Default data: methods and interpretation

A guidance document for 2018 UNCCD reporting

April 2018

Acknowledgments

This guidance document was a team effort led by the secretariat of the United Nations Convention to Combat Desertification (UNCCD) in collaboration with technical partners. Rik van den Bosch, Michael Cherlet, Marc Paganini and Stefan Sommer are acknowledged for their valuable inputs and suggestions.

Chapter lead authors

Land Cover: Daniela Mattina; Land Productivity Dynamics: Hakkı Emrah Erdogan; Soil Organic Carbon: Ichsani Wheeler; Proportion of Degraded Land: Neville Crossman.

Contributing authors

Sara Minelli, Renato Cumani

How to cite this document

UNCCD, 2018. Default data: methods and interpretation. A guidance document for 2018 UNCCD reporting. United Nations Convention to Combat Desertification (UNCCD), Bonn, Germany.

1 General introduction

This guidance document is intended to assist Parties to the United Nations Convention to Combat Desertification (UNCCD) in preparing their national reports for the 2018 reporting process. In particular, the document offers guidance on methods and interpretation of the default data provided to Parties for use in the absence of, or to complement and enhance, national data sources.

The Conference of the Parties to the UNCCD adopted the following land-based indicators (and associated metrics) to report on progress towards the strategic objectives of the Convention:

- Trends in land cover (LC) (LC change);
- Trends in land productivity or functioning of the land (land productivity dynamics (LPD));
- Trends in carbon stocks above and below ground (soil organic carbon (SOC) stock).

These three indicators provide good coverage and together can assess the quantity and quality of land-based natural capital and most of the associated ecosystem services (Orr et al., 2017).

Using these three indicators, 2018 reporting will estimate the proportion of land that is degraded over total land area, which is also Sustainable Development Goal (SDG) indicator 15.3.1, corresponding to SDG 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”.

While in the long term, all countries should be able to perform relevant data collection, analysis and report independently, national estimates derived from regional and global products provide a viable alternative in the absence of other suitable national datasets.

The computation of the indicators may be classified via a tiered approach:

- Tier 1 (default method): Global/regional earth observation and geospatial information and modelling;
- Tier 2: National statistics based on data acquired for administrative or natural reference units (e.g. watersheds) and national Earth observation;
- Tier 3 (most detailed method): Field surveys, assessments and ground measurements.

This approach enables national authorities to use methods consistent with their capacities, resources and data availability.

With a view to reducing the reporting burden and in accordance with the procedure established in UNCCD decision 22/COP.11, paragraph 8, the UNCCD secretariat and Global Mechanism have provided Parties with default Tier 1 data on the metrics associated with these three land-based indicators. The default data is sourced from the following publicly available and free global data sources: (i) the European Space Agency (ESA) Climate Change Initiative on Land Cover (CCI-LC) for LC and LC change data; (ii) the Joint Research Centre of the European Commission for LPD data; and (iii) the International Soil Reference and Information Centre’s (ISRIC) SoilGrids250m dataset for SOC data. The aim of providing this data is to assist countries in complementing and enhancing national data, subject to verification and approval by national authorities.

This document provides guidance on the use and interpretation of the default data. In particular, the document focuses on the new release of the default data, which refers to the period 2000−2015. This guidance document can be considered as an updated version of the “Methodological note to set national voluntary Land Degradation Neutrality (LDN) targets using the UNCCD indicator framework”, which was prepared in 2017 by the UNCCD secretariat within the framework of the Land Degradation Neutrality Target Setting Programme (LDN TSP) and provided information on the original release of the default data (2000−2010).

This document complements (i) the reporting manual for the 2017−2018 UNCCD reporting process, which provides information on the use and compilation of the reporting templates; and (ii) the Good Practice Guidance for SDG indicator 15.3.1,[1] which describes methods to assess and quantify the proportion of degraded land based on the three land-based indicators.

Chapters 2, 3 and 4 provide information on default data sources and outputs for LC, LPD and SOC stocks, respectively. Chapter 5 explains how default estimates of the proportion of land that is degraded over total land area were derived using the three indicators. The annexes provide additional information on the interpretation of three land-based indicators to determine proportion of degraded land, default data accuracy and limitations, and differences in area and boundary selection.

[1] Available at: <http://www2.unccd.int/sites/default/files/relevant-links/2017-10/Good%20Practice%20Guidance_SDG%20Indicator%2015.3.1_Version%201.0.pdf>.

2 Land cover

Land cover (LC) refers to the observed physical and biological cover of the Earth's surface. It includes vegetation and man-made features as well as bare rock, bare soil and inland water surfaces. It refers to an area of land that has been classified according to the spectral signature of its physical cover captured by satellite remote sensing.

An LC classification system or map legend is a framework to define and organize the LC classes used in a specific application (Di Gregorio and O'Brien, 2012). It is an abstract representation of the situation in the field using well-defined diagnostic criteria and a defined mapping scale. It should be exhaustive and capable of describing the entire region of interest or existing whole earth surface features and landscape elements.

Because LC can change relatively quickly, it is an important indicator of land dynamics resulting from a variety of drivers and factors, both natural and related to human activity. This indicator serves two functions: (i) changes in LC may identify land degradation when there is a loss of ecosystem services that are considered desirable in a local or national context; and (ii) an LC classification system can be used to disaggregate the other two indicators (i.e. LPD and SOC).

2.1 Data sources and selection

The default LC data was selected based on several criteria:

- Global coverage;
- Validation;
- Temporal coverage (i.e. availability of a reasonably long time series, including at least two or more epochs, with regular intervals);
- Timeliness (i.e. availability of future updates at regular intervals);
- Relatively fine spatial resolution.

Based on these criteria, the ESA CCI-LC 300m dataset was selected as default Tier 1 data for the assessment of the LC trend. ESA has released two global LC datasets:

1. The original ESA CCI-LC 300m released for three epochs (2000, 2005, 2010), ver. 1.6.1 (22 classes);
2. The new ESA CCI-LC 300m annual global LC time series from 1992−2015, ver. 2.0.7 (22 classes), released in April 2017.

The original release was made available by the UNCCD secretariat to countries that participated in the LDN TSP. The new release was made available by the UNCCD secretariat to all country Parties within the framework of the UNCCD 2018 reporting process. This guidance document focuses on the new release.

The new ESA CCI-LC release (ver. 2.0.7) (see number 2 above) is a high-quality and reliable dataset which has undergone extensive global validation and delivered consistent global LC maps at 300m spatial resolution on an annual basis from 1992 to 2015 inclusive, based on moderate resolution satellite data (National Oceanic and Atmospheric Administration Advanced Very High Resolution Radiometer High Resolution Picture Transmission (NOAA-AVHRR HRPT), Envisat MEdium Resolution Imaging Spectrometer (MERIS), Envisat Advanced Synthetic Aperture Radar (ASAR), *Satellite Pour l'Observation de la Terre Vegetation* (SPOT VGT) and Proba-V). The CCI-LC maps legend was defined using global common standards, with the description of the classes based on the Land Cover Classification System (LCCS) developed by the Food and Agriculture Organization of the United Nations (FAO), and independent of any specific local legend, geographic area or scale. It counts 22 classes at 'level 1' for the entire world and 14 additional classes at 'level 2' based on more accurate and regional information where available. The adoption of a common LC classification system implemented at global level ensured the harmonization and standardization of the LC analysis and a certain degree of inter-comparability between countries.

The ESA used a series of processes to avoid the independent classification of annual updates, ensuring temporal and spatial consistency between successive maps and facilitating the identification of change processes.[2] While the Envisat MERIS 300m resolution full archive (2003−2012) was used for LC discrimination to establish an LC baseline (t^0), the change detection involved use of the NOAA-AVHRR HRPT at 1km dataset (1992−1999), SPOT VGT time series (1999−2012) and Proba-V (2013–2015) to produce annual global LC change maps. For change detection, the LC classes were mapped to a smaller number of broader Intergovernmental Panel on Climate Change (IPCC) categories. The temporal trajectory of each 1km pixel was systematically analysed to depict the main LC change (13 types of change were detected based on the IPCC classes). As a last step, the change detected at 1km was disaggregated at 300m according to the 300m data availability. The annual LC maps were complemented by high quality ice, glaciers and urban layers.

2.2 Adaptation for UNCCD reporting

For UNCCD reporting purposes, Parties are provided with national subsets of the ESA CCI-LC data on an annual basis from 2000 to 2015, both in the original format with 22 'level 1' LC classes and reclassified using the following 7 aggregated UNCCD classes:

1. Tree-covered areas
2. Grassland
3. Cropland
4. Wetland
5. Artificial surfaces
6. Other land
7. Water bodies.

Table 1 shows how the 36 ESA CCI-LC classes and the 7 main LC classes correspond to one another for UNCCD reporting.

---

[2] For more information on the ESA CCI-LC project 2017 see <https://www.esa-landcover-cci.org/?q=webfm_send/88> and <http://maps.elie.ucl.ac.be/CCI/viewer/download/ESACCI-LC-Ph2-PUGv2_2.0.pdf>.

UNCCD Label	UNCCD Code	ESA CCI Code	ESA's CCI-LC label
Tree-covered areas	1	50	Tree cover, broadleaved, evergreen, closed to open (>15%)
		60	Tree cover, broadleaved, deciduous, closed to open (>15%)
		61	Tree cover, broadleaved, deciduous, closed (>40%)
		62	Tree cover, broadleaved, deciduous, open (15-40%)
		70	Tree cover, needle leaved, evergreen, closed to open (>15%)
		71	Tree cover, needle leaved, evergreen, closed (>40%)
		72	Tree cover, needle leaved, evergreen, open (15-40%)
		80	Tree cover, needle leaved, deciduous, closed to open (>15%)
		81	Tree cover, needle leaved, deciduous, closed (> 40%)
		82	Tree cover, needle leaved, deciduous, open (15-40%)
		90	Tree cover, mixed leaf type (broadleaved and needle leaved)
		100	Mosaic tree and shrub (>50%) / herbaceous cover (< 50%)
Grassland	2	110	Mosaic herbaceous cover (>50%) / tree and shrub (<50%)
		120	Shrubland
		121	Shrubland evergreen
		122	Shrubland deciduous
		130	Grassland
		140	Lichen and Mosses
		151	Sparse trees (<15%)
		152	Sparse shrub (<15%)
		153	Sparse herbaceous cover (<15%)
Cropland	3	10	Cropland, rainfed
		11	Herbaceous cover
		12	Tree or shrub cover
		20	Cropland, irrigated or post-flooding
		30	Mosaic cropland (>50%) / natural vegetation (tree, shrub, herbaceous cover) (<50%)
		40	Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) / cropland (< 50%)
Wetland	4	160	Tree cover, aquatic or regularly flooded in fresh or brakish water
		170	Tree cover, aquatic, regularly flooded in salt or brakish water, Mangroves
		180	Shrub or herbaceous cover, flooded, fresh/brakish water
Artificial surfaces	5	190	Urban areas
Other land	6	200	Bare areas
		201	Consolidated bare areas
		202	Unconsolidated bare areas
		220	Permanent snow and ice
Waterbodies	7	210	Waterbodies

Table 1 Aggregated land cover legend: European Space Agency Climate Change Initiative on Land Cover vs. UNCCD

Land cover change

The ESA CCI-LC epochs from 2000 to 2015 were used to estimate annual LC change for the full database with 22 classes and the 7 UNCCD LC classes. Furthermore, the changes were estimated at the five-year intervals and as net change for the period 2000−2015 for the 7 UNCCD LC classes. The LC changes were coded following a two-digit system, where the first digit refers to the class of the first year of change and the second digit refers to the class of the second year of change. An example is shown here:

- 11, 22, 33 and so on means that there is no change in LC between two different years;
- 13 indicates a change from Tree-covered areas (code 1, first year) to Cropland (code 3, second year).

2.3 Default data outputs

Default data are provided as geo-referenced spatial layers both in raster (GeoTIFF) and vector formats (shapefile) (the latter only for the LC change layer); both are readable and usable with a broad range of standard commercial and open source GIS packages.[3] The raster and vector data are provided both in the original geographical coordinates (WGS84) and the MODIS sinusoidal equal area projection (SR-ORG:6842), which was used as the basis for area calculations. National LC area estimates and the net change for the period 2000−2015 are also provided as numerical data (‘Reporting table’ and ‘Matrix of area changes’), together with the layout maps of LC for the years 2000 and 2015, LC change, and LC flows from 2000 to 2015 (TIFF, PDF).

2.3.1 Metadata

The metadata have been provided according to the ISO 19115 standard, which defines the schema required for describing geographic information and services. The metadata provide information about the identification, extent, quality, spatial and temporal schema, spatial reference and distribution of digital geographic data on LC change (see Table 2).

[3] Including ArcGIS, SAGA GIS, QGIS and R.

Title	*%Country_name%_LC_7/22class_%Year%_300m*
Date of creation/publication/revision	*21-11-2017*
Character Set	*utf8*
Language	*English*
Abstract	*Default data are derived from the European Space Agency's Climate Change Initiative Land Cover dataset (CCI-LC) (http://www.esa-landcover-cci.org/).The CCI-LC project delivers consistent global LC maps at 300 m spatial resolution on an annual basis from 1992 to 2015, based on Meris and Spot-Vegetation satellite imagery.This unique dataset was produced thanks to the reprocessing and the interpretation of 5 different satellite missions.* *The MERIS full archive (2003-2012) was used for land cover discrimination (i.e. to establish a land cover baseline) at 300 m resolution. The land cover change detection made use of the NOAA-AVHRR dataset at 1 km spanning from 1992 to 1999, along with the SPOT-Vegetation time series from 1998 to 2012 and the PROBA-V from 2013 to 2015. The temporal trajectory of each 1-km pixel was systematically analysed to depict the main land cover change using the IPCC classes (13 types of change were detected based on the IPCC classes). As a last step, the change detected at 1 km was disaggregated at 300 m according to the 300 m data availability.* *The LC legend was defined using the Land Cover Classification System (LCCS), a hierachical classification developed by the United Nations (UN) Food and Agriculture Organization (FAO). The "level 1" legend, also called "global" legend, counts 22 classes and each class is associated with a ten values code (i.e. class codes of 10, 20, 30, etc.). The CCI-LC maps are also described by a more detailed legend, called "level 2" or "regional" with 14 additional classes, which makes use of more accurate and regional information so to reach a higher level of detail in the legend. The regional classes are associated with non-ten values (i.e. class codes such as 11, 12, etc.). The 22 original classes were aggregated into 7 main land cover types (aligned with the 7 land use classes recommended by IPCC) to easily estimate the critical change trend*
Point of Contact	*Programme Officer*
Individual Name	*Sara Minelli*
Organization Name	*UNCCD*
Contact Info	sminelli@unccd.int
Role	*Programme Officer*
Descriptive Keywords	
Topic Category	*Land Cover, Land Cover Change, Land Productivity Dynamic, Land Degradation, Soil Organic Carbon, SDG*
Geographic Bounding Box	
West Longitude	
East Longitude	
South Latitude	
North Latitude	
Temporal Extent	*1992 -2015*
Begin Date	*1992*
End Date	*2015*
Metadata section	
File Identifier	*Unique code*
Metadata Language	*English*
Character Set	*utf8*
Date Stamp	*Date formatted as YYYY-MM-DDTHH:mm:ss (filled out automatically by the system)*
Metadata Standar Name	*ISO 19115*
Metadata Standard Version	*FDIS*

Table 2 Example of International Organization for Standardization (ISO) standard metadata for the land cover indicator

2.3.2 Maps

Figure 1 shows an example of LC maps for Madagascar based on the UNCCD 7-class LC legend. These include: (i) LC 2000; (ii) LC 2015; (iii) LC change 2000−2015; and (iv) LC flows 2000−2015, where the LC flows identify the gains and losses for each represented LC class.

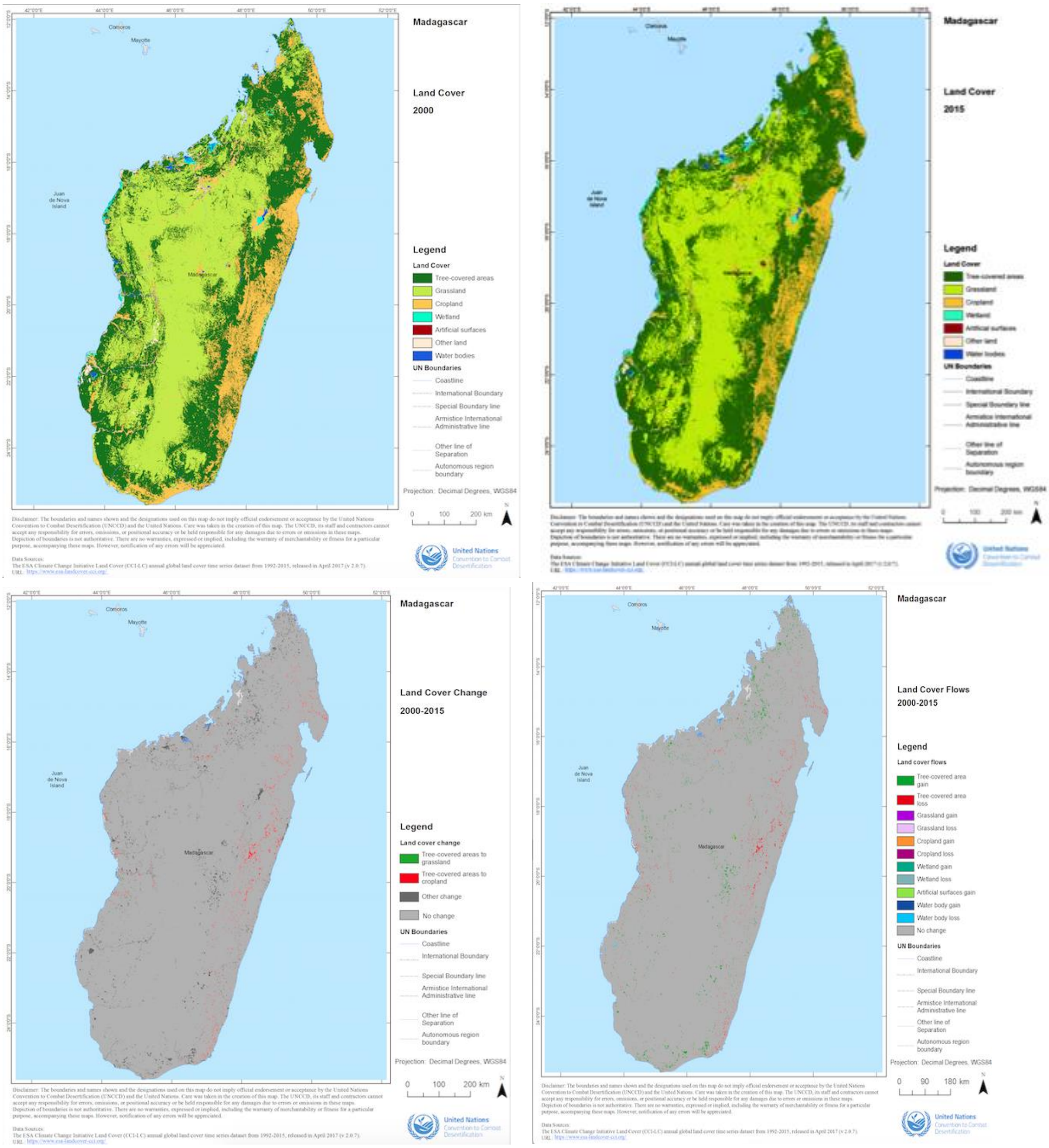

Figure 1 Maps of land cover (LC) 2000, LC 2015, LC change 2000−2015 and LC flows 2000−2015

2.3.3 Tables

The tabular data are presented in “reporting tables” and “matrices of area change”. The reporting table shows the annual LC area estimates and the net LC change between 2000 and 2015 (see Table 3).

Year	Land cover (km2)					
	Tree-covered areas	Grassland	Cropland	Wetland	Artificial surfaces	Other land
2000	250999	246036	79227	4378	345	3367
2001	251254	245394	79571	4383	353	3376
2002	251509	244958	79738	4392	360	3387
2003	252077	244178	79986	4515	363	3409
2004	254609	241367	80266	4581	366	3422
2005	255324	240643	80265	4592	372	3423
2006	255758	240050	80423	4610	376	3427
2007	256330	239425	80462	4635	383	3426
2008	256790	238803	80604	4652	388	3429
2009	257560	237944	80678	4671	395	3432
2010	257247	237947	80987	4706	402	3434
2011	256929	237923	81304	4747	410	3436
2012	256552	237932	81657	4754	421	3434
2013	256421	237925	81779	4754	440	3433
2014	256289	237811	81992	4760	455	3431
2015	256288	237807	81989	4760	463	3431
Net area change	5289	-8229	2762	382	118	64

Table 3 Reporting table showing the annual LC statistics and the net area changes from 2000 to 2015 for Madagascar. Each set of areas is based on the equal-area sinusoidal projection.

The distribution of the main LC classes for Madagascar for the years 2000 and 2015 and the annual LC changes from 2000 to 2015 are shown in the following pie charts and histogram, respectively (see Figure 2).

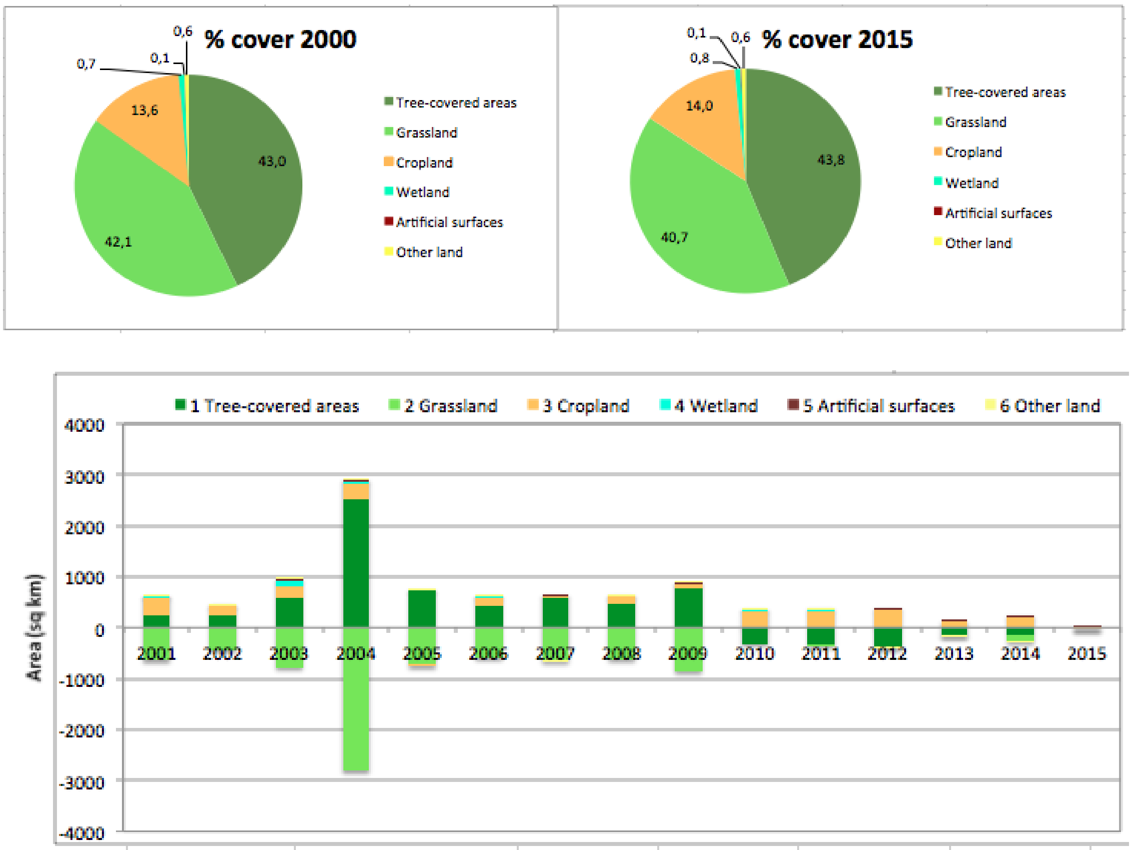

Figure 2 Distribution of main land cover (LC) categories as percentage of total area for 2000 and 2015 and annual trend in changes in LC from 2000 to 2015 for Madagascar

The changes were organized in a matrix of area changes (km^2), which shows the change from one LC class to another between the initial year and the current monitoring year. For example, the 2000−2015 matrix of area changes summarizes the cross-tabulated data between LC classes in 2000 and 2015 and shows the total area of land in km^2 associated with each change (see Table 4 and Figure 3).

2015 / 2000	Tree-covered areas	Grassland	Cropland	Wetland	Artificial surfaces	Other land	Water body
Tree-covered areas	245017	787	5025	123	6	22	20
Grassland	8540	236980	265	38	83	41	89
Cropland	2562	4	76608	20	22	1	10
Wetland	33	5	12	4306	5	2	17
Artificial surfaces	0	0	0	0	345	0	0
Other land	5	0	0	4	0	3339	20
Water body	131	32	80	270	3	27	4119

Table 4 Matrix of area changes: cross-tabulated data between LC in 2000 and 2015 for Madagascar. Each set of areas is expressed in square kilometers and based on the equal-area sinusoidal projection.

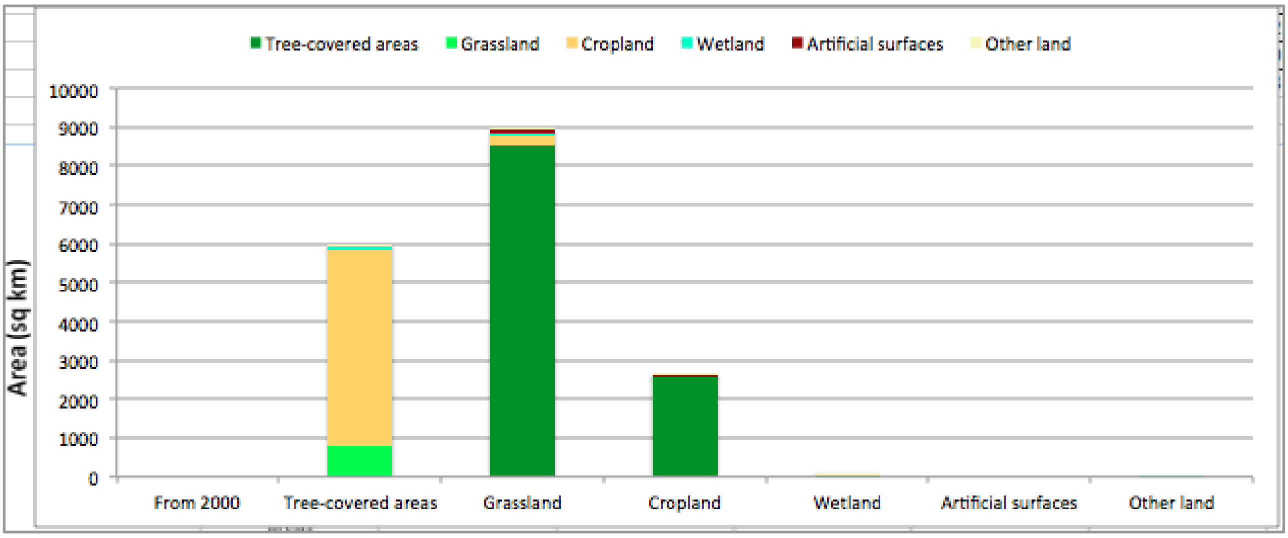

Figure 3 Histogram showing the land cover (LC) changing between classes from 2000 to 2015: the abscissa represents the LC classes while the columns represent the classes of changes for 2015.

In the matrix of area changes the rows total (minus the ‘no change’ diagonal value) represents the reductions (losses) and the columns total (minus the ‘no change’ diagonal value) represents the additions (gains) for each of the represented LC classes.

The total gains and losses (flows) resulting from the processes of change from one land cover class to another from 2000 to 2015 are shown in table 5 and Figure 4 below.

Land cover flows from 2000 to 2015	Tree-covered area	Grassland	Cropland	Wetland	Artificial surfaces	Other land	Water body
Opening land cover (2000)	251000	246036	79227	4380	345	3368	4662
Additions to land cover	11271	828	5382	455	119	93	156
Reductions to land cover	5983	9056	2619	74	0	29	543
Closing land cover (2015)	256288	237808	81990	4761	464	3432	4275
Tot gains/losses	5288	-8228	2763	381	119	64	-387

Table 5 Summary of land cover classes gains (additions) and losses (reductions) from 2000 to 2015.

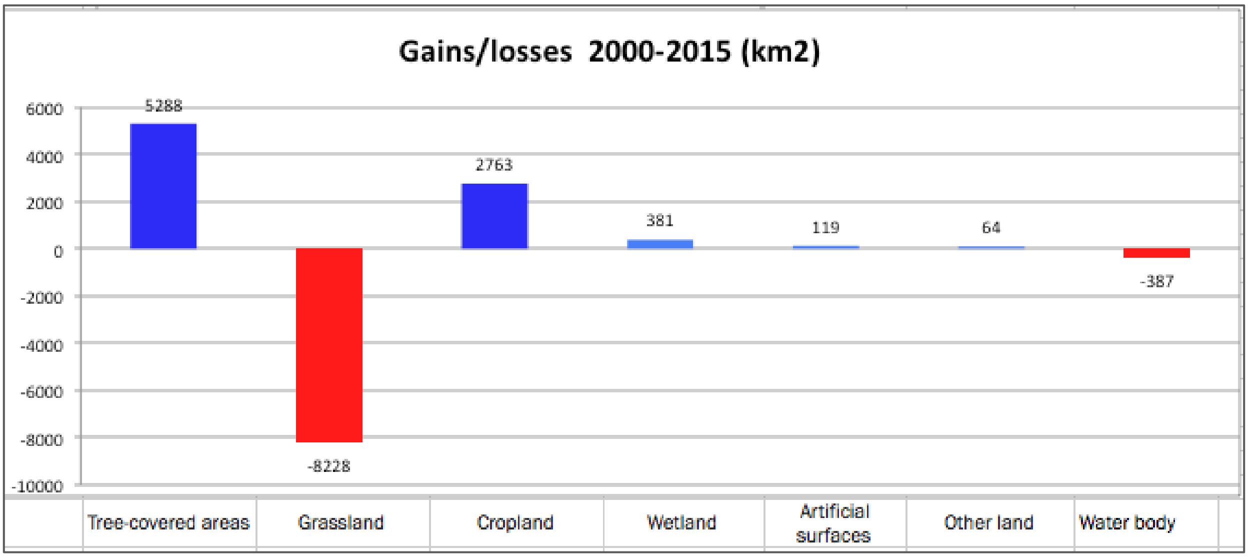

Figure 4 Land cover flows showing the total gains and losses for each represented class for Madagascar.

3 Land productivity dynamics

Land productivity estimates the overall above-ground vegetation biomass productivity resulting from all land components and their interactions. It points to long-term changes in the health and productive capacity of the land. It also reflects the effects of changes in ecosystem functions for plant and biomass growth.

For the purposes of reporting on SDG indicator 15.3.1, it is not necessary to quantify the magnitude of change in productivity in biomass units of net primary productivity (NPP); rather it is important to determine whether productivity is increasing (positive), decreasing (negative), or stable for the land unit over time (Sims et al., 2017).

In this regard, the land productivity dynamics (LPD) dataset provides five qualitative classes of land productivity trends over the time period 1999−2013. These qualitative classes do not directly correspond to a quantitative measure (e.g. tonne/ha of NPP or gross primary production (GPP)) of lost or gained biomass productivity, nevertheless there is an indirect relationship. The five classes are a qualitative combined measure of the intensity and persistence of negative or positive trends and changes of the photosynthetically active vegetation cover over the observed period. While not an absolute measure of land productivity, it depicts trajectories of long-term seasonal dynamics and departures from it that are typically related to overall land productivity change.

3.1 Data sources and selection

Populating data on land productivity for reporting can be challenging due to the lack of information based on long-standing Earth observations in many countries, or to the limited capacity to conduct remote sensing analyses. For this reason, global Earth observation products were used to provide harmonized information on land productivity to countries.

3.1.1 The 1km resolution land productivity dynamics dataset as default

The European Commission's Joint Research Centre (JRC) LPD datasets at 1km resolution were used as the default dataset for UNCCD reporting (Ivitis & Cherlet, 2013). The JRC LPD product was developed in the framework of the World Atlas of Desertification (WAD).

It is a global 15-year (1999 to 2013) time series of daily SPOT VGT normalized difference vegetation index (NDVI) images aggregated/composited for observation every 10 days (i.e. 540 observations overall for each pixel). As with other operational global remote sensing time series products, which are typically generated by national and international space agencies, it follows comparable standards and includes corrections for radiometric system specifications, atmospheric effects, illumination conditions and cloud detection to obtain continuous standardized vegetation indices over time.

The JRC's LPD dataset provides the following five qualitative classes of persistent land productivity trajectories from 1999 to 2013:

1. Declining;

2. Moderate decline;
3. Stressed;
4. Stable;
5. Increasing.

The WAD method interprets NDVI to derive three main metrics: trend, state and performance. These three metrics can help identify potential degradation in areas where productivity may be increasing over time (trend) but remain low relative to the historical range of productivity levels for that location over time (state) or compared to other regions of similar NPP potential (performance). Table 5 shows the steps of LPD default data processing in relation to the recommended metrics in the Good Practice Guidance for SDG indicator 15.3.1.[4]

The default 1km LPD dataset has undergone a very detailed validation process by comparing it with other operational NDVI time series and against global field validation/calibration networks. Overall, no significant differences were found between the LPD dataset and other operational validated NDVI time series over the same geographic areas.[5]

Recommended metrics in UNCCD Good Practice Guidance for SDG indicator 15.3.1, 2017	Land productivity dynamics (LPD) default data processing steps
Trend	Aggregation of the 36 annual normalized difference vegetation index (NDVI) observations for all 15 years to an annual productivity proxy metric, e.g. integral NDVI over the main seasonal growth cycle in cases of pronounced ecosystem seasonality or integrated yearly NDVI in the absence of pronounced seasonality Calculation of the linear trend of the z-score normalized time series of aggregated NDVI values over the 15 years and parallel calculation of the net change over the same period by applying the Multi Temporal Image Differencing (MTID) method[6] Combination of the two variables trend and change, with four possible variants (+trend/+change; +trend/-change; -trend/+change; -trend/-change)
State	Per pixel derivation of the mean annual land productivity in the initial and final three years of the time series, followed by unsupervised classification into two productivity level class layers representing the 'land productivity state' at the beginning and end of the time series; a productivity class change layer is also generated.
Performance	Generation of performance weighting factors through local net scaling applied to the last five years' average values of the annual productivity metric within ecosystem functional units[7]

[4]Available at: <http://www2.unccd.int/sites/default/files/relevant-links/2017-10/Good%20Practice%20Guidance_SDG%20Indicator%2015.3.1_Version%201.0.pdf>.
[5] Validation report SPOT VGT <http://proba-v.vgt.vito.be/sites/proba-v.vgt.vito.be/files/20170214_-_evaluation_vgt_reprocessing_-_versie_voor_website.pdf>.
[6] Guo, W. Q., Yang, T. B., Dai, J. G., Shi, L., & Lu, Z. Y. (2008). Vegetation cover changes and their relationship to climate variation in the source region of the Yellow River, China, 1990–2000. International Journal of Remote Sensing, 29(7), 2085-2103.
[7] Ivits, E., Cherlet, M., Mehl, W., & Sommer, S. (2013). Ecosystem functional units characterized by satellite observed phenology and productivity gradients: A case study for Europe. Ecological indicators, 27, 17−28.

Final map of land productivity dynamics (synthesized using the metrics: trend, state and performance)	Logical matrix combination of the above-mentioned trend, state and performance layers for conclusive aggregation to the final 5 LPD classes.

Table 6 Land productivity dynamics default data processing in relation to the UNCCD Good Practice Guidance for SDG indicator 15.3.1, 2017

3.1.2 Land productivity dynamics dataset 250m resolution for small island developing States

Since the 1km resolution JRC LPD dataset is unsuitable for small island developing States (SIDS), a 250m resolution product was developed specifically for these countries. The 250m resolution LPD dataset was calculated from the Moderate Resolution Imaging Spectroradiometer (MODIS)/Terra Vegetation Indices 16-Day L3 Global 250m SIN Grid V005 on board the United States National Aeronautics and Space Administration (NASA) Aqua satellite. The MODIS NDVI product was computed from atmospherically corrected bi-directional surface reflectance that have been masked for water, clouds, heavy aerosols and cloud shadows. The algorithm for generating a 250m resolution LPD dataset from NDVI MODIS was validated for Cape Verde using the 1km LPD dataset and expert knowledge of the island. The algorithm was then used to process LPD for other SIDS.

3.2 Adaptation for UNCCD reporting

To meet the requirements for UNCCD reporting, the LPD data was overlaid with the LC data, and the area distribution of LPD classes between 2000 and 2013 over each LC class was estimated. The same process was used for LC change, whereby the locations experiencing LC change were overlaid with the LPD data and the area distribution of LPD classes was calculated.

3.3 Default data outputs

LPD default data are provided as geo-referenced spatial layers in raster (GeoTIFF) format, readable and usable with a broad range standard commercial and open source geographic information system (GIS) packages. The raster data are provided both in the original geographical coordinates (WGS84) and the MODIS sinusoidal equal-area projection (SR-ORG:6842), which was used as the basis for area calculations. LPD area estimates in km^2 for the period 2000−2013, for each LC class as well as where the LC has changed, are also provided as numerical values (reporting table) and maps (TIFF).

3.3.1 Metadata

The metadata have been provided according to the ISO 19 115 standard, which defines the schema required for describing geographic information and services. The metadata provide information about the identification, extent, quality, spatial and temporal schema, spatial reference, and distribution of digital geographic data on LPD.

3.3.2 Maps

An example of the LPD map for Bolivia is shown in Figure 5. For Bolivia, 15.3 per cent of the country's vegetated land surface shows persistent declining trends or stress in land productivity (i.e. LPD classes 1, 2 and 3). However, 23.6 per cent of the country is stable and 55.8 per cent of the country shows an increasing trend in land productivity.

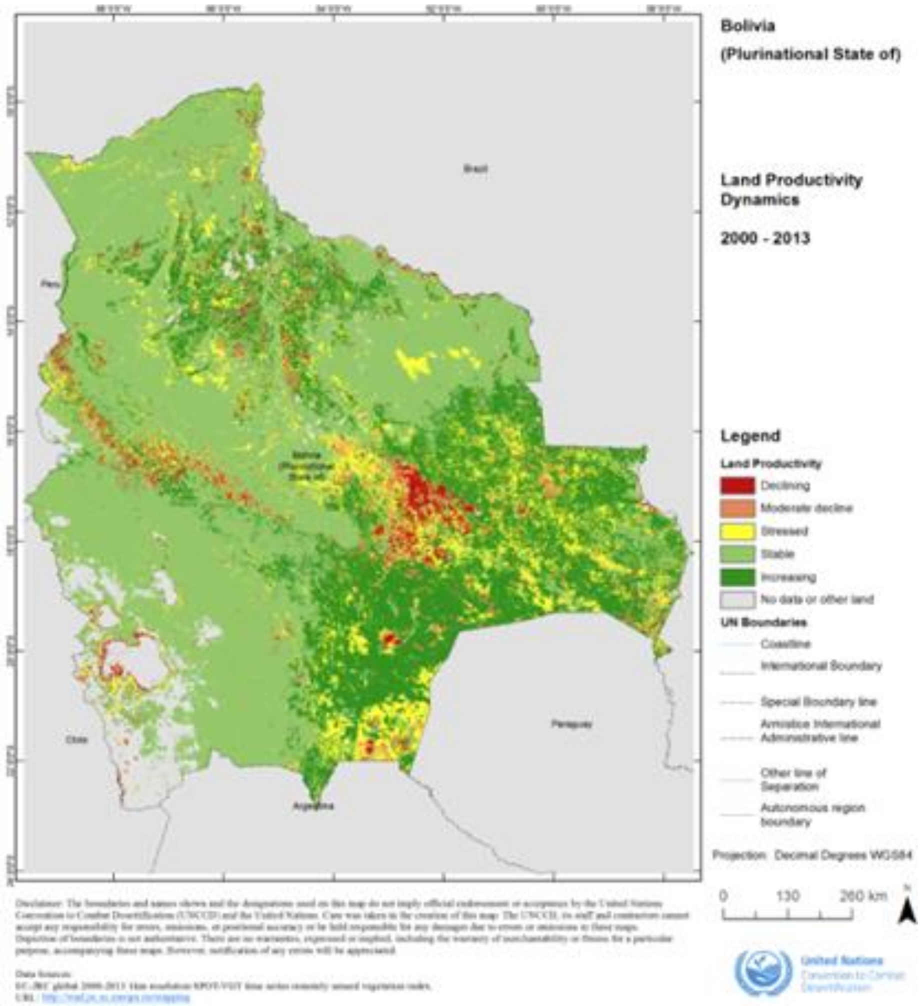

Figure 5 Land productivity dynamics classes for Bolivia

3.3.3 Tables

In the reporting table, the distribution of LPD classes is further broken down into the seven UNCCD LC classes (see Table 7).

Table 8 shows the proportion of LPD classes per LC change type. The table only includes the top four LC changes (by area) that are generally considered to be a 'degrading process'.

In both tables, each set of areas is based on the equal-area sinusoidal projection.

Land cover class	Net land productivity dynamics 2000-2013 (km 2)					
	Declining	Moderate decline	Stressed	Stable	Increasing	No data
Tree-covered areas	9193	14813	69598	339435	157220	2638
Grassland	6449	4597	18516	159034	53423	9244
Cropland	7452	4594	11954	21810	19000	406
Wetland	1377	939	2994	11454	12811	1483
Artificial surfaces	199	58	88	370	89	15
Other land	2542	140	2374	41890	65	40528

Table 7 Area distribution of land productivity dynamics classes by unchanged land cover class

Land conversion		Net area change (km2)	Net land productivity dynamics 2000-2013 (km 2)				
From	To		Declining	Moderate decline	Stressed	Stable	Increasing
Tree-covered areas	Cropland	12273	808	1678	3725	3877	2142
Tree-covered areas	Grassland	8564	601	901	2264	1058	3712
Tree-covered areas	Wetland	2267	89	92	272	1441	336
Wetland	Tree-covered areas	2035	72	59	138	1421	303

Table 8 Area distribution of land productivity dynamics classes by change, limited to the top four land cover changes considered to be a 'degrading processation'

4 Soil organic carbon stock

Soil organic carbon (SOC) is one of the most important constituents of soil due to its capacity to promote plant growth, recycle nutrients to maintain soil fertility, and clean and store freshwater whilst reducing downstream flooding and promoting dry season flows. SOC is therefore intrinsically connected to soil quality. Maintaining carbon stocks in soils by providing adequate fresh organic matter for decomposition (and/or preventing excessive loss) can also generate additional benefits through climate change mitigation and biodiversity conservation.

A common point of all forms of land degradation is SOC content depletion, where reduced organic matter inputs and inappropriate use destroy soil structure and reduce biodiversity, leading to the progressive erosion of the non-renewable mineral fraction of soil. Once degraded, this mineral fraction is difficult to impossible to recover in the near future (most mineral fractions of soils are far in excess of 10,000 years in development, weathering from solid rock into more biologically useful particle sizes).

SOC stocks are influenced by land-use and management activities that affect litter input rates and soil organic matter loss rates: inputs are primarily controlled by decisions impacting NPP and/or the retention of dead organic matter (e.g. how much harvested biomass is removed as products and how much is left as residues), while outputs are mostly influenced by management decisions that affect microbial and physical decomposition of soil organic matter (e.g. tillage intensity) (IPCC, 2006). Depending on interactions with previous land-use, climate and soil properties, changes in management practices may induce increases or decreases in soil carbon stocks.

4.1 Data sources and selection

Populating the SOC indicator is challenging, but data sources and methodologies for this vital indicator are now becoming available. In order to derive trends in SOC, two types of information are required:

- **Baseline SOC stocks** (e.g. tonne/ha) for the country in the year of interest (here 2000);
- Some way of relating changing land use/LC conditions to **changes in SOC stocks**.

While a number of data sources are available for the computation of the SOC indicator, the selected data sources of default Tier 1 data were identified taking into account their:

- Immediate availability and readiness for use;
- Global spatial coverage;
- Appropriate resolution.

After evaluation of the above considerations relating to the identified datasets for SOC, the default data source selected was the ISRIC SoilGrids250m[8] global soil mapping products, specifically the SOC percentage, bulk density and gravel content layers (Hengl et al., 2016). Whilst SoilGrids250m was not made specifically to represent SOC in the year 2000 (being constructed from legacy soil data spanning several decades), it is a readily accessible, globally consistent product, containing modelled relationships between 150,000+ soil profiles and 158 remotely sensed covariates and is at a suitable resolution for national reporting. As the large number of sample points cover a wide range of environmental covariate combinations, it is also possible to transfer the relationships

[8] <http://www.isric.org/explore/soilgrids>.

between SOC and the environmental covariates found in one country to another country that contains the same combinations but no observed data.

In addition, as the spatial variation of SOC stocks is several times larger than the temporal variation of SOC stocks (e.g. Conant et al., 2011), the derived products from SoilGrids250m for tier 1-level reporting are considered a suitable source of information in the absence of national SOC stock estimates for the year 2000.

4.2 Adaptation for UNCCD reporting

Source data was adapted to meet the needs of the UNCCD default data for reporting on the indicator SOC stocks using the following steps.

4.2.1 Baseline soil organic carbon stocks

Baseline SOC stocks and changes thereto can either be modeled or directly measured, or some combination thereof. In order to obtain an indication of default baseline SOC stocks, two products derived from ISRIC's SoilGrids250m were combined into an ensemble product for the 0−30 cm depth (Hengl et al., 2016, ver. October 2017). These two products are the direct prediction of SOC density (integrated over the 0−30 cm depth) and a simple calculation using separate rasters of the SOC percentage, bulk density, gravel fraction and depth to bedrock products to calculate a predicted SOC stock for 0–30 cm (i.e. topsoil). These two different paths to the same outcome (0−30 cm SOC stocks) were then averaged as an ensemble product.

4.2.2 Change in soil organic carbon stocks 2000−2015

In order to obtain an estimate in the change of SOC stocks suitable for UNCCD reporting, a modified Tier 1 IPCC methodology for compiling national greenhouse gas inventories for mineral soils is used to predict SOC trends at country level (IPCC, 2006). Three types of broadly defined 'change factors' exist within the Tier I IPCC methodology:

- A land-use factor (FLU) that reflects carbon stock changes associated with type of land use;
- A management factor (FMG) representing the main management practice specific to the land use sector (e.g. different tillage practices in croplands),
- An input factor (FI) representing different levels of carbon input to soil.

Assuming LC can be a stand-in for land use, then the change factors based on transitions from one land use to another (FLU) can be populated from the indicator for LC and its annual transitions. However, there are currently no known global data at a sufficient resolution to obtain information for the management (FMG) and input (FI) change factors (see Table 9).

From Land cover class	To Land cover class	Climate	Default FLU	Default FMG	Default FI
Tree-covered areas	Tree-covered areas	all	1	1	1
Grassland	Grassland	all	1	1	1
Cropland	Cropland	all	1	1	1
Wetland	Wetland	all	1	1	1
Artificial surfaces	Artificial surfaces	all	1	1	1
Other land	Other land	all	1	1	1

Table 9 Change factors for land-use change (FLU), management styles (FMG) and inputs for land cover classes remaining in the same class between two dates. Setting each factor to 1 indicates no changes applied.

Therefore, the dynamic component informing SOC trends is the land use/cover information as a proxy for land-use change. Such changes are combined with the SoilGrids estimate, the general bioclimatic zone and the ESA annual assessment of LC in order to make coarse estimates of SOC stock change using change factors (e.g. see Table 3.3.4 in IPCC (2006) for Cropland change factors). Such changes are averaged over 20 years and then applied on an annual basis for the duration of the change within the 2000−2015 period. Where LC switches multiple times within the 2000−2015 period, the new LC change is applied to the previous SOC estimate and carried through the rest of the period (or until another LC change occurs).

During the 2000—2015 period, however, many LC changes occur globally that are additional to the IPCC methodology, even if they are uncommon/unlikely changes. For these less common transitions, the below FLUs were derived. All FLUs are summarized in Table 10.

- Catastrophic loss scenario: Where LC has moved from a vegetated type (e.g. trees or grassland) to an unvegetated ‘other lands’ type, the loss of SOC from soils upon conversion is estimated as a 90 per cent loss in 20 years (FLU = 0.1), intended to reflect both catastrophic degradation and substantial surface soil erosion (implied in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) and implemented here).
  Exception: Where the transition into the ESA subclass of ‘permanent snow & ice’ occurs, no change in SOC stocks are applied (FLU = 1).
- Restoration scenarios: Where LC has moved from a degraded type (e.g. other land) to a less degraded type (e.g. trees or grassland), an inverse relationship is employed to estimate the restoration of SOC stocks (e.g. cropland into tree-covered areas for wet boreal climates): FLU = 1/0.69 = 1.45).
  Where the FLU for the restoration cases is < 0.4 (e.g. a 60 per cent loss), the FLU is capped at two times the initial SOC stock for these ‘restoration cases’ due to a paucity of SOC stock sequestration/restoration studies after a catastrophic loss of soil and SOC has occurred.
- For the wetland class moving to any other LC class, a worst case scenario is assumed, where the transition is expected to result in drainage/excavation/erosion/burning, leading to the decomposition of all SOC except for refractory (charcoal) carbon. Here, the 96 per cent loss of SOC is spread over 20 years and is based on the loss of SOC stocks from organic soils (previously) under mangrove cover (IPCC, 2014).

- For soils moving from vegetated classes (e.g. trees/grasslands/croplands) into the ‘artificial areas’ classes (e.g. urban areas), an FLU of 0.32 was derived from the average difference in SOC stocks reported for adjacent urbanized (after15 years) and vegetated soils, where soil sealing via urbanization is assumed to have led to 68 per cent lower SOC stocks on average (Wei et al, 2014).
- Where the LC class of ‘other lands’ has moved from an ESA subclass of permanent snow & ice to any other LC class, an FLU of 0.7 is derived from the 30 per cent lower SOC stocks found under former thaw lakes representing the historic loss of former permafrost SOC (Zimov et al, 2006). As noted above, the inverse of this state, where any class moves into the subclass of permanent snow, is assumed to lead to no change in SOC stocks, despite moving into the ‘other lands’ class.

For organic soils, Tier I (and II) IPCC methodologies only estimate fluxes and not carbon stock changes, which are found only in Tier III IPCC methodologies. Additionally, as the default separation of organic soils from mineral soils based on SOC stocks is not reliable at the global level, it was not possible to achieve separation of organic and mineral carbon stocks. Instead, the most catastrophic scenario for any changes in the Wetlands class is employed; however, this approach may still underestimate the degradation effects on upland organic soils.

From land cover class	**To land cover class**	**Climate**	**Default FLU**	**Notes**
Wetlands	*Any other class*	all	0.04	1, a
Any other class	Other land	all	0.1	b
Any other class	Artificial surfaces	all	0.32	2, c
Tree-covered areas	Cropland	Temperate dry/Boreal dry	0.8	3
	Cropland	Temperate wet/Boreal moist/Boreal wet	0.69	D
	Cropland	Tropical dry	0.58	d
	Cropland	Tropical moist/Wet	0.48	d
Grassland	Cropland	Temperate dry/Boreal dry	0.8	4
	Cropland	Temperate wet/Boreal moist/Boreal wet	0.69	d
	Cropland	Tropical dry	0.58	d
	Cropland	Tropical moist/wet	0.48	d
Other land, subclass ‘Permanent snow & ice’	*Any other class*	all applicable	0.7	e
Any other class	Other land, subclass ‘Permanent snow & ice’	all applicable	1	e
Water bodies	*Any other class*	all	1	f
Grassland	Forest	all	1	f
Forest	Grassland	all	1	f
Cropland	Tree-covered areas	Temperate dry/Boreal dry	1.25	g
	Tree-covered areas	Temperate wet/Boreal moist/Boreal wet	1.45	g
	Tree-covered areas	Tropical dry	1.72	g
	Tree-covered areas	Tropical moist/wet	2.08	g

Cropland	Grassland	Temperate dry/Boreal dry	1.25	4,g
	Grassland	Temperate wet/Boreal moist/Boreal wet	1.45	g
	Grassland	Tropical dry	1.72	g
	Grassland	Tropical moist/wet	2.08	g
Any other class	Wetlands	all	2	5,g
Other land	*Any other class*	all	2	5,g
Artificial surfaces	*Any other class*	all	2	5, g

1) Except transition to European Space Agency (ESA) subclass Permanent snow & ice where FLU = 1.
2) Except any transition from Wetlands to Artificial where CFLU=0.04 and any other transition to ESA sub-class Permanent snow & ice where FLU = 1.
3) Except Wetlands to Croplands where CFLU = 0.04 and any other transition from ESA subclass 'Permanent snow & ice' where CFLU = 0.7.
4) Grassland is treated the same as Tree-covered areas with regard to SOC.
5) Capped at 2 due to a lack of data relating to restoration after catastrophic SOC losses (<60%).

a) All but refractory carbon is considered oxidized (IPCC 2013, Wetlands Supplement) as per guidance for Mangrove soils.
b) Catastrophic loss of SOC due to loss of all vegetation inputs and subsequent erosion vulnerability, except Permanent snow & ice = no change.
c) Average loss of 68% for soil sealing (Wei et al, 2014).
d) Adapted from IPCC Table 5.5 (IPCC, 2006).
e) Assuming thawing permafrost leading to a 30% loss of SOC (Zimov et al, 2006). The inverse case assumes no change in SOC.
f) Assumes no change in SOC.
g) Restoration cases are assumed to be the inverse of the opposite land-use conversion, and FLU is capped at 2 for 'previous losses' of SOC greater than 60% or an FLU < 0.4.

Table 10 Default change factors for land use change (FLU) for land cover classes moving to another land cover class one or more times between 2000−2015. A factor of 1 it indicates there were no changes applied.

4.3 Default data outputs

The default data are provided as geo-referenced spatial layers in raster (GeoTIFF) format, readable and usable with a broad range of standard commercial and open-source GIS packages.[9] National area estimates for the period 2000−2015 and the distribution of SOC per LC class for the years 2000 and 2015 are also provided as numerical values calculated from the equal-area sinusoidal projection.

4.3.1 Metadata

The metadata have been provided according to the ISO 19115 standard, which defines the schema required for describing geographic information and services. The metadata provide information about the identification, extent, the quality, spatial and temporal schema, spatial reference, and distribution of digital geographic data on SOC (see Table 11).

[9] Including ArcGIS, SAGA GIS, QGIS and R.

Title	Kazakhstan_OCS_%year%_dd.tif
Date of creation/publication/revision	December 04, 2017
Character Set	utf8
Language	English
Abstract	SOC average (ton/ha) to 30 cm is derived from the October, 2017 version of SoilGrids250m. (Hengl, T., de Jesus, J.M., Heuvelink, et al. 2017. SoilGrids250m: Global Gridded Soil Information Based on Machine Learning. PLoS ONE 12(2): e0169748.) Change factors are collected from IPCC 2006 Good Practice Guidlines and other associated sources and applied to the land cover change as reported by ESA CCI LC for the period 2000 to 2015. Effects of management and/or inputs within a land cover category need to be derived at the country level.
Point of Contact	Programme Officer
Individual Name	Sara Minelli
Organization Name	UNCCD
Contact Info	sminelli@unccd.int
Role	Programme Officer
Descriptive Keywords	Provides category keywords and their type i.e. place keywords, theme keywords..
Topic Category	Global SOC stock estimates
Geographic Bounding Box	Minimum bounding rectangle within which data is available
West Longitude	46.49186
East Longitude	87.3126600000001
South Latitude	40.5911100000001
North Latitude	55.4322595917257
Temporal Extent	2000 -2015
Begin Date	2000
End Date	2015
Metadata section	Provides information about the metadata
File Identifier	Unique code
Metadata Language	English
Character Set	utf8
Date Stamp	Date formatted as YYYY-MM-DDTHH:mm:ss (filled out automatically by the system)
Metadata Standar Name	ISO 19115
Metadata Standard Version	FDIS
Metadata Author	UNCCD
Individual Name	Renato Cumani
Organization Name	UNCCD
Contact Info	rcumani@unccd.int
Role	Spatial Data Analyst

Table 11 Example of the metadata supplied for soil organic carbon stocks for each country

4.3.2 Maps

Rasters of SOC stocks for the initial year (2000) and each subsequent year (2001−2015), as well as the total change in SOC stocks for the period 2000−2015 are provided in GeoTIFF format. TIFF files are provided both in the original geographical coordinates (WGS84) and the MODIS sinusoidal equal-area projection (SR-ORG:6842), which was used as the basis for area calculations. Layouts of the SOC stock in 2015 and the summary of SOC changes are also provided (see Figure 6).

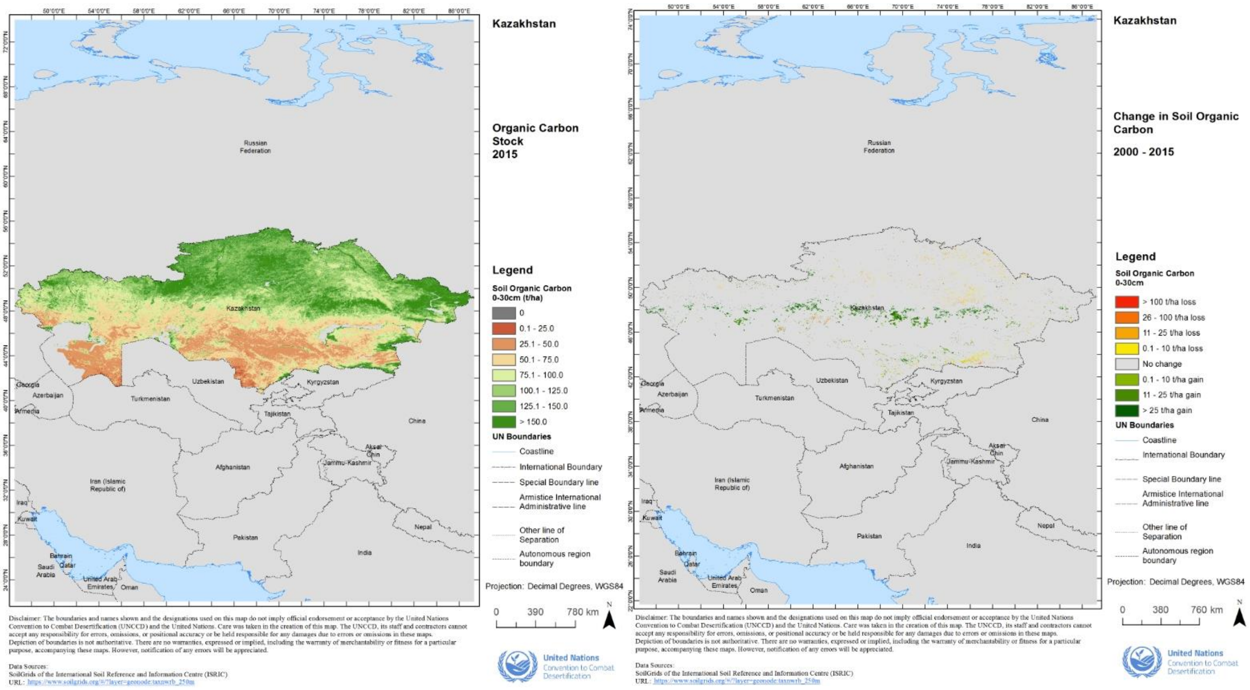

Figure 6 Soil organic carbon (SOC) stock map in 2015 and summation of SOC stock change based on land cover change between 2000—2015 for Kazakhstan.

4.3.3 Tables

The numerical tables provided for SOC stocks and changes are provided per country as laid out in Table 12 and Table 13. Each set of areas is based on the equal-area sinusoidal projection. Average SOC stocks per LC for each year from 2000−2015 (see Table 12) fluctuate due to a combination of land moving to/from each LC class as well as any predicted changes in SOC stocks from that change. The summation of SOC stock changes per LC change (see Table 13) provides the overall average SOC stock for the initial (2000) and final (2015) year – despite there being varying dates of change occurring between 2000 and 2015 − for the top four LC changes (by area) generally considered to be a 'degrading process'.

Year	SOC stock in topsoil (ton/ha)					
	Tree-covered areas	Grassland	Cropland	Wetland	Artificial surfaces	Other land
2000	162.3	95.1	127.6	161.7	100.3	60.7
2001	162.3	95.1	127.6	161.7	100.3	60.7
2002	162.3	95.1	127.6	161.7	100.2	60.7
2003	162.3	95.1	127.6	161.7	100.1	60.7
2004	162.3	95.1	127.6	161.7	100	60.7
2005	162.3	95.1	127.6	161.7	99.8	60.7
2006	162.3	95.1	127.6	161.7	99.7	60.7
2007	162.3	95.1	127.6	161.7	99.6	60.7
2008	162.3	95.1	127.6	161.7	99.5	60.7
2009	162.3	95.1	127.6	161.7	99.3	60.7
2010	162.3	95.1	127.6	161.8	99.2	60.7
2011	162.3	95.1	127.6	161.8	99.1	60.7
2012	162.3	95.1	127.6	161.8	99	60.7
2013	162.3	95.1	127.6	161.8	98.8	60.7
2014	162.3	95.1	127.6	161.8	98.7	60.7
2015	162.3	95.1	127.6	161.9	98.6	60.7

Table 12 Average soil organic carbon (SOC) stocks (tonne/ha) per land cover (LC) class for each year (2000−2015). Fluctuations in average SOC stocks are a combination of land moving to/from a given LC class as well as any predicted changes in SOC stocks.

Land conversion		Net area change (km2)	Soil organic carbon (SOC) stock change (2000-2015)				
From	To		Initial SOC stock (t/ha)	Final SOC stock (t/ha)	Initial SOC stock total (t)	Final SOC stock total (t)	SOC stock change (t)
Cropland	Grassland	8287	110	124.1	91152018	102772836	11620818
Grassland	Other land	1961	87.5	58.2	17157735	11405358	-5752377
Cropland	Artificial surfaces	1034	83.8	61.2	8666307	6330510	-2335797
Grassland	Artificial surfaces	609	97.2	69.3	5913162	4216752	-1696410

Table 13 Summation of SOC stocks for each type of land cover (LC) change occurring in the 2000−2015 period − limited to the top four LC changes considered to be a 'degrading process' (e.g. see annex I). The median year of a particular type of change will influence the magnitude of the SOC change.

5 Proportion of degraded land

SDG indicator 15.3.1 – “the proportion of land that is degraded over total land area” − is derived from the three indicators for estimating land degradation (LC change, LPD and SOC stock). The indicator is used to report on progress towards SDG 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”.

5.1 ‘One out, all out’ rule

Based on the Scientific Conceptual Framework for Land Degradation Neutrality (Cowie et al., 2018), a location is considered degraded if at least one of the three land-based indicators shows a negative change. This is known as the ‘one out, all out’ rule. This rule is applied as a precautionary measure, because stability or improvements in land condition in any of the three indicators cannot compensate for degradation in the others. The three indicators for estimating land degradation are not additive; rather, they are complementary.

5.2 Adaptation for UNCCD reporting

Total land area is defined as the total surface area of a country less the area covered by inland waters, like major rivers and lakes. Thus, the total land area is calculated by summing the area of all land-based LC classes. Areas that are permanently inundated by water are excluded. Areas that are permanently inundated are defined as locations either classified as water bodies in the ESA CCI-LC dataset (ver. 2.0.7) (see Table 1), or masked as permanent water using the European Commission’s Joint Research Centre Global Surface Water product.[10] The Global Surface Water dataset records the percentage of time (0−100 per cent) that it was inundated during the period 1984−2015 for each location on Earth; a threshold of 75 per cent was used here to classify an area as permanently inundated.

The three indicators for estimating land degradation were classified into a degraded or not degraded state following the Good Practice Guidance for SDG indicator 15.3.1.[11] Only the baseline extent of land degradation is calculated to derive the SDG 15.3.1 baseline (t_0) year 2015.

For LC change, those changes between 2000−2015 considered as degrading processes were classified as degradation (see red cells in Figure 7). For land productivity, the locations classified as ‘Declining’, ‘Moderate decline’ or ‘Stressed’ in the LPD default data covering 1999−2013 were classified as degradation. For SOC stocks, locations experiencing a decline in SOC stock over the period 2000−2015 based on the modified and expanded Tier 1 IPCC calculations (Section 4.2.2 of this document) were classified as degraded. The LC change processes where SOC degradation occurs are ‘Deforestation’, ‘Urban expansion’, ‘Vegetation loss’ and ‘Wetland drainage’ (see Figure 7).

[10] Available at: <https://ec.europa.eu/jrc/en/scientific-tool/global-surface-water-explorer>
[11] Available at: <http://www2.unccd.int/sites/default/files/relevant-links/2017-10/Good%20Practice%20Guidance_SDG%20Indicator%2015.3.1_Version%201.0.pdf>.

ORIGINAL CLASS \ FINAL CLASS	Tree-covered area	Grassland	Cropland	Wetland	Artificial surfaces	Other land
Tree-covered area	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
Wetland	Woody Encroachment	Wetland drainage	Wetland drainage	Stable	Wetland drainage	Wetland drainage
Artificial surfaces	Afforestation	Vegetation establishment	Agricultural expansion	Wetland establishment	Stable	Withdrawal of settlements
Other land	Afforestation	Vegetation establishment	Agricultural expansion	Wetland establishment	Urban expansion	Stable

Figure 7 Graphical summary of the land cover (LC) change matrix for the 6 UNCCD classes (30 possible transitions). LC changes considered as a degrading process (red) are classified as degradation in the calculation of proportion of degraded land.

5.3 Default data outputs

5.3.1 Maps

Figure 8 shows the location of degraded land in Colombia. Degraded land is shown in red and represents all locations where there is degradation as classified in the indicators for LC change (2000−2015), or LPD (2000−2013), or change in SOC stock (2000−2015). This is the SDG 15.3.1 (t_0) baseline. Rasters of land degradation for the period (2000−2015) are provided in GeoTIFF format. Cells are classified as '1' (degraded) or '0' (not degraded). TIFF files are provided both in the original geographical coordinates (WGS84) and the MODIS sinusoidal equal-area projection (SR-ORG:6842), which was used as the basis for area calculations.

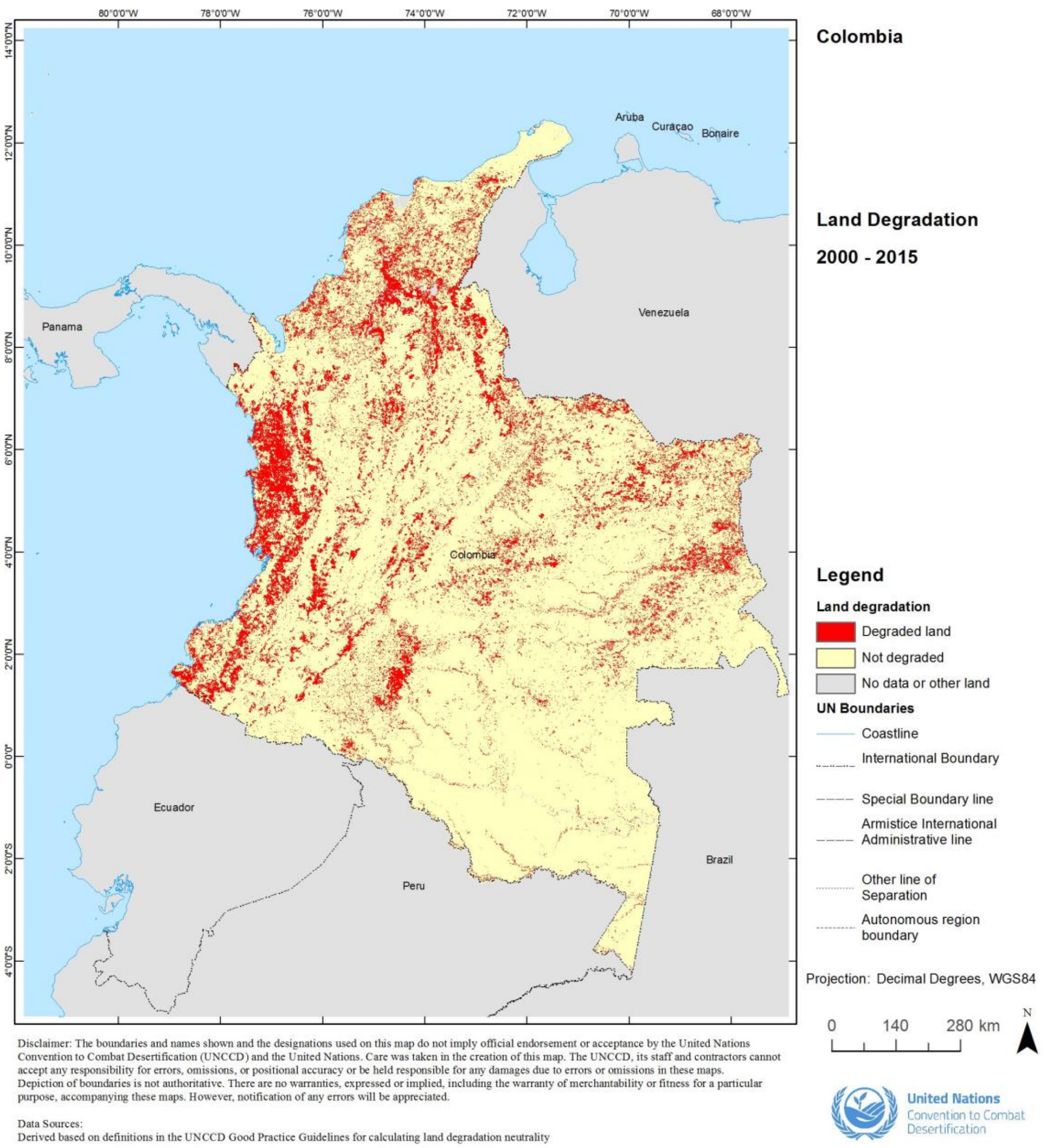

Figure 8 Extent of land degradation in Colombia

5.3.2 Tables

Table 14 shows how the proportion of degraded land is provided in the reporting table for each country, using Colombia as an example.

Total area of degraded land (km2)	Proportion of degraded land	Year
162375	14.6%	2000-2015

Table 14 Proportion of degraded land in Colombia

6 References

Conant, R. T., Ogle, S. M., Paul, E. A., & Paustian, K. (2011). Measuring and monitoring soil organic carbon stocks in agricultural lands for climate mitigation. Frontiers in Ecology and the Environment, 9(3), 169-173.

Cowie, A. L., B. J. Orr, V. M. Castillo Sanchez, P. Chasek, N. D. Crossman, A. Erlewein, G. Louwagie, M. Maron, G. I. Metternicht, S. Minelli, A. E. Tengberg, S. Walter, and S. Welton. (2018). Land in balance: The scientific conceptual framework for Land Degradation Neutrality. Environmental Science & Policy 79:25-35.

Di Gregorio, A. & O'Brien, D., 2012. Overview of Land-Cover Classifications and Their Interoperability. In Remote Sensing of Land Use and Land Cover: Principles and Applications, pp. 37–48.

Eva Ivits, Michael Cherlet. 2013. Land-Productivity Dynamics Towards integrated assessment of land degradation at global scales title; EUR 26052; doi:10.2788/59315. Available at: <http://publications.jrc.ec.europa.eu/repository/bitstream/JRC80541/lb-na-26052-en-n%20.pdf>.

Hengl, Tomislav, Jorge Mendes de Jesus, Gerard BM Heuvelink, Maria Ruiperez Gonzalez, Milan Kilibarda, Aleksandar Blagotić, Wei Shangguan et al. "SoilGrids250m: Global gridded soil information based on machine learning." PloS one 12, no. 2 (2017): e0169748. <http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0169748>.

IPCC, 2006. Guidelines for National Greenhouse Gas Inventories. Volume 4: Agriculture, Forestry and Other Land Use. Geneva. Available at: <http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html>.

IPCC 2014, 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands, Hiraishi, T., Krug, T., Tanabe, K., Srivastava, N., Baasansuren, J., Fukuda, M. and Troxler, T.G. (eds). Published: IPCC, Switzerland Available at: <http://www.ipcc-nggip.iges.or.jp/public/wetlands/index.html>.

Orr et al., 2017. Scientific Conceptual Framework for Land Degradation Neutrality. A Report of the Science-Policy Interface. United Nations Convention to Combat Desertification (UNCCD), Bonn, Germany. Available at: <http://www2.unccd.int/sites/default/files/documents/2017-08/LDN_CF_report_web-english.pdf>.

Seong, Jeong Chang, Karen A. Mulcahy, and E. Lynn Usery. "The sinusoidal projection: A new importance in relation to global image data." *The Professional Geographer* 54, no. 2 (2002): 218-225. DOI: 10.1111/0033-0124.00327.

Sims, N.C., Green, C., Newnham, G.J., England, J.R., Held, A., Wulder, M.A., Herold, M., Cox, S.J.D., Huete, A.R., Kumar, L., Viscarra-Rossel, R.A., Roxburgh, S.H., McKenzie, N.J. (2017). Good Practice Guidance SDG Indicator 15.3.1: Proportion of Land that is degraded over total land area. United Nations Convention to Combat Desertification (UNCCD), Bonn, Germany. Available at: <http://www2.unccd.int/sites/default/files/relevant-links/2017-10/Good%20Practice%20Guidance_SDG%20Indicator%2015.3.1_Version%201.0.pdf>.

UNCCD. (2013b). Report of the Conference of the Parties on its eleventh session, held in Windhoek from 16 to 27 September 2013. Part two: Action taken by the Conference of the Parties at its eleventh session. ICCD/COP(11)/23/Add.1. Bonn: United Nations Convention to Combat Desertification (UNCCD).

Wei, Zongqiang, Shaohua Wu, Xiao Yan, and Shenglu Zhou. “Density and stability of soil organic carbon beneath impervious surfaces in urban areas.” PloS one 9, no. 10 (2014): e109380. <http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0109380>.

Zimov, S. A., S. P. Davydov, G. M. Zimova, A. I. Davydova, E. A. G. Schuur, K. Dutta, and F. S. Chapin. “Permafrost carbon: Stock and decomposability of a globally significant carbon pool.” Geophysical Research Letters 33, no. 20 (2006). <http://onlinelibrary.wiley.com/doi/10.1029/2006GL027484/full>.

Annex I: Interpretation of indicators to determine proportion of degraded land

The purpose of this section is to detail some of the subjective interpretation (decisions) that are required to arrive at the calculation of total degraded lands.

Here we seek to clarify how to interpret the default data at country/national level and point to some areas where a country may consider whether any changes to their definition of 'degradation' at the level of the three land-based indicators is required for their country.

1 Land cover flows and determining degradation

A key aspect for monitoring land cover (LC) includes the definition of degradation in terms of changes between LC classes, which will be stratified and integrated with the other indicators. The major changes identified in the matrix of area changes can be classified as degradation, stable or improvement in terms of net change of natural land capital and are helpful to individuate where change in the LC is not leading to stable or improved land capital.

LC change processes from one class to another can be referred to as land cover flows. While LC changes represent the type of change of one LC class to another between an initial and final monitoring year, the LC flows represent the losses and gains of natural land resulting from the processes of change of one LC class to the others and help to identify the degradation status of the land and what changes are considered to be degrading (see Figure 9). The assignment of flows to an LC change type is a subjective assessment. For example, a transition from a tree-covered area to cropland could be considered as 'deforestation' (tree-covered areas loss) or 'agriculture expansion' (cropland gain), while a transition from grassland to wetland could be considered as 'inundation' (wetland gain) or 'vegetation loss'. Depending on one's standpoint as well as local context and nuances, a pixel of a raster layer of LC flows could be a gain or a loss. Therefore, the prioritization of gains and losses should be done with due consideration of the national and local context of the country.

For example, the natural colonization of land previously used for human activities can be considered at local level as the result of farmland abandonment or direct afforestation. The withdrawal of agricultural activity in favour of forests or natural land is a broader concept than farmland abandonment with forest creation; it is more the result of the decline of agriculture than afforestation programmes. Additional information is necessary to identify an abandonment process (type of agriculture, landscape type, socioeconomic statistics, etc.), which can represent a negative change (cropland loss) or an afforestation process that can be considered as a positive change (tree-covered area gain). Similarly, the change from tree-covered areas and natural land to cropland should be considered in the local context before defining it as deforestation or agriculture expansion.

1.1 Identification of 'degrading processes' at national level – land cover

When calculating default national estimates of the proportion of degraded land for Sustainable Development Goal (SDG) indicator 15.3.1, those LC changes between 2000−2015 considered as degrading processes were classified as degradation (see red cells in Figure 9). Because a single LC change could represent a gain or a loss, a choice must be made as to which type of flow the cell belongs. The definitions in Figure 9, which are from the Good Practice Guidance for SDG indicator 15.3.1, show (i) how the LC changes among the six main UNCCD classes (considering only the land-based LC classes) in the default data were assigned to the major LC flows; and (ii) whether they are generally considered as degradation or not.

These are suggested interpretations and should be evaluated through a participatory process considering national and local conditions. While some changes may be universally agreed as negative (such as conversion of high conservation value forest to cropland or artificial surfaces or conversion of natural areas and productive cropland to artificial surfaces), countries may declare other specific transitions to be negative depending on the local conditions (e.g. bush encroachment). In this regard, a country may consider whether any changes to what is considered 'degradation or not' is required for their particular country. The identification of illogical or improbable flows in the change matrix (highlighted in yellow) will assist in the verification of the LC change analysis.

ORIGINAL CLASS \ FINAL CLASS	Tree-covered area	Grassland	Cropland	Wetland	Artificial surfaces	Other land
Tree-covered area	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
Wetland	Woody Encroachment	Wetland drainage	Wetland drainage	Stable	Wetland drainage	Wetland drainage
Artificial surfaces	Afforestation	Vegetation establishment	Agricultural expansion	Wetland establishment	Stable	Withdrawal of settlements
Other land	Afforestation	Vegetation establishment	Agricultural expansion	Wetland establishment	Urban expansion	Stable

Figure 9 Graphical summary of the land cover (LC) change matrix for the 6 UNCCD classes (30 possible transitions). Unlikely transitions are written in yellow text. Major LC processes (flows) are identified and boxes colour-coded as improvement (green), stable (blue) or degradation (red).

2 Land productivity dynamics classes and determining degradation

The 5 classes of the land productivity dynamics (LPD) dataset integrate information (covering a 15-year observation period from 1999 to 2013) on the direction, intensity and persistence of trends and changes in above-ground biomass generated by photosynthetically active vegetation cover, widely equivalent to the GPP of the global land surface.

Declining and increasing land productivity do not necessarily indicate conditions contributing to land degradation. Decreasing productivity trends may not indicate land degradation, and increasing trends may not indicate recovery. A more detailed assessment of the major land degradation issues is required to establish the contribution of increasing and decreasing productivity of areas. The same LPD classes can represent different ecosystem service outcomes in different parts of the country. For example, a decline in land productivity in some part the country could indicate fewer benefits obtained from provisioning services such as supply of food, water, fiber, wood and fuel. In another part of the country, the same land productivity classes could indicate fewer benefits obtained from regulating services such as maintaining the quality of air and soil, providing flood and disease control, or pollinating crops. In order to better understand the relationships between ecosystem services and land productivity, the distribution of LPD class by each LC class (and preferably models of the ecosystem service supply) should be assessed and complemented by local expertise and observations.

The interpretation of the five classes of land productivity dynamics is presented in Table 15. Additional thematic information is needed to more precisely identify critical land degradation areas. Variations in the main drivers of degradation should be observed within the country’s territory and reported using national information.

<table>
<tr><th>Land productivity dynamics (LPD) classes</th><th>Interpretation of main drivers</th><th>Guidance for interpretation</th></tr>
<tr><td>Declining</td><td rowspan="3">These can be caused by processes including meteorological extremes such as droughts (and the related increased fire risk) or floods, climate variability resulting in a different level of change to the start and/or end of the growing season, and/or abnormally warmer or colder periods.

In densely populated areas, they may be due to the loss of soil or productive land that is caused by expanding infrastructure rather than lower biomass production per surface area unit.

In agricultural areas, changes in land management (e.g. overgrazing, less cultivated varieties producing biomass, fertilization regime, irrigation and land drainage), loss of semi-natural vegetation after conversion to</td><td rowspan="2">A high probability of recently active land degradation processes</td></tr>
<tr><td>Moderate decline</td></tr>
<tr><td>Stressed</td><td>Persistent strong inter-annual productivity variations, which indicate the beginning instability in land conditions</td></tr>
</table>

	agriculture or other land cover changes can be the main drivers.	
Stable	This may not be a steady state but can be caused by natural or human-induced (e.g. sustainable land management) adaptation to the considerable natural variability of environmental conditions.	Low probability of active land degradation and therefore a satisfactory or acceptable situation, but it does not exclude that the land has been degraded before and remains in the that degraded state (i.e. it is not further degrading but also not recovering)
Increasing	This can be caused by approaches to forest or crop production that may result in higher biomass, and, in the longer term, can contribute to improving or deteriorating soil conditions, e.g. wetter periods, regeneration of semi-natural vegetation, and expansion of forests or crop varieties that produce more biomass, such as intensive maize production compared to low/moderate wheat production.	An indication of a satisfactory or improving situation from a degraded state, but in some cases it may also indicate unfavorable processes such as encroachment in grassland or land abandonment.

Table 15 Guidance for the interpretation of land productivity dynamics default data. Source: European Commission Joint Research Centre, 2013, Land-Productivity Dynamics Towards integrated assessment of land degradation at global scales <http://publications.jrc.ec.europa.eu/repository/bitstream/JRC80541/lb-na-26052-en-n%20.pdf>.

2.1 Identification of 'degrading processes' at national level – land productivity dynamics

When calculating the proportion of degraded land for SDG indicator 15.3.1 at national level, the LPD default dataset was aggregated into 2 classes as "degraded" and "non-degraded" as indicated in Table 16.

These land productivity evaluations should be further integrated and contextualized with additional information and adjusted through a participatory process considering national and local conditions.

Land productivity dynamics (LPD) values	**LPD classes**	**Degradation status for the calculation of Sustainable Development Goal 15.3.1**
1	Decline	Degraded
2	Moderate Decline	
3	Stressed	
4	Stable	Non-degraded
5	Increasing	

Table 16 Aggregation of land productivity dynamics default data for the calculation of Sustainable Development Goal indicator 15.3.1

3 Soil organic carbon and determining degradation

In general, any loss in soil organic carbon (SOC) stocks is considered degradation (see Figure 10). However, as the magnitude of SOC loss is important in differentiating significant from non-significant losses, a general default rule of 10 per cent loss in 20 years (the duration period of a change factor) is utilized. This threshold loss represents a loss of 0.05 per cent per annum as compared to a reference year and indicates sustained low-level degradation.

If countries decide to populate management factors (FMGs) and input factors (FIs) for use in land changing classes and/or remaining in the same LC class, then the sensitivity of the default threshold level for SOC stock degradation may be reconsidered in order to detect areas only impacted by management and/or input differences. In practice, FMG and/or FI have smaller impacts on the total SOC stocks that can be less than 10 per cent in 20 years.

	Tree-covered areas	**Grassland**	**Cropland**	**Wetland**	**Artificial surfaces**	**Other land**
Tree-covered areas	Stable	Stable	Degradation	Restoration	Degradation	Degradation
Grassland	Stable	Stable	Degradation	Restoration	Degradation	Degradation
Cropland	Restoration	Restoration	Stable	Restoration	Degradation	Degradation
Wetland	Degradation	Degradation	Degradation	Stable	Degradation	Degradation
Artificial surfaces	Restoration	Restoration	Restoration	Restoration	Stable	Degradation
Other land	Restoration	Restoration	Restoration	Restoration	Stable	Stable

Figure 10 Summary of soil organic stock changes where default land use factors (FLU) lead to losses (red), gains (green) or no change (blue)

3.1 Identification of ‘degrading processes’ at national level – soil organic carbon

When considering the interpretation of predicted SOC stock changes at a national level, there are a number of ‘false positives’ and ‘false negatives’ to consider (e.g. see Figure 11). For example, whilst the transition from Cropland to Grassland may on average have a substantial positive effect on SOC stocks, it can also represent a loss of cropping capacity. Similarly, a switch from Grassland to Cropland will result in SOC losses due to loss in biomass/vegetation inputs from conventional cropping, but can conversely represent an increase in food production.

For these reasons, only general interpretation is possible at the global level, and more locally suitable interpretation is reserved for the national level.

	Tree-covered areas	Grassland	Cropland	Wetland	Artificial surfaces	Other land
Tree-covered areas	Stable	Tree cover loss	Deforestation	Wetland establisment	Deforestation	Deforestation
Grassland	Woody encroachment	Stable	Vegetation loss	Wetland establisment	Urban expansion	Vegetation loss
Cropland	Withdrawal of agriculture	Withdrawal of agriculture	Stable	Wetland establisment	Urban expansion	Vegetation loss
Wetland	Wetland drainage	Wetland drainage	Wetland drainage	Stable	Wetland drainage	Wetland drainage
Artificial surfaces	Urban greening	Urban greening	Urban agriculture	Water sensitive urban design	Stable	Withdrawel of settlements
Other land	Afforestation	Vegetation establishment	Vegetation establishment	Wetland establisment	Urban expansion	Stable

Figure 11 Example of the interpretation of underlying processes driving soil organic carbon stock changes

Annex II: Default data accuracy and limitations

1 Land cover

The adoption of a common land cover (LC) classification system implemented at global level ensures the harmonization and standardization of the LC analysis and a certain degree of inter-comparability between countries. The advantages and disadvantages are as follows:

- Advantages: same classification techniques and classification system used;
- Disadvantages: lower accuracy than using a specific LC data source for each local ecosystem with higher spatial resolution.

Generally, a higher spatial resolution can allow for improved accuracy as smaller differences between LC can be distinguished.[12] For several countries there will likely be suitable regional or national datasets offering a relatively fine spatial resolution, which can be considered as a good option as long as a country is equipped and qualified to handle this type of complex dataset.

1.1 Land cover and land-cover change

The European Space Agency's Climate Change Initiative Land Cover (ESA CCI-LC) dataset is a high-quality and reliable global dataset which has undergone extensive global validation. A critical step in the acceptance of these LC maps by the wider user communities has been providing confidence in their quality through validation against independent data such as ground-based reference measurements and alternate estimates from other projects and sensors. Such a validation process was undertaken and ensured that (i) independent validation datasets were used (i.e. data that was not used during the production of the LC maps); and (ii) the process was carried out by external parties (i.e. by staff not involved in the production of the LC maps).[13]

As a preliminary validation process, the accuracy of the 2015 CCI-LC map was assessed using the GlobCover 2009 validation dataset. A more detailed validation is currently ongoing based on a new validation dataset collected within the framework of the ESA CCI-LC project and which should allow the complexity of the landscape to be captured more effectively and should also validate the LC changes.

The overall accuracy values were weighted by the area percentages of various LC classes (number of samples proportional to the surface area of each LC class). The weighted-area overall accuracy result of the 2015 CCI-LC map is between 71.1 per cent and 71.7 per cent, referring to the overall accuracy assessment for the 22 full classes (with weighted producer/user accuracies depending on the importance of the subject classes). A similar analysis for the 7 LC-aggregated classes used would result in a higher value. Indeed, even if some tree-covered subclasses have low accuracy values (as some different types of tree-covered areas are difficult to distinguish), the aggregated 'tree-covered areas' class has higher accuracy overall (as the different types of tree-covered areas difficult to distinguish are integrated in a simple non-ambiguous class).
In the original ESA CCI-LC dataset, different LC classes have different levels of accuracy:

[12] However, sources of error still derive from the type of algorithms used, the manner of classification, differences in sensors/dates/epochs, etc.
[13] More information on the validation procedure and results of the ESA CCI LC maps can be found at: <http://maps.elie.ucl.ac.be/CCI/viewer/download/ESACCI-LC-Ph2-PUGv2_2.0.pdf>.

- The highest user accuracy values are found for the classes of rainfed cropland, irrigated cropland, broadleaved evergreen forest, urban areas, bare areas, water bodies and permanent snow & ice, which are the most unambiguous and spectrally homogeneous and recognizable classes. A highly positive result is the high accuracy associated with the cropland classes, which are often poorly captured in global LC products due to their dynamic nature and the high variety of agro-systems;
- Conversely, mosaic classes of natural vegetation are associated with the lowest user accuracy values, as well as the classes of lichens and mosses, sparse vegetation, flooded forest with fresh water and mixed broadleaved and needle-leaved forest.

It shall also be mentioned that the quality of the map varies according to the region of interest. Regional accuracy is poorer in the western part of the Amazon basin, Chile, southern Argentina, the western Congo basin, the Gulf of Guinea, eastern Russia, the eastern coast of China, and Indonesia due to poorer European Space Agency Medium Resolution Imaging Spectrometer (MERIS) coverage in these areas.

Regarding the LC change assessment, the ESA CCI-LC dataset (ver. 2.0.7) has the LC changes as an ‘integral part’ of the processing chain, and consequently the accuracy of LC changes is higher, especially for urban and wetlands areas, because the LC maps are more consistent in terms of time. The change detection made use of the National Oceanic and Atmospheric Administration Advanced Very High Resolution Radiometer High Resolution Picture Transmission (NOAA-AVHRR HRPT) 1km dataset (1992−1999), the *Satellite Pour l’Observation de la Terre Vegetation* (SPOT VGT) time series (1999−2012) and the Proba-V (2013–2015) to produce annual global LC maps. The change analysis was detected considering the temporal trajectory of each pixel, which avoids an independent classification of annual updates, ensuring temporal and spatial consistency between successive maps and allowing for the identification of important change processes.

Given the methodology to detect the change, it is important to highlight that:

- The CCI-LC dataset does not capture all the possible changes between the 22 Land Cover Classification System (LCCS) LC classes. The 22 LCCS LC classes are grouped into the 6 IPCC land categories for change detection. Consequently, any change occurring between LCCS classes that are part of the same Intergovernmental Panel on Climate Change (IPCC) land category is not captured by the CCI-LC dataset.
- In order to allow for the detection of a change from class X to class Y, the developed method needs to observe the new class Y for at least two consecutive years. As a consequence, abrupt changes are better captured than gradual ones. Abrupt changes are characterized by sudden LC transitions from one IPCC class to another that most often last more than two years (e.g. loss of forest to an agriculture class). Conversely, gradual changes that can be understood as slow transitions between two IPCC classes by going through intermediate mosaic classes are not so well detected (e.g. transitions from shrubland to bare area by going through successive LC states such as mosaic and grassland classes).
- All annual CCI-LC maps are delivered at 300 m spatial resolution, but the change detection is performed at 1 km spatial resolution. This means that only LC changes visible at 1 km are detected.

- The change detection performance is highly dependent on the input data quality and availability. The general lower quality of AVHRR surface reflectances and georeferencing implies a less reliable change detection during the 1992−1999 period.

Seasonality is important to consider because it could create uncertainty in LC change detection. Images from different seasons (e.g. the dry season vs. the wet season) could produce different LC classifications due to major changes in vegetation cover at different times of the year. These seasonal factors are most often recorded in:

- Natural vegetation areas: For example, woody vegetation in the dry season is leafless and its total cover can appear less extensive than it is;
- Wetland and water areas: According to the LC classes present in the legend, which depict perennial/non-perennial natural water bodies (standing or flowing), it is not possible to classify the differences due to seasonal factors or link them to the depth of a water body itself.

However, the processing chain of the ESA CCI-LC is designed to capture the seasonality (inter-annual temporal variation), and hence it is not affected much by the acquisition times of images from different seasons, unless these images were not available due to atmospheric perturbations (such as clouds). The CCI-LC used 7-day composite images as input, and the seasonality of the LC was an essential input to the classification system for distinguishing classes that are similar spectrally but that have a totally different temporal behavior.

Finally, it is important to note that the pixels of LC datasets are rarely homogenous (in reality they may contain a mix of, for example, built-up land, grassland and tree cover). Therefore, calculating areas based on these datasets is inherently only approximate.[14]

2 Land productivity dynamics

The five classes of the LPD data set provide information over a 15-year observation period (1999—2013) by determining the photosynthetically active vegetation cover, which is widely equivalent to the gross primary production (GPP) of the global land surface.

An LPD 1km resolution pixel may contain a considerable amount of vegetation heterogeneity. Furthermore, the 5 LPD classes provided are not associated with specific levels of above-ground biomass production or specific biomass quantities lost or gained during the observation period. Each class primarily characterizes the overall direction, relative change intensity and persistence of GPP independently of the actual level of vegetation abundance or LC type. This means that each LPD class can appear in any type of LC and any level of vegetation density. Nevertheless, the quantitative information on biomass productivity levels is contained in the input normalized difference vegetation index (NDVI) time series data. From this, it is possible to extract, for example, the average annually integrated NDVI over a reference period of three to five years as a baseline GPP proxy as well as subsequently determine the percentage of deviation (positive or negative) from the baseline in defined time steps (e.g. every five to ten years).

[14] OECD, 2017. Green Growth Headline Indicators. Land cover changes and conversions: methodology and results for OECD and G20 countries. ENV/EPOC/WPEI(2017)3. OECD, Paris, France.

The validation of LPD classes is not easy because there is typically no available directly comparable field data on land productivity change. Nevertheless, the validation of LPD classes in terms of plausibility testing against the LC change detected by the ESA CCI-LC dataset and locally against multi-temporal high-resolution data in Google Earth has been performed by the European Commission Joint Research Center.

A preliminary global statistical validation of LPD classes was performed against mapped LC changes between the ESA CCI-LC epochs 2000 and 2010, which were released as part of the ESA CCI-LC dataset (ver.1.6.1) and considered the full range of mapped CCI-LC classes. The area of mapped LC change globally covers approximately 246,067 km^2 (see Figure 12 below).

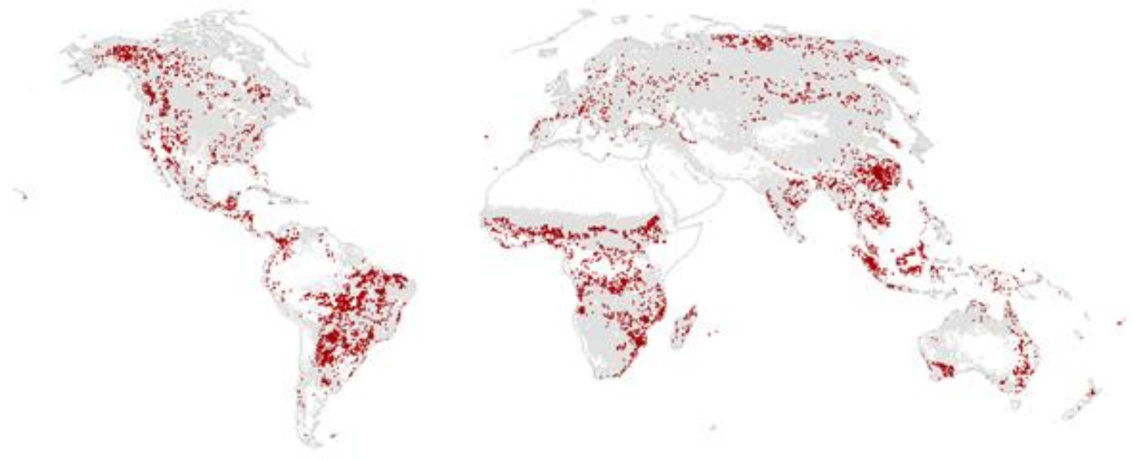

Figure 12 Areas with land cover (LC) change mapped using the European Space Agency Climate Change Initiative on Land Cover dataset (ver. 1.6.1) between 2000 and 2010. Area extents are exaggerated to be visible at presented scale. Source: United Nations Convention to Combat Desertification, 2017. Global Land Outlook, first edition. Bonn, Germany.

Cross correlation between the expected LPD class distributions in relation to observed changes were investigated for several critical LC transitions. For example, transitions from semi-natural LC classes with tree cover to bare/sparsely vegetated areas are expected to feature predominantly in LPD classes 1 to 3, but less so in LPD classes 4 and 5. This highlights a somewhat different picture than the overall global LPD class distribution where classes 4 and 5 account for the majority, that is roughly 80 per cent of all pixels.

This example is illustrated in Figure 13 (a) and (b), where a high level of correspondence between declining land productivity and independently mapped loss of vegetation cover, expressed as LC class change, provides evidence of the plausibility and relative accuracy of the LPD class distribution. The inverse case is shown with transitions from semi-natural tree cover to irrigated crops (see Figure 13 (c)), one of the limited cases where high input and intensive agriculture may exceed the natural potential of primary productivity.

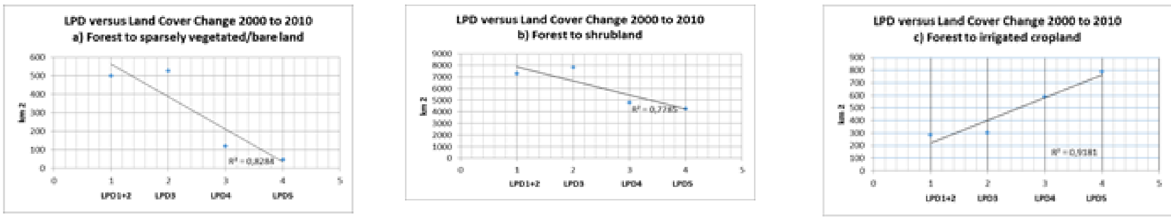

Figure 13 Distribution of land productivity dynamics (LPD) classes within areas transitioning from (a) forest to sparsely vegetated/bare land; (b) forest to shrubland; and (c) forest to irrigated cropland

The vast majority of LPD classes indicating a clear and persistent change of land productivity fall into areas where no mapped information of LC change is available. Therefore, local verification using Google Earth multi-temporal high-resolution images is recommended as a quick option for verifying land productivity changes. During the United Nations Convention to Combat Desertification's first land degradation neutrality (LDN) pilot project (2014−2015), it was shown that in many cases, declining productivity classes were due to urban and infrastructure expansion (e.g. dam construction, mine openings), which acted as a driver of localized land productivity losses affecting ecosystem functioning in their wider surroundings.

During the verification at national level, it must be considered that the analysis of temporal efficiency levels of vegetation to detect long-term changes in that efficiency (the LPD product) is only a first input, and other information for correct local/regional interpretation in a land degradation context is required. For this reason, the LPD results must be further integrated and contextualized as far as possible with additional information that reflects climatic and/or socioeconomic factors such as local land use, changes in land use practices and/or yield outputs, population changes, etc. This integrative analysis is needed to obtain a holistic interpretation of possible ongoing land degradation that explains the biophysical dynamics in relation to anthropogenic drivers.

To test this integration, an initial analysis at global level dealt with the correlation of some spots of decreasing productive capacity in the long time-series product (i.e. 15 years, from 1999 to 2013) against actual global drought monitoring data. These revealed strong correlations with areas having undergone recent and recurrent droughts.[15]

While using alternative data sources to verify the LPD default data at national level, the recommendations in the Good Practices Guidance for SDG indicator 15.3.1 should be followed. The most common verification approach involves the use of national, subnational or site-based indicators, data and information to assess the accuracy of the indicators derived from these regional and global data sources. This could include a mixed-method approach that makes use of multiple sources of information or combines quantitative and qualitative data, including the ground-truthing of remotely sensed data using Google Earth images, field surveys or a combination of both.

[15] CHERLET,M et al, 2015, Use of the NDVI to Assess Land Degradation at Multiple Scales <http://link.springer.com/book/10.1007%2F978-3-319-24112-8>.

3 Soil organic carbon

3.1 Soil organic carbon stock baseline

The soil organic carbon (SOC) stock maps for 0–30 cm were created from a combination of three soil predictions from SoilGrids250m (Hengl et al., 2017): SOC percentage, bulk density and gravel content. As a result, the accuracy of the current product is a function of the accuracies of each of its inputs. The amount of variation explained for each map in a global 10-fold cross-validation was 64 per cent, 76 per cent and 56 per cent, respectively (see Figure 14). The amount of variation explained (or R^2 value) for a continuous variable (like SOC percentage) can be understood as: 64 per cent of the spatial variation in cross-validation (test) points being explained by the ensemble of models used. In other words, the pattern of the SOC percentage map captures 64 per cent of the information in the points. Information that is lost tends to be from the smoothing of the local variation (see middle and bottom panel in Figure 15).

As these accuracies are not a direct test of the SOC stock map itself, a global validation for the 0−30 cm combined product, as well as the recent Global Soil Organic Carbon (GSOC) product (ver. 1.1),[16] was established. Here the World Soil Information Service (WoSIS)[17] dataset was collated to represent the direct 0−30 cm SOC stock for all available points globally, and the results are summarized in Figure 16. The resulting amount of variation explained in the SOC stock estimates within the default data at a global level is ~46 per cent versus 16 per cent for the GSOC map. Whilst over- and under-prediction is equally large in the GSOC map, there is an apparent over-prediction at lower SOC stock levels in the default SOC stock data (Figure 16). This means that the lower SOC stock values are over-predicted in the default data, but that the patterns of SOC stock distribution provide the most reliable information available from current global datasets (16 per cent vs. 46 per cent variation, as explained in Figure 16). It must be noted, however, that this validation has not included the refitting of any models that may or may not have included points from the validation dataset and so may or may not inflate the accuracy measures.

In general, limitations to the current maps used to construct the SOC stock primarily stem from predictions being based on soil legacy data and include:

- Measurements of the SOC percentage, bulk density, gravel content and soil depth have been collected with different measurement methods (e.g. different laboratory methods, even when corrected for, introduce small amounts of noise).
- Soil data was collected over a large space of time (approximately 60 years for SOC, with the bulk centered on ~1995) and predictions were not made for the year 2000 (but assumed so in the absence of other, more suitable global data) (see Figure 18).
- Soil data was compiled from multiple sampling campaigns, which were selected for their own purpose. In other words, soil observations were not collected specifically for the generation of SoilGrids, meaning that there may be a sampling bias (e.g. an over-representation of agricultural areas is common) (see Figure 17).

---

16 <http://www.fao.org/global-soil-partnership/pillars-action/4-information-and-data/global-soil-organic-carbon-gsoc-map/en/>.

17 <http://www.isric.org/explore/wosis>.

- The collection of legacy data (using WOSIS) is nowhere near exhaustive. Much of the currently unaccessed legacy data exists in the databases of many agencies/companies in a multitude of languages.

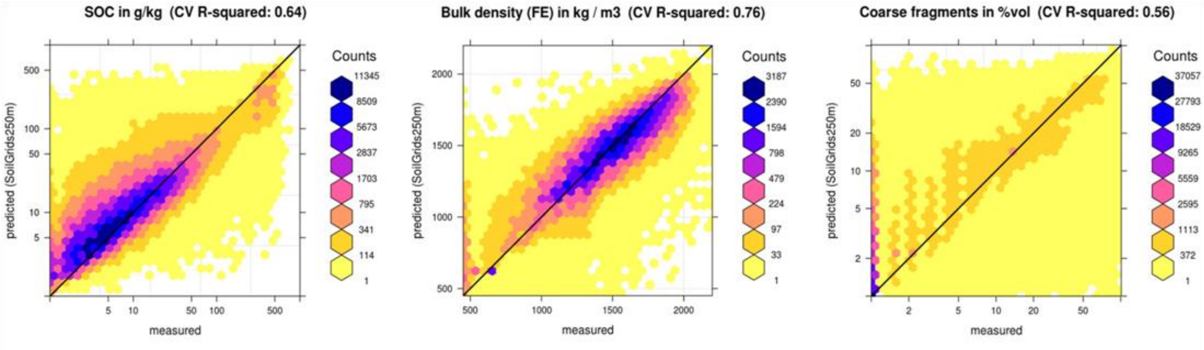

Figure 14 Amount of variation in observed data explained by SoilGrids 250m for soil organic carbon percentage, bulk density and gravel content (coarse fragments) (Hengl et al., 2017)

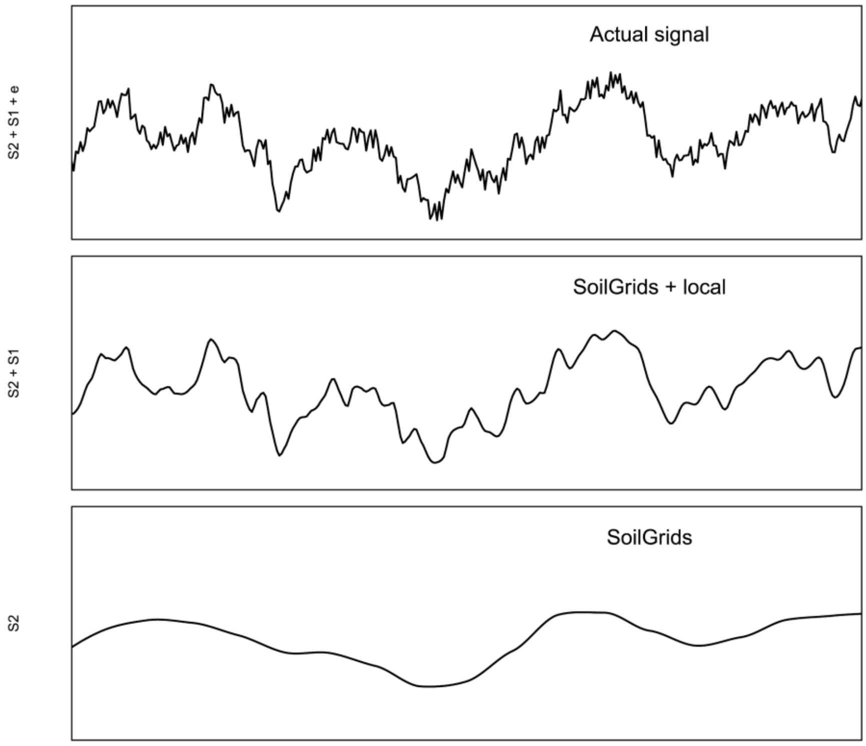

Figure 15 Amount of spatial variation captured by SoilGrids 250m (bottom) as compared to SoilGrids 250m plus local information (middle) and the actual signal in reality (top) (Hengl et al., 2017)

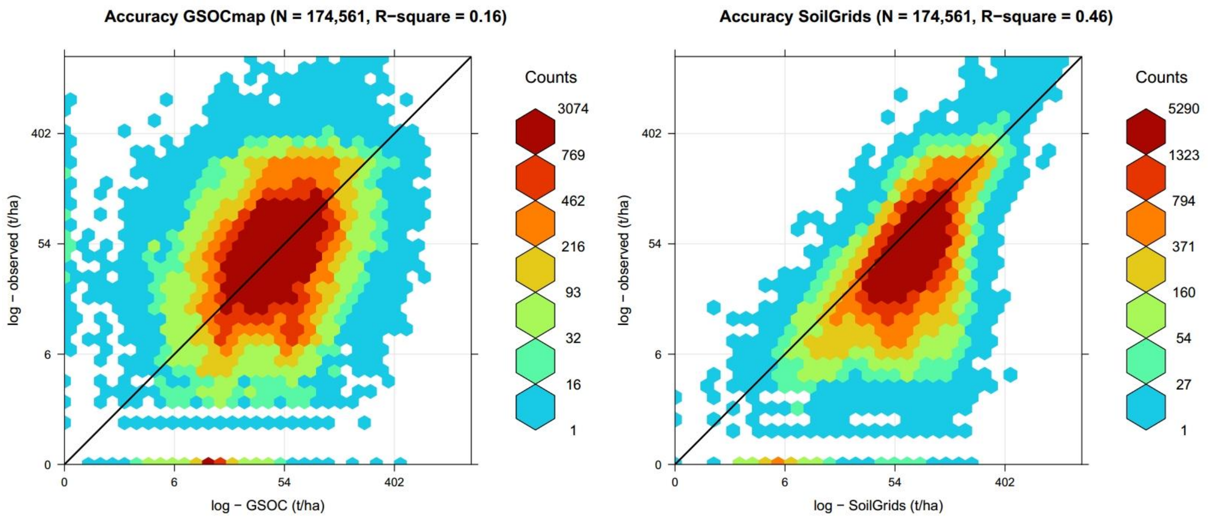

Figure 16 Comparison of the accuracy of the recent Global Soil Organic Carbon map (ver. 1.1) (left) and the SoilGrids250m (right) global soil organic carbon (SOC) stock estimates for a 0−30 cm soil layer

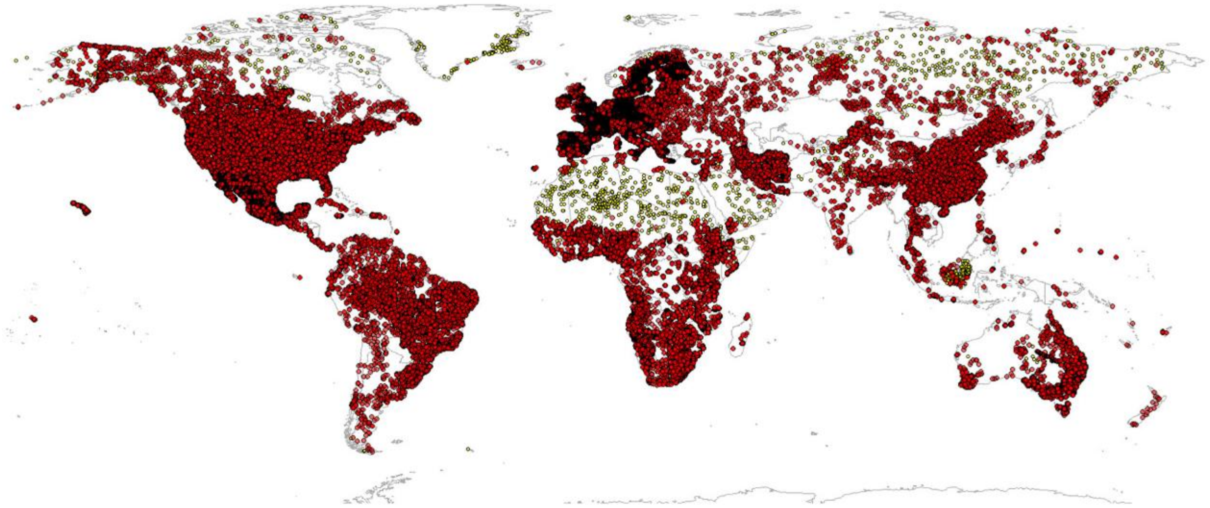

Figure 17 Location of soil profiles included in the production of SoilGrids250m. Note clustering of observations and large (mostly dryland) areas with few points (Hengl et al., 2017)

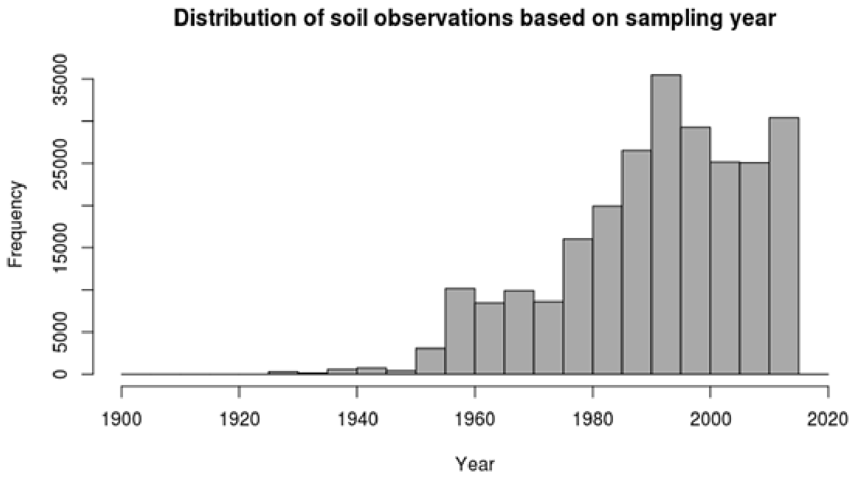

Figure 18 Temporal distribution of soil observations used in the construction of SoilGrids250m. Source: <http://gsif.isric.org/doku.php/wiki:soil_organic_carbon>

3.2 Changes in soil organic carbon stocks 2000−2015

Changes in SOC stocks are based on change factors modified from the Tier 1 IPCC methodology for compiling National Greenhouse Gas Inventories and are employed to predict SOC trends at country level based on land-use/LC change (see Table 10).

As these change factors are based on collations of field trials and long-term experiments, they themselves come with confidence measures that may be applied by countries to their estimates of change to determine if they are significant. The accuracy of change factors can be considered as the average case of response for that LC change for a given climate. Limitations of this method include the lack of change factors for some climates (the nearest climate was used) as well as a paucity of change factors that could be applied to positive trends/restoration cases, that is for LC changes where SOC stocks could be expected to increase. Where change factors were utilised, the following limitations need to be understood:

- **Misclassification in the LC change products propagate through to SOC stock change predictions**. It is assumed the LC change product always reflects a real change. This means that any misclassification in LC will propagate into the prediction of SOC stock changes, for example, 'false negatives' for wetland losses in northern latitudes, where improved classification/discrimination of wetland areas (northern latitudes) in the mid-2000s as compared to 2000 has led to large predicted SOC stock losses that are spurious (see Figure 19).
- **Baseline SOC stock is assumed to fully reflect past degradation**. The application of change factors assumes that the SOC stock in 2000 has reached an equilibrium state with past LC changes.
- **Restoration cases assume current/new LC was original LC**. For example, transitioning from cropland to tree-covered areas implicitly assumes that land was a tree-covered area prior to being cropland.

- **Restoration is limited to two times the inverse of the opposite change**. As estimation of the effects on SOC stocks for the restoration cases are supported by very little observation data; it is assumed that SOC restoration after catastrophic losses (land-use factor (FLU) < 0.4) will be limited by loss of soil mineral mass (erosion) and so will physically limit the SOC restoration possible.

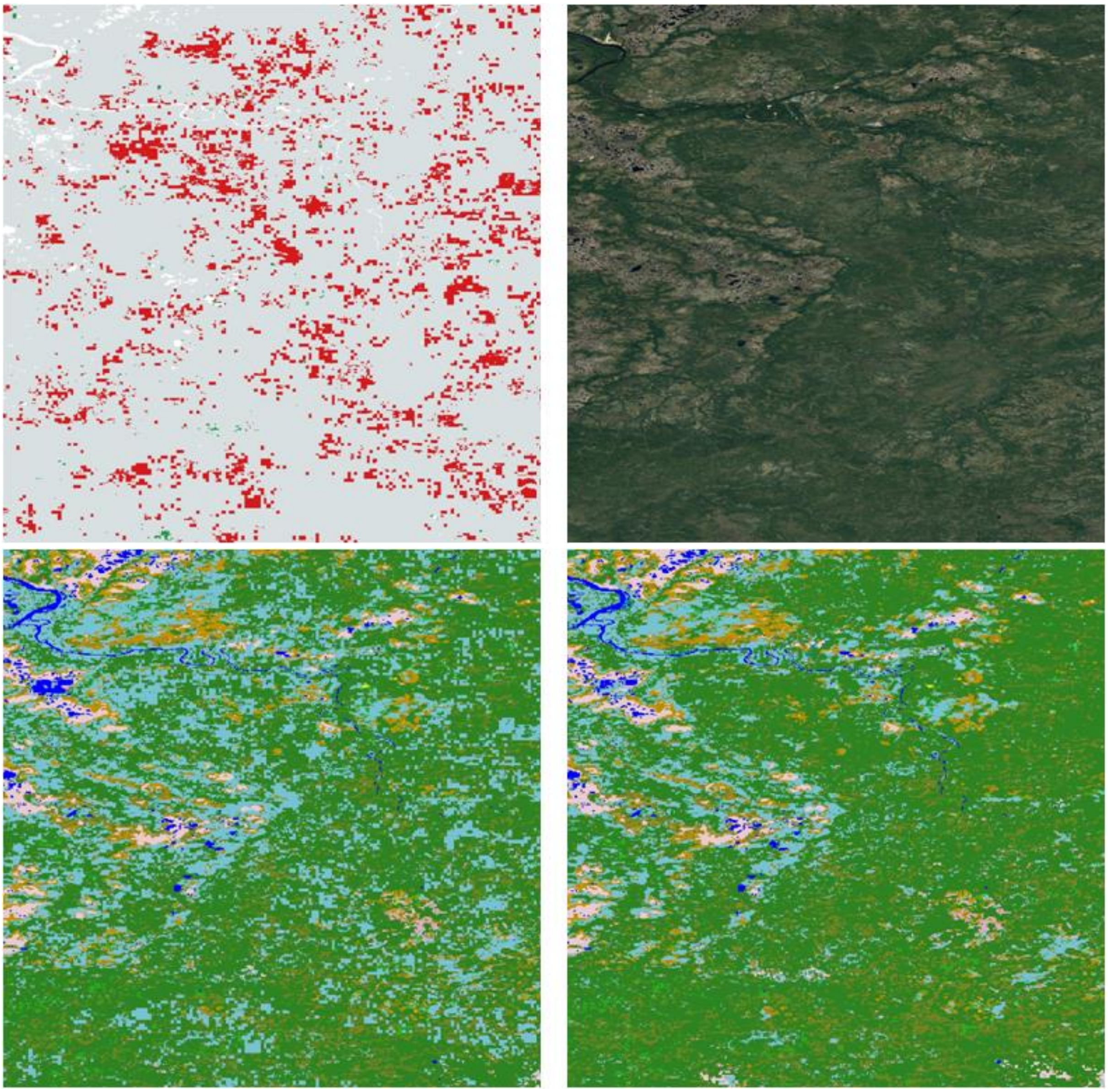

Figure 19 An example of a 'false negative' from improved sensor discrimination of the wetlands class for the northern latitudes. Top left: Delta soil organic carbon (SOC) where red shows high SOC stock loss. Top right: Satellite image of location. Bottom left: Extensive wetlands class in 2000 (pale blue) and a better discriminated wetlands class by 2004 (bottom right) due to improved sensor use in northern latitudes.

Additionally, no assumptions could be made for other change factors for inputs (FI) or management (FMG) for land changing classes or land remaining in the same class. This is primarily due to a lack of global information to populate these factors. Should countries have their own information on the trends involved in both LC change and the effect of management within LC classes (change factors for land-use change, management within land use, and/or inputs) they are encouraged to do so in accordance with Tier 2 methodologies for preparing National Greenhouse Gas Inventories (IPCC, 2006). Data must use standardized measurement units; that is tonnes of SOC per ha for 0−30 cm depth and scientifically documented/substantiated change factors.

Where countries use the default data for reporting, it may be useful to consider the following local information:

- Does the management of land after LC change tend to decrease SOC stocks? (And what management interventions for the new LC could be set as targets to alleviate said loss?)
- After examining local information, are SOC losses associated with soil loss? (And what targets could be set to stabilize soils and prevent SOC loss from surface erosion?)
- For other areas remaining under the same LC, how does the LPD align with areas that may have undergone SOC loss? Where LPD is declining, there is a greater chance of SOC loss occurring.
- What can be derived from other, only locally understood information?

4 Proportion of degraded land

4.1 Propagation of uncertainties

SDG indicator 15.3.1 is derived from the three land-based indicators (LC changes, LPD and SOC stock). Any uncertainties in these three input indicators carry through to the estimates of the proportion of degraded land.

Although the uncertainties for each default data indicator are discussed in detail above, it is worth emphasizing that uncertainties and potential errors can be found in each indicator via:

- **LC change**: seasonality, spatial variation, and accuracy in LC classification;
- **LPD**: within-pixel vegetation heterogeneity and temporal variability;
- **SOC stocks**: data smoothing, data collection and sampling errors, missing or unknown SOC change factors.

The subjective classification of degrading processes applied to each default data indicator may provide a further source of uncertainty. For example, the assignment of an LC change as a gain or a loss, as per the LC flows in Figure 9, introduces considerable subjectivity because specific nuances on the ground and within each country may change whether the pixel is classified as a gain or loss, and therefore whether the location is considered degraded or not. Local data and expertise should be used where there is considerable disagreement and uncertainty in the default estimate of proportion of degraded land.

Annex III: Differences in areas reported and boundary selection

There are several sources of small differences in country areas derived from default data. Here we outline small deviations that come from the projection system used to make calculations, differences in water masks/definitions or differences in administrative boundary used.

1 Projection systems used for area calculations

There are two types of coordinate systems used in geographic information systems (GIS) as depicted in Figure 20:

- Geographic 3D (e.g. lat long)
- Projected 2D (e.g. Mercator, Albers, etc.)

Projected coordinate systems flatten (project) the Earth's spherical surface onto a two-dimensional (Cartesian) plane. Projection systems come in three different 'types': (a) cylindrical; (b) conical; and (c) planar projections (see the right side of Figure 20).

Every projection shows some distortion in angle, distance and/or area. The choice of the projection system depends on the use of the projected maps, be it navigation or measurement of distance or areas. Equal-area projections over large extents (from countries to continents) are the most precise for determining areas,[18] however this precision comes at the cost of angular conformity (shape), resulting in obvious deformities when visualizing such maps.

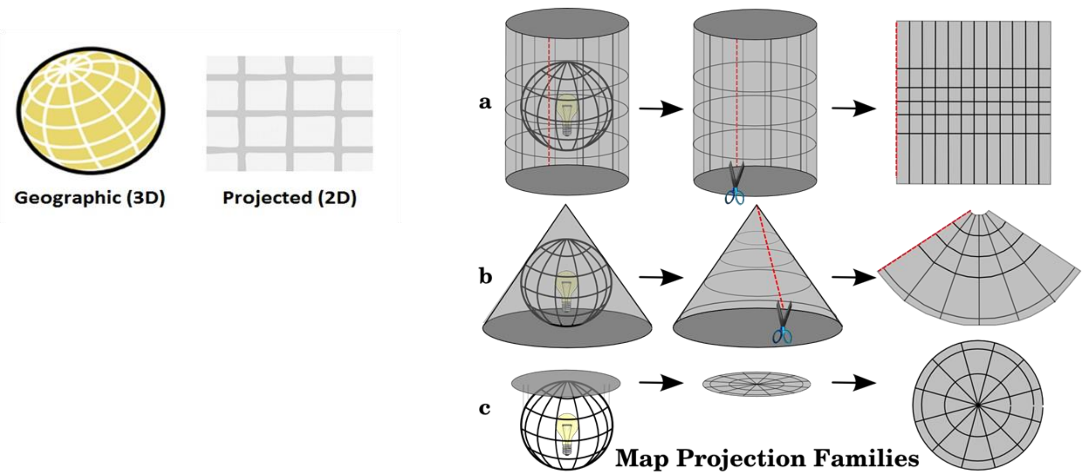

Figure 20 Two types of coordinate systems in GIS: geographic 3D and projected 2D (left); and three types of projected systems: (a) cylindrical; (b) conical; and (3) planar (right).

The Universal Transverse Mercator (UTM) is an equal-area cylindrical projection system that is intended to minimise area/distance/shape distortions for maps within a given zone by segmenting the globe into equal slices (see the left side of Figure 21). However, the further from the outer edge of a UTM Zone the projection is applied, the greater the inaccuracies become. Given this characteristic, using the UTM projection for whole country area summaries will lead to inaccuracies

[18] See also <http://usersguidetotheuniverse.com/index.php/2011/03/03/whats-the-best-map-projection/>.

(e.g. see Figure 22). Many countries that cover larger areas will use their own equal-area projections (e.g. Geoscience Australia Lambert)[19] for larger map extents to overcome these practical processing issues. Similar problems with large extents are encountered by mapping projects working at global level. These projects use equal-area projections where area calculations are the primary task, rather than distances or visualisation (shapes). An example is the MODIS sinusoidal projection where monitoring changes in surface properties is of key interest (see right side of Figure 21). See Seong et. al. (2002)[20] for more detail.

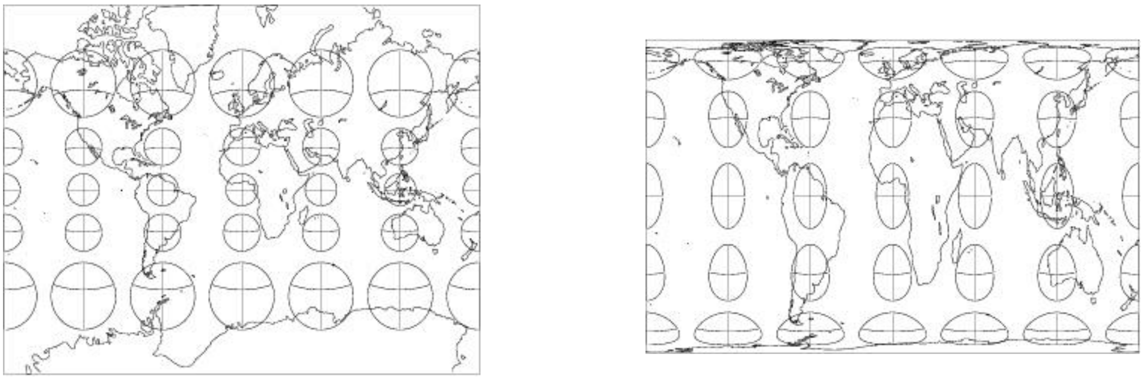

Figure 21 Representation of Universal Transverse Mercator (left) and continuous equal-area projection system (right)

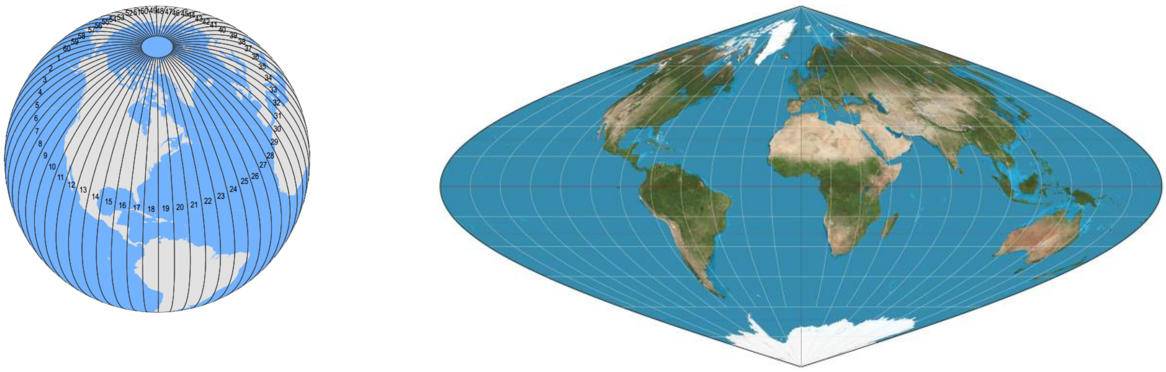

Figure 22 Comparison of the method used to create equal area projection from a spherical surface for Universal Transverse Mercator (UTM) (left) and MODIS Sinusoidal (right). Note that UTM minimizes area distortion by segmenting a sphere into sections and MODIS Sinusoidal does so by a continuous transformation of the sphere surface to minimize area errors.

To illustrate these differences, a number of different global, regional and local equal area projection systems were compiled for an example country and compared to the Food and Agriculture Organization Corporate Statistical Database (FAOSTAT) total land area (see Table 17). Here, the lowest errors are achieved from the global sinusoidal, regional and local projection systems (see Table 17). As we are calculating area statistics from global data, the MODIS

19 <http://spatialreference.org/ref/epsg/gda94-geoscience-australia-lambert/>.
20 <http://onlinelibrary.wiley.com/doi/10.1111/0033-0124.00327/abstract>.

Sinusoidal[21] projection was chosen as the default projection for country-level area calculations used in default data generation.

Therefore, the chosen projections for deliverables are:

- All maps in WGS84 geographic coordinates[22] (lat long) (to allow visualization and reprojection by country teams);
- All maps in MODIS Sinusoidal projection (to maximize area accuracy, enable rapid default production and allow country teams to repeat analysis if desired);
- All aggregate tables for all indicators calculated on the basis of the MODIS Sinusoidal projection (to enable rapid production of default analysis and progress onto country level quality control).

	Global	**Global**	**Segmented**	**Regional**	**Local**	**Global (non-area, lat long)**
Projection system → Land cover ↓	World Plate Carree ESRI:54001	MODIS Sinusoidal SR-ORG:6842	Universal Transverse Mercator 38S EPSG:32738	Africa Albers Equal Area Conic ESRI:102022	Madagascar Laborde Tan 1925 SR_ORG:6618	Lat Long WGS84 EPSG:4326
1	271 009	253 976	254 251	254 005	253 962	229 818
2	310 886	291 249	291 434	291 269	291 111	248 466
3	33 613	31 399	31 425	31 347	31 394	3 1243
4	4 434	4 199	4 218	4 195	4 206	4 176
5	288	271	272	270	270	270
6	3 576	3 331	3 329	3 331	3 314	3 355
7	4 746	4 461	4 448	4 466	4 456	4 460
Total	628 552	588 886	589378	588882	588711	521788
Difference to FAOSTAT[23] (587 040 km^2)	**41 512**	**1 846**	**2 338**	**1 842**	**1 671**	**-65 252**

Table 17 Comparison in differing areas for the total area of Madagascar for several equal-area projection systems used at global to local scale, as compared to a geographic projection (lat long)

2 Boundary selection

The most recent (2015) release of the Food and Agriculture Organization of the United Nations Global Administrative Unit Layers (GAUL) country boundary file was used to extract and produce the default data indicators and data delivery packages for each country. GAUL compiles and disseminates the best available information on administrative units for all the countries in the world. Because GAUL works at global level, unsettled territories are also reported. GAUL's approach is to deal with these areas in such a way as to preserve national integrity for all disputing countries. This file was chosen ahead of other country boundary files because it has the highest level of detail and precision along coastlines in comparison with other country boundary files, and it reports on

21 <http://spatialreference.org/ref/sr-org/modis-sinusoidal/>.
22 <http://spatialreference.org/ref/epsg/wgs-84/>.
23 Food and Agriculture Organization Corporate Statistical Database

disputed territories. The cartographic presentation of country borders in map layouts follows the United Nations cartographic standards.

The boundaries and names shown and the designations used on the default maps produced for each country do not imply official endorsement or acceptance by the UNCCD and the United Nations. Care was taken in the creation of the maps. The UNCCD, its staff and contractors cannot accept any responsibility for errors, omissions, or positional accuracy or be held responsible for any damages due to errors or omissions in these maps. Depiction of boundaries is not authoritative. There are no warranties, expressed or implied, including the warranty of merchantability or fitness for a particular purpose, accompanying these maps. However, notification of any errors will be appreciated.