) and the Intergovernmental Technical Panel on Soils (ITPS) in a consultative and participatory process involving 110 countries. It allows for SOC stock estimations from 0 to 30 cm, providing information to monitor soil condition, to identify degraded areas, set restoration targets, explore SOC sequestration potentials, etc. http://www.fao.org/3/i8195en/I8195EN.pdf
Platforms and Tools:	There are several online platforms and tools that provide options and support for accessing or deriving various inputs for computation of indicator 15.3.1. • **Trends.Earth** represents a platform for monitoring land change using EO in a desktop and cloud-based system. The tool is providing land degradation estimations at 250m. spatial resolution. • **Swiss Data Cube (SDC)**: UN Environment/GRID-Geneva and the University of Geneva are currently building the SDC. The SDC has started to implement algorithms for monitoring land cover and land productivity changes using the Trends.Earth algorithms on Sentinel data streams. • For more information, please visit the CEOS page related to SDG with a list of commonly-used EO enabling infrastructure using free and open dataset: **https://ceos.org/sdg/**
International Initiatives	**GEO LDN initiative:** The GEO Land Degradation Neutrality (LDN) Initiative promotes the collaborative development, and support the provision and use, of EO datasets, quality standards, analytical tools and capacity building to avoid, reduce, and reverse land degradation with the aim of achieving LDN in all countries by 2030 (SDG 15.3). The Initiative will help connect data providers to data users, including researchers, decision-makers, land use planners, commercial sector, donors/investors and other stakeholders in order to optimize the use of EO datasets for LDN assessment, planning, implementation, monitoring and reporting.
Proposed Methodology	
Step-by-Step guide for EO integration into SDG indicator framework	• The GPG outlines the current approach in detail and explicitly states how EO can be incorporated into the reporting framework. • A step-by-step summary of the information on the methodology is outlined in the PRAIS4 reporting manual:https://prais4-reporting-manual.readthedocs.io/en/latest/index.html • GEO LDN have produced Decision Trees to help countries identify the most appropriate datasets for use for calculating Indicator 15.3.1 and LDN (http://earthobservations.org/documents/ldn/20200703_GEOLDN_TechnicalNote_FINAL_SINGLE.pdf) • A guidance document to assist Parties to the UNCCD in preparing their national reports for the 2018 reporting process is available: https://prais.unccd.int/sites/default/files/helper_documents/3-DD_guidance_EN.pdf

Recommendations for implementation	
Activities	*Tentative, not necessarily in sequential order* • Create a simulated land cover dataset at a maximum of 30m resolution showing monthly land cover change from 2000 to the present date • Investigate incorporating fractional cover products into land productivity assessment of Arab countries • Facilitate the implementation of land cover transition matrices within LCEU zones • Implement degradation severity assessment methods • Engage with UNCCD to identify additional data requirements • Engage with GEO LDN Initiative to facilitate incorporation of new CEOS products into SDG 15.3.1 analysis and the LDN process
Timeframe	**Current indicator timeframe considerations:** According to the latest metadata It is anticipated that countries can report consistently after 2-3 years (relative to 2018) and hereafter repeated regularly in 4-year intervals, allowing for three reporting points until the year 2030.
References	**Indicator background** • Good Practice Guidance on methods to assess Indicator 15.3.1: https://www.unccd.int/resources/manuals-and-guides/good-practice-guidance-sdg-indicator-1531-proportion-land-degraded • 15.3.1 UNSD metadata January 2018, https://unstats.un.org/sdgs/metadata/files/Metadata-15-03-01.pdf • PRAIS4 reporting platform PRAIS4 reporting platform | UNCCD • UNCCD reporting process overview: here • UNCCD Reporting Manual: https://www.unccd.int/resources/manuals-and-guides/prais4-reporting-manual • Default data: methods and interpretation. A guidance document for the 2018 UNCCD Reporting https://prais.unccd.int/sites/default/files/helper_documents/3-DD_guidance_EN.pdf **Publications** • Sims, N.C., Newnham, G.J., England, J.R., Guerschman, J., Cox, S.J.D., Roxburgh, S.H., Viscarra Rossel, R.A., Fritz, S. and Wheeler, I. 2021. Good Practice Guidance. SDG Indicator 15.3.1, Proportion of Land That Is Degraded Over Total Land Area. Version 2.0. United Nations Convention to Combat Desertification, Bonn, Germany https://www.unccd.int/sites/default/files/relevant-links/2021-03/Indicator_15.3.1_GPG_v2_29Mar_Advanced-version.pdf • Sims, N.C., Barger, N.N., Metternicht, G.I., & England, J.R. (2020). A land degradation interpretation matrix for reporting on UN SDG indicator 15.3.1 and land degradation neutrality. Environmental Science & Policy, 114, 1-6, https://doi.org/10.1016/j.envsci.2020.07.015 • Neil C. Sims, Jacqueline R. England, Glenn J. Newnham, Sasha Alexander, Carly Green, Sara Minelli, Alex Held, 2019: Developing good practice guidance for estimating land degradation in the context of the United Nations Sustainable Development Goals, Environmental Science & Policy, Volume 92, Pages 349-355, https://doi.org/10.1016/j.envsci.2018.10.014. • Mücher, S., De Simone, L., Kramer, H., de Wit, A., Roupioz, L., Hazeu, G., Boogaard, H., Schuiling, R., Fritz, S., Latham, J. and Cormont, A., 2016. A new global agro-environmental stratification (GAES) (No. 2761). Wageningen Environmental Research. • Note: Please also refer to the GPG list of references. **EO Technical websites** • Trends.Earth hosted by Conservation International (CI), with partners: Lund University, NASA, and the GEF.

	• ESA Climate Change Initiative Land Cover dataset v. 2.0.7: https://www.esa-landcover-cci.org/ Copernicus Dynamic Land Cover: https://land.copernicus.eu/global/products/lc Copernicus Global Land Service products: https://land.copernicus.eu/global/ Harmonized World Soil Database (HWSD), Version 1.2: http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/harmonized-world-soil-database-v12/en/ • ISRIC's SoilGrids250m: https://www.isric.org/explore/soilgrids • Global Soil Organic Carbon Map v1.0: http://www.fao.org/3/i8195en/I8195EN.pdf • EarthExplorer: https://earthexplorer.usgs.gov/ • Sentinel Open Access Hub" https://scihub.copernicus.eu/