Good Practice Guidance for Assessing UN Sustainable Development Goal Indicator 15.3.1: Proportion of land that is degraded over total land area

Deriving the Indicator

DRAFT

Executive Summary

The UN Sustainable Development Goals (SDGs) are a set of 17 goals that provide a framework for countries to determine how best to improve the lives of their people now, while ensuring improvements are maintained for future generations. The SDGs came into effect in January 2016, and will guide United Nations (UN) policy and investment for the next 15 years.

SDG goal 15 promotes the sustainable development of life on land and sets out 12 targets to achieve the SDG 15 goal. Target 15.3 states:

"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."

The UN Convention to Combat Desertification (UNCCD) has taken responsibility for developing guiding principles for monitoring this target, which will be assessed using the sole indicator: 15.3.1 - *Proportion of land that is degraded over total land area*. Table 1 summarises the three sub-indicators and their associated metrics defined by the UNCCD[1] to evaluate and report against Indicator 15.3.1.

Table 1: Sub-indicator metrics for SDG Indicator 15.3.1 – Proportion of land that is degraded over total land area

Indicator	Sub-Indicator	Metric
Proportion of land that is degraded over total land area	Land Cover	Land cover change
	Land Productivity	Net Primary Productivity
	Carbon Stocks - Above and Below ground	Soil Organic Carbon Stocks[a]

[a] As outlined in Decision 22/COP.11[2], *soil organic carbon stock* is the metric that will be used to assess carbon stocks above and below ground, and once operational, this metric will be replaced by *total terrestrial system carbon stock*, including carbon stocks in above and below ground biomass, debris (litter and dead wood) and soil.

The sub-indicators are also relevant to other UN mechanisms and reporting frameworks including Land Degradation Neutrality (LDN), United Nations Framework Convention on Climate Change (UNFCCC) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)[3], enabling countries to take advantage of existing reporting mechanisms and official national data sources, where possible.

This good practice guidance document presents methodological guidance for the integration of the sub-indicators to estimate the *proportion of land that is degraded over total land are*a, which involves:

1. **Setting the baseline** to determine the initial status of the sub-indicators.
2. **Detecting change** in each of the sub-indicators, including the identification of areas subject to change and their validation.

[1] By its decision 22/COP.11, the Conference of the Parties established a monitoring and evaluation approach consisting of: (a) indicators; (b) a conceptual framework that allows the integration of indicators; and (c) indicators sourcing and management mechanisms at the national/local level.

[2] http://www.unccd.int/en/programmes/Science/Monitoring-Assessment/Documents/Decision22-COP11.pdf

[3] IPBES is placed under the auspices of four United Nations entities: UNEP, UNESCO, FAO and UNDP and administered by UNEP.

3. **Deriving the indicator** by summing all areas subject to change whose conditions indicate degraded lands and dividing by the total land area to generate an estimate of the *proportion of land that is degraded over total land are*a.

4. **Aggregating** degradation scores to enable reporting at continental, regional or global scales.

Good practice guidance specific to the calculation of each of the sub-indicators are provided in Annexes to this report.

Contents

Acronyms

COP	Conference of the Parties
EVI	Enhanced Vegetation Index
FAO	Food and Agriculture Organization of the United Nations
GEO	Group on Earth Observations
GEOGLAM	Global Agricultural Monitoring Initiative
IPCC	Intergovernmental Panel on Climate Change
LCCS	Land Cover Classification System (FAO)
LDN	Land Degradation Neutrality
LULUCF	Land-Use, Land-Use Change and Forestry
NDC	Nationally Determined Contributions
NDVI	Normalized Difference Vegetation Index
NPP	Net Primary Productivity
SDGs	Sustainable Development Goals
SOC	Soil Organic Carbon
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change

1 Definition and Concepts

Aboveground biomass is all biomass of living vegetation, both woody and herbaceous, above the soil including stems, stumps, branches, bark, seeds, and foliage (IPCC 2003).

Baseline (SOC_{t0}) carbon stocks are required to enable an assessment of the initial status of the sub-indicator in *absolute* terms. January 2016 is considered the nominal start date for setting the baseline for the 15.3 target. Specifically, this means that it is good practice to determine the baseline for carbon stocks in the SOC pool prior to the 1st of January 2016. This start date is referred to as t_0 and future reporting is referred to as $t_1,\ldots,t_n$. The baseline should be quantified over an extended period prior to t_0, rather than using the values of a single year to take account of climatic variation. We recommend the baseline period should be 10-15 years. This agrees with recommendations for monitoring progress towards the Land Degradation Neutrality target (Orr et al. 2017) and is comparable to the historical periods used for REDD+ Forest Reference Emission Levels.

Belowground biomass is all biomass of live roots. Fine roots of less than (suggested) 2 mm diameter are often excluded because these often cannot be distinguished empirically from soil organic matter or litter (IPCC 2003).

Carbon stock is the quantity of carbon in a pool (i.e. a system which has the capacity to accumulate or release carbon). Ecosystem carbon pools, as defined in IPCC (2003, Table 3.1.2), are biomass (aboveground biomass and belowground biomass), dead organic matter (dead wood and litter, above and below ground), and soil (soil organic matter).

Change in carbon stocks, is defined as the change in C stocks between the monitoring period (t_n) and the baseline (t_0), in the units of t C ha^{-1}.

Country area is defined as the total of the areas of land, inland water and coastal water. This may include rivers and lakes, and the extent of a country's exclusive economic zone (United Nations 2014).

Dead wood is all non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil (IPCC 2003). Dead wood includes wood lying on the surface, dead roots, and stumps, larger than or equal to 10 cm in diameter (or the diameter specified by the country).

False positive refers to a case where one or more sub-indicators has increased for a land use transition that is actually considered land degradation. Assessment of this type of exception (i.e., "false positive") requires knowledge and interpretation at the local level.

Indicators are variables that reflect a process of interest.

Land cover has been defined by the UN Food and Agriculture Organisation (FAO) as the "*observed (bio) physical cover of the earth's surface"* (Latham et al. 2014). To some extent land cover is one of the most easily detectable properties of the earth's surface and has been used as an important indicator of change, both human induced and natural. However, at the fine scale, land cover can be a complex arrangement of different vegetation and abiotic components. For example a given land unit may include vegetation with a soil substrate. The vegetation may include a community of woody and non-woody species arranged in a complex structure both horizontally and vertically. Land cover is the description of these components in a way that has meaning at the spatial unit of interest and in the thematic context being considered. Thus, land cover is categorised in different ways depending on the application.

Land degradation is the reduction or loss of the biological or economic productivity and complexity of rain fed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes arising from human activities.

Land productivity is the biological productive capacity of the land, the source of all the food, fibre and fuel that sustains humans. Land productivity points to long-term changes in the health and productive capacity of the land and reflects the net effects of changes in ecosystem functioning on plant and biomass growth (UNSTATS 2016).

Land use represents a type of activity being carried out on a unit of land, in urban, rural and conservation settings.[4]

Litter is all non-living biomass with a size greater than the limit for soil organic matter (suggested 2 mm) and less than the minimum diameter chosen for dead wood (e.g. 10 cm), lying dead, in various states of decomposition above or within the mineral or organic soil (IPCC 2003). This includes the litter layer as usually defined in soil typologies. Live fine roots above the mineral or organic soil (of less than the minimum diameter limit chosen for below-ground biomass) are included in litter where they cannot be distinguished from it empirically.

Metrics are measures that are used to quantify or assess indicators/sub-indicators.

Monitoring will be based on evaluating the significant changes in the sub-indicator via the associated metric.

Monitoring Period (t_n) is the time period over which the metric is measured in years. The 15.3 target date (specified as 2030) is referred to as t_1. The metric should be quantified for the monitoring period using the same methods employed for the baseline period. Potential intermediate monitoring points have been suggested on an interval of 4 years for land degradation neutrality (Orr et al 2017), noting that for land cover, available data sets cover epochs of five years. In the context of SOC change, this frequency is likely to be too short to detect change where an on-ground monitoring approach is used. Even in landscapes where soil carbon is changing, the minimum period for reliable detection will rarely be less than 10 years (e.g. Smith 2004); the obvious case being when land clearing occurs. Thus although methods may allow for calculation of SOC stock change at shorter intervals, the results are unlikely to be meaningful in the context of assessing degradation.

One-out, all-out (1OAO) is a conservative approach to combining different indicators/metrics to assess status, which follows the precautionary principle. The one-out, all-out approach is applied such that where any of the indicators shows significant negative change, it is considered a loss (and conversely, if at least one indicator shows a positive trend and none shows a negative trend it is considered a gain).[5]

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[4] IPCC. 2006. IPCC Guidelines for National Greenhouse Gas Inventories: Glossary. Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K., eds. Institute for Global Environmental Strategies (IGES), Hayama, Japan. Available online: http://www.ipccnggip.iges.or.jp/public/2006gl/pdf/0_Overview/V0_2_Glossary.pdf

[5] Adapted from Society for Ecological Restoration International Science and Policy Working Group. 2004. The SER International Primer on Ecological Restoration. Society for Ecological Restoration International, Tuscon, Arizona. Available online: http://c.ymcdn.com/sites/www.ser.org/resource/resmgr/custompages/publications/SER_Primer/ser_primer.pdf

Significant change (with respect to indicators/metrics) is a change in a given metric that is either: (i) considered to be significant by experts, taking into consideration the precision of the method; or (ii) unlikely to have arisen by chance, according to statistical analysis.

Soil organic carbon (SOC) is the amount of carbon stored in soil and is a component of soil organic matter.

Soil organic carbon stock is the mass of soil organic carbon per unit area. The reporting standard is SOC stock in tonnes of organic C per hectare to a depth of 0-30 cm (IPCC, 1997). Determination of soil organic C stock requires measurements of soil organic C concentration, soil bulk density and gravel content:

$$SOC\ stock = SOC_m \times \rho \times \left(1 - \frac{g}{100}\right) \times d \qquad (1)$$

Where: SOC_m is the mass of organic carbon in the soil (%), ρ is the soil bulk density (g cm^{-3}), g is the gravel content (g g^{-1}), and d is the thickness of the layer (cm).

Soil organic matter includes organic carbon in mineral and organic soils (including peat) to a specified depth chosen by the country and applied consistently through the time series. Live fine roots (of less than the suggested diameter limit for below-ground biomass) are included with soil organic matter where they cannot be distinguished from it empirically (IPCC 2003).

Spatial feature refers to the spatial unit (e.g. watershed, polygon) at which degradation is reported on and may be a uniform land cover class or a mix of land cover classes.

Total carbon stock is the quantity of carbon in all of the ecosystem carbon pools i.e. aboveground biomass, belowground biomass, dead wood, litter and soil.

Total Land Area refers the total land area of the reporting country.

2 Introduction

Expanding human requirements and economic activities are placing ever increasing pressures on land resources, creating competition and conflicts and resulting in suboptimal use of resources. As a result, land resources are degrading at an alarming pace affecting livelihoods and food security of the global population (UNCCD 2015b). Estimates of global land degradation indicate that up to 25% of all land worldwide is currently highly degraded, 36% is slightly or moderately degraded but in a stable condition, while only 10% in improving (Dubois 2011). Global vegetation productivity (an indicator of land degradation) is reported to have declined persistently between 1981 and 2003 (Bai et al. 2008) indicating that the overall health and productivity of land is declining while at the same time the demand for resources is increasing (Montanarella et al. 2016).

Human activities are the principal drivers of the processes of land degradation, desertification and climate change. Society must therefore mitigate or reverse these stresses through innovative approaches to attain land degradation neutrality. The very best modern science and technology will be needed, allied with local or traditional knowledge that has developed over time (UNCCD 2015a).

In December 2015, countries adopted the Paris Agreement and agreed to implement its agenda to achieve sustainable development by 2030. The Agenda includes 17 Sustainable Development Goals that aim to end poverty, protect the planet and ensure prosperity for all. The UN Convention to Combat Desertification (UNCCD) has taken responsibility for monitoring 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."

This good practice guide describes methods to measure and report on Indicator 15.3.1, the *"Proportion of land that is degraded over total land area."*

For the purposes of reporting on Indicator 15.3.1, degraded land is identified on the basis of three sub-indicators:

1. Land cover and land cover change,
2. Land productivity, and
3. Carbon stocks (above and below ground)

The three sub-indicators are closely linked while also addressing unique aspects of degradation. **Land cover and land cover change** reflects the state of, and changes in, the structure and composition of the landscape from natural events and human activities. **Land productivity** captures human impacts on the dynamics and level of plant growth. **Carbon stocks (above and below ground)** addresses longer-term changes resulting from the net effects of biomass growth and disturbance or removal.

This good practice guidance (GPG) describes methods for combining degradation assessments from the three sub-indicators to derive indicator 15.3.1. This document should be read in conjunction with the GPG documents for each sub-indicator, which are attached as Annexes to this report, and with consideration of the overarching good practice principles presented in Box 1.

Box 1 – Indicator 15.3.1 Good Practice Principles

- The interpretation of degradation status should always be conducted, and justified, in the context of local knowledge of the climatic, land use and any other factors influencing land conditions. Ideally, degradation identified from Earth observation methods should be validated with coincident field observations.
- An area is considered degraded if negative change is detected between monitoring periods in any one of the three sub-indicators, subject to national/local verification including the capacity to report and explain "false positives".
- The *proportion of land that is degraded over total land area* must include land historically identified as degraded that has not recovered, as well as newly degraded lands identified in the current monitoring period.

2.1 Tiers

The status of Indicator 15.3.1 is determined following the consideration of the status of three sub-indicators: land cover; land productivity and carbon stocks. The good practice guidance for each of the sub-indicators presents methods at three tier levels[6] with increasing spatial detail, assessment rigour and processing requirements.

> **Tier 1** uses global datasets such as spatially-coarse land use change statistics, globally-available agricultural production statistics and global land cover maps, and minimises the burden of data processing and analysis.
>
> **Tier 2** improves local representativeness through the use of National land use, land cover productivity, and carbon stock information, and may include more rigorous and advanced data processing and analysis requirements.
>
> **Tier 3** includes the use of nationally calibrated models and inventory measurement systems to refine degradation estimates. These methods may be tailored to address national circumstances, repeated over time, driven by high-resolution data and disaggregated at sub-national to fine grid scales. These methods provide estimates of greater certainty than lower tiers and require the highest level of data collection, processing and analytical rigour.

Ideally Nations should strive to use Tier 3 methods to assess and report on degradation, acknowledging national circumstances, which may evolve over time, such as: a) level of engagement by government entities; national policy and reporting needs including tracking of progress against targets; b) nature and availability of historical and future data c) availability of technical expertise and institutional capacity d) available financial resources to design, build and operate monitoring systems.

Details of the data and processing options at each tier for each sub-indicator are presented in Annexes 1 to 3 to this good practice guidance document. Strictly quantitative assessment of degradation may not always be appropriate, and degradation should be interpreted in the context of local knowledge and National development goals. However, consistency in the methods of assessing

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[6] Consistent with the IPCC Guidelines and Good Practice Guidance, the tier structure (Tier 1, Tier 2 and Tier 3) is hierarchical, with higher tiers implying increased accuracy of the method and/or emissions factor and other parameters used in the estimation of the emissions and removals.

changes in the sub-indicators is an important step in reaching comparability across regions, countries and the globe.

2.2 Sub-indicators to represent land degradation

2.2.1 Land cover and land cover change

This sub indicator describes the observed biophysical character of the earth's surface and identifies degradation by comparing changes in land cover over time. The determination of whether a particular transition from one land cover type to another indicates degradation is made at the National scale in the context of a range of factors including environmental and development objectives. Key points of the Land cover and land cover change assessment are:

- Tier 1 analysis should use the European Space Agency's Climate Change Initiative Land Cover (CCI-LC) product. CCI-LC classes may be aggregated to match the Intergovernmental Panel on Climate Change (IPCC) land cover classes for consistent reporting globally.
- National land cover classes should represent a single category or type of land cover within a broader set of classes. These should be defined logically based on the actual biophysical elements present, their arrangement and their properties.
- A legend shall be defined such that land cover mapping can be performed. Classes should be unambiguous and exhaustive in the sense that they can be used to map all land area in the study region.
- A spatial disaggregation scheme shall be defined and justified.
- Change categories that represent degradation (negative transition), stable state (no transition), or improvement (positive transition) shall be defined and justified.
- The interpretation of whether land cover transitions represent degradation should be made at the National level in the context of local information and development objectives.
- Once land is classified as degraded (negative transition) it shall be included in the degraded category until it is re-classified as not-degraded. This will ensure that all degraded lands are considered in the proportion calculated within the monitoring period.

2.2.2 Land productivity

Land productivity is the biological productive capacity of the land, the source of all the food, fibre and fuel that sustains humans. This can be measured from satellite remote sensing data using surrogates of net primary production (NPP), such as the Normalised Difference Vegetation Index (NDVI). Areas of degradation are indicated by having either a significant negative slope of NPP trajectory over time, or low productivity compared to other similar vegetation in the same bioclimatic region *and* low productivity at a given location compared to historical observations for that location, or a negative slope and low productivity. Key points of the Land productivity sub-indicator analysis are:

- Tier 1 analysis should use the MODIS MOD17 NPP product or the MODIS MOD13Q1 NDVI product if preferred. Use of the NDVI data requires calculation of annual NPP metrics from the growing season each year. Degradation is identified on the basis of trajectory slope, performance relative to that of other similar land units, and state relative to the observed range of historical values for that area.
- Tier 2 uses higher resolution NDVI datasets or an alternative index if it is justified.

- Tier 3 incorporates validation of land degradation assessments using additional sources of data potentially including field samples.
- Datasets at all Tier levels must be calibrated to account for the influence of variations in moisture availability over time, which has a strong influence variations in land productivity that can mask the impacts of degradation.
- Increases in NPP may not always be representative of a positive change. Potential false positives and explainable anomalies should be defined, justified and maintained in the original data set.
- Land productivity shall be calculated annually and reported consistent with the requirements at the Indicator level.

2.2.3 Carbon stocks above and belowground

Carbon stocks reflect the integration of multiple processes affecting plant growth and the gains and losses from terrestrial organic matter pools. The metric used to assess carbon stocks adopted for Indicator 15.3.1 is soil organic carbon (SOC). Key points of the carbon stocks sub-indicator analysis are:

- Tier 1 analysis includes the use of reference soil organic carbon (SOC) stocks either from IPCC defaults for all major soil types stratified by climate zone, or from the best available global soil grid product, and stock change and emission factors from IPCC defaults for all identified land uses/management categories.
- An assessment of SOC stocks within each land unit shall be made for the baseline period and the current time series. An average long-term SOC stock shall be generated for each land unit in the baseline period. C stock changes shall be calculated as differences between estimates in the baseline period and current time series.
- The 95% confidence interval of long term SOC stocks and of SOC stock changes should be estimated and reported.
- The choice of degradation assessment method will depend on the magnitude of the uncertainty in the estimates at the National scale. If a significant decline in SOC is identified, the area would be considered degraded; a significant increase or no change in SOC, the area would be considered not degraded.
- Increases in SOC stocks may not always be representative of a positive change. Potential "false positives" and explainable anomalies should be defined, justified and maintained in the original data set.

3 Method of computation

3.1 Establishing the baseline

The period 2000 – 2015 represents the baseline period for Indicator 15.3.1 and is referred to as t_0. The specific target date for SDG 15.3 (specified as 2030) is a special case for reporting and is referred to within this document as t_n and future reporting between the baseline (t_0) and the target date (t_n) dates are referred to as t_1->t_n. It is the change between the land cover states at t_0 and t_n that will determine if degradation has occurred.

Land conditions vary over time, therefore the baseline should be quantified as an historical average over the baseline period[7]. For the purposes of defining degradation in the sub-indicators, parameters calculated from the baseline may include trends and/or absolute values. Degradation (or improvement) as compared to the baseline may be identified with reference to modelling parameters describing the slope and confidence limits around the trend, or to the level or distribution of conditions in space and/or time as shown during the baseline period. Degradation may be determined using statistical significance tests or by interpretation of results in the context of local knowledge and National development objectives.

It is *good practice* to assess change for interim and final reporting periods with respect to the baseline (t_0) for each sub-indicator and the overall Indicator 15.3.1. This will ensure that land defined as degraded, will remain in the degraded category unless it is improved relative to the baseline.

3.2 Spatial disaggregation

Although the SDG 15.3.1 target will be reported as a single figure quantifying the area of land degraded as a proportion of land area, spatial disaggregation to the smallest possible unit has been highlighted as a preferable way to present SDG indicators (UNHQ 2015). The UNSTATS (UNSTATS 2016) suggests that SDG 15.3 can be mapped and disaggregated by land cover type or other policy-relevant units, such as agro-ecological, bio-cultural or administrative. These spatial feature boundaries can provide a reporting basis for the Indicator and all sub-indicator assessments.

It is good practice to ensure that feature boundaries are kept constant over the reporting period, since flows should be calculated from two land cover epochs within the same geographic area. The method of defining these boundaries is best determined at the National level, but could include a number of options:

- **Grid based features**: Since source data for land cover mapping is often based on satellite-derived remote sensing imagery, the native spatial unit is often the pixel grid structure used by the satellite data provider. For example, the MODIS sinusoidal level 2 grid tiling system (Wolfe et al. 1998) has an official spatial reference (SR-ORG:6842) such that pixels always refer to the same ground area, rather than the field of view of a sensor for a given satellite overpass.

  The benefit of using a native remote sensing image with grid-based spatial boundaries is that no reformatting or reprojecting of data is required prior to analysis. The disadvantage is that pixel based boundaries may have a tendency to erroneously indicate change due to slight variations in satellite instantaneous field of views (IFOVs), data correction artefact and data errors.

- **Homogeneous land cover features**: A dataset representing the state of land cover at t_0 can be used to provide spatial boundaries for assessment of change in the sub-indicators. Segmentation of homogeneous regions from pixel based t_0 land cover data would provide polygon boundaries for the future land cover change assessment. The aggregation

[7] Comparing trends (rather than an absolute numerical values) to assess degradation can lead to an unintended outcome where, for example, the metric could have increased from a low start point in 2000-2010, increased significantly from 2010-2015, but then declined a little from 2015-2030. The unintended outcome is that this would be labelled as declining when the magnitude of the change suggests otherwise (Orr et al., 2017).

methodology to delineate homogeneous land cover polygons will need to consider the minimum acceptable size for spatial features. Without this condition, issues associated with the instability of land cover at the pixel level will not be improved.

Although polygons defined at t_0 should be maintained for reporting at subsequent dates (e.g. at t_n, 2030) these boundaries will have no enduring physical meaning beyond t_0. It should be expected that the mix of land cover classes within the polygon will become increasingly complex over time. Reporting of the sub-indicator at the spatial feature level will therefore be a proportion of the polygon that is degraded.

Natural features: Natural features are a physically meaningful and enduring spatial unit to use for assessing land cover change, as well as other SDG 15.3.1 sub-indicators. A method suggested for the Land Degradation Neutrality (LDN) target setting program uses watershed boundaries for aggregation of sub-indicators (UNCCD 2016). HydroSHEDS (Lehner et al. 2006a) is an example of one publicly-available vector watershed boundaries dataset, based on NASA's Shuttle Radar Topography Mission (SRTM) data (Figure 1).

The advantage of using natural boundaries is that they are enduring over time and provide a policy-relevant spatial feature for mitigation of degradation. One disadvantage of using a natural boundary like a watershed is that the area of individual features may vary significantly. For example watersheds in flat areas will generally be much larger than areas with significant topographic variation. For this reason, it is good practice to determine a minimum and maximum feature size based on acceptable limits for policy setting. Natural boundaries are likely to be of mixed land cover at t_0. Reporting of the sub-indicator at subsequent epochs should therefore be based on the proportion of the polygon that is considered degraded.

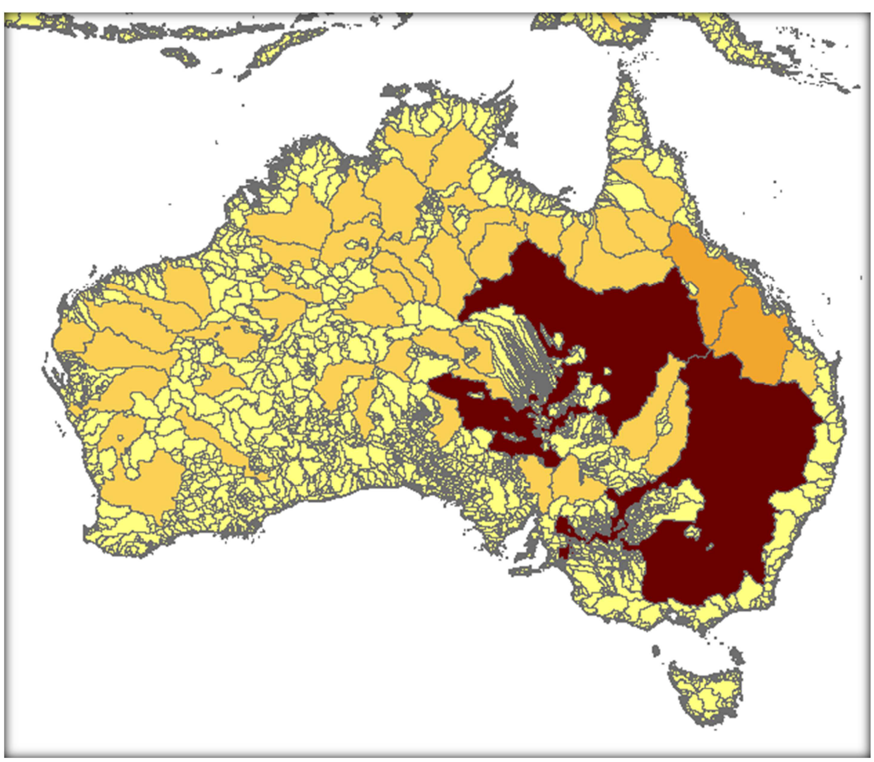

Figure 1: Watershed boundaries for Australia based on HydroSHEDS (Lehner et al. 2006b) global polygon data.

- **Political features**: Geopolitical features provide another objective spatial unit from which to assess land cover change. These boundaries are possibly the most relevant for policy setting, since action to mitigate and remediate land cover will often be managed at the local government level.

  The Global Administrative Unit Layers (GAUL) dataset (FAO 2014a), is one publicly accessible example that maps administrative boundaries at the national, state and local levels. However, this is considered a dynamic layer, as political boundaries are constantly changing. As such, it is good practice to define administrative boundaries at t_0 and maintain these features for subsequent reporting (e.g. at t_1). The sub-indicator proportion of land that is degraded over total land area is then the accumulation of degraded proportions, weighted by the area of features defined by natural boundaries. Reporting of degradation at subsequent epochs should therefore be based on the proportion of the polygon that is considered degraded. Reporting of the sub-indicator at subsequent epochs would be the proportion of the administrative area determined to be degraded.

The most appropriate method for spatial disaggregation will depend on the source data for land cover classification, the expertise of national agencies and existing practices. Selection of methods should, as far as possible, optimise the policy relevance of derived data and be aligned with existing methods so as to minimise the burden of reporting on the target.

3.3 Deriving Indicator 15.3.1

There are a number of approaches for combining metrics, indicators or criteria to assess status (Table 2). Each method has its advantages and disadvantages and may be suited to combining particular types of metrics such as those that are sensitive to the same pressure (averaging approaches) or 'preference' metrics to determine an overall degradation level (probabilistic approaches).

The methodological steps required to distinguish degraded lands in each sub-indicator are summarised in Section 2.2. The individual sub-indicators are complementary and non-additive components of land-based natural capital that are sensitive to different degradation pressures. Gains in one of these sub-indicators cannot compensate for losses in another (Orr et al. 2017). Aggregation approaches would mask the changes detected in the individual indicators and prevent the interpretation of individual measures taken at the national level. In cases where sub-indicators are sensitive to different pressures a "one-out, all-out" approach is recommended (Caroni et al. 2013).

3.3.1 One-out-all-out (1OAO)

The one-out, all-out (1OAO) approach is used to combine the results from the three sub-indicators, to assess degradation status for each monitoring period at the Indicator level. Within the spatial features that comprise the reporting units within the study region, degradation is considered to have occurred if degradation is reported in any one of the sub-indicators. The method applied to generate the Indicator is shown in Figure 2. Table 3 presents the transition matrix to determine the classification of each land unit at t_1.

Table 2. Approaches for combining metrics to derive the Indicator of degradation

General Approach	Details of Method	Advantages	Disadvantages
One-out, all-out (1OAO) principle	All variables have to achieve good status	Most comprehensive approach. Follows the precautionary principle	Trends in quality are hard to measure. Does not consider weighting of different indicators and descriptors. Chance of failing to achieve good status very high
	Variation: Two-out all-out: if two variables do not meet the required standard, good status is not achieved	More robust compared to 1OAO approach	See above
Averaging approach	*Non-weighted*: Variable values are combined, using the arithmetic average or median	Indicator values can be calculated at each level of aggregation. Recommended when combined parameters are sensitive to a single pressure	Assumes all variables are of equal importance
	Weighted: Like the previous method, with different weights assigned to the various variables *Hierarchical*: With variables defined at different hierarchical levels	Reflects the links between descriptors and avoids double counting	High data requirements. Problem of agreeing on weights
Conditional rules	A specific proportion of the variables have to achieve good status	Focuses on the key aspects (i.e., biodiversity descriptors)	Assumes that status is well represented by a selection of variables
Scoring or rating	Sum of weighted scores	Different weights can be assigned to the various elements	Problem of agreeing on weights. Metrics may not be sensitive to the same pressures
Multimetric approaches	Multi-metric indices	Integrates multiple indicators into one value. May result in more robust indicators, compared to indicators based on single parameters	Correlations between parameters can be an issue. Results are hard to communicate to managers. Metrics may not be sensitive to the same pressures
Multi-dimensional approaches	Multivariate analyses	No need to set rigid target values, since values are represented within a domain	Results are hard to communicate
Decision tree	Integrating elements into a quality assessment using specific decision rules	Possible to combine different types of elements, flexible approach	Only quantitative up to a certain level
Probabilistic	Bayesian statistics	Produces a probability estimate of how likely the area is in a certain state; can decide the acceptable uncertainty	Difficult to calculate
High-level integration	Assessment results for three groups: biological indicators, hazardous substances indicators and supporting indicators, each applying 1OAO	Reduces the risks associated with 1OAO while still giving an overall assessment	Technical details

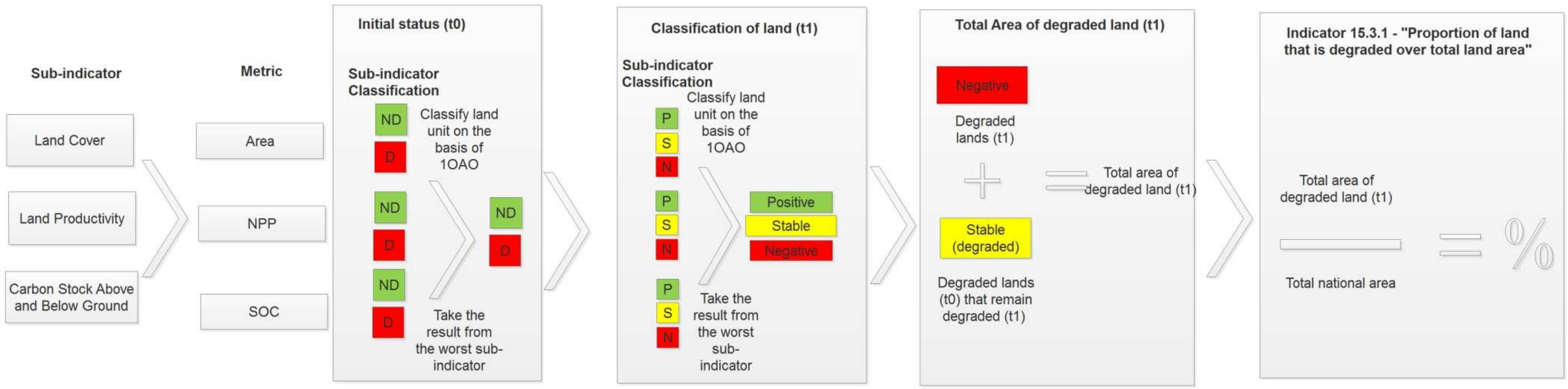

Figure 2: Process for determining Indicator 15.3.1 from the three sub-indicators. ND not degraded, D degraded, P positive, S stable, N negative.

Table 3: Land Unit Transition Classification Matrix

t0/t1	Degraded	Not Degraded
Degraded	Stable (degraded)	Negative
Not Degraded	Positive	Stable (Not Degraded)

3.3.2 Significance thresholds

Defining degradation can be subjective in the national context, therefore consistency in methods of assessing significant changes in the sub-indicators is an important consideration. This good practice guidance defines significant change (with respect to indicators/metrics) as change in a given metric that is either: (i) considered to be significant by experts, taking into consideration the precision of the method; or (ii) unlikely to have arisen by chance, according to statistical analysis.

Clear documentation, outlining how significant change was determined at the sub-indicator level, will assist in transparent and consistent reporting of degradation through time. Guidance specific to each sub-indicator can be found in the relevant Annexes to this document.

3.3.3 False positives

When considering the aggregation method for sub-indicators, the reliability of the individual indicators to be aggregated is an important factor. With each sub-indicator, it is possible to make a type I error or false positive error (i.e., to get a non-degraded result when the land unit is in fact degraded, or vice versa). The probability of errors varies (i) between indicators depending on natural variability; (ii) with the amount of data used to define the indicator value; and (iii) with the target level compared to the sensitivity of the metric (Borja et al. 2014). The criteria applied for assessing false positives and significance should be transparent and well documented, in order to make comparisons across different geographic regions.

The following two additional steps at the sub-indicator level, adopted jointly, can help to address false positives/negatives when reporting at a national scale:

1. International guidelines for defining a "negative land cover change" adopted with the definition of degradation being set at the national level and any divergence from the global "standard" justified.
2. Generation of an "explainable anomalies" or "false positive" map, particularly for the NPP and SOC sub-indicator metrics. Original data are maintained and any anomalies identified and explained, within globally accepted guidelines.

To assist with the interpretation of explainable anomalies, it may be useful to generate a 'support class' map showing which sub-indicator or combination of sub-indicators supports the conclusion of degradation (or otherwise) in a given pixel or region. **Error! Reference source not found.** shows support class numbers for all possible combinations of the three sub-indicator metrics, and whether that combination of sub-indicators should be interpreted as degraded in the Indicator.

Table 4. Lookup table indicating support class combinations of sub-indicators to assist in the interpretation of confidence in degradation assessments. Y is degradation at the sub-indicator or indicator level. N is not degraded.

	Sub indicator			Indicator
Support Class	Land cover	Productivity	SOC	Degraded
1	Y	Y	Y	Y
2	Y	Y	N	Y
3	Y	N	Y	Y
4	Y	N	N	Y
5	N	Y	Y	Y
6	N	Y	N	Y
7	N	N	Y	Y
8	N	N	N	N

3.3.4 National level aggregation

The *proportion of land that is degraded over total land area* should be reported for each defined land cover unit in addition to the total proportion of land degraded at the national level. The area degraded in the monitoring period t_n within land cover class *i* is estimated by summing all the area units within the land cover class determined to be degraded within one or more of the sub-indicators plus all area units that had previously been defined as degraded that remain degraded:

$$A(Degraded)_{i,\mathrm{n}} = \sum_{j=1}^{n} Arecent_{i,n} + Apersistent_{i,n} \qquad (1)$$

Where:

$A(Degraded)_{i,n}$ is the total area degraded in the land cover class *i* in the year of monitoring *n* (ha);

$Arecent_{i,n}$ is the area defined as degraded in the current monitoring year following 1OAO assessment of the sub-indicators (ha);

$Apersistent_{i,n}$ is the area previously defined as degraded which remains degraded in the monitoring year following the 1OAO assessment of the sub-indicators (ha).

The proportion of land cover type *i* that is degraded is then given by:

$$P_{i,n} = \frac{A(degraded)_{i,\mathrm{n}}}{A(total)_{i,n}} \qquad (2)$$

Where

$P_{i,\mathrm{n}}$ is the proportion of degraded land in that land cover type *i* in the monitoring period *n*;

$A(Degraded)_{i,\mathrm{n}}$ is the total area degraded in the land cover type *i* in the year of monitoring *n* (ha);

$A(total)_{i,\mathrm{n}}$ is the total area of land cover type *i* within the national boundary (ha).

The total area of degraded land at the national scale is the accumulation across the *m* land cover classes within the monitoring period *n*:

$$A(Degraded)_{\mathrm{n}} = \sum_{i}^{m} A(Degraded)_{i,\mathrm{n}} \qquad (3)$$

Where

$A(Degraded)_{\mathrm{n}}$ is the total area degraded in the year of monitoring *n* (ha);

$A(Degraded)_{i,\mathrm{n}}$ is the total area degraded in the land cover type *i* in the year of monitoring *n*.

The total *proportion of land that is degraded over total land area*, as specified in the SDG 15.3.1 target is given by:

$$P_{\mathrm{n}} = \frac{A(Degraded)_{\mathrm{n}}}{\sum_i^m \mathrm{A(Total)}} \quad (4)$$

Where

P_{n} is the proportion of land that is degraded over total land area;

$A(Degraded)_{\mathrm{n}}$ is the total area degraded in the year of monitoring *n* (ha)*;*

$\mathrm{A(Total)}$ is the total area within the national boundary (ha).

Proportions can be converted to possibly more intuitive percentage values by multiplying proportions by 100.

3.3.5 Regional/global aggregation

Regional and global estimates of land degradation status and trends over time can provide important contributions to land management and to understanding the factors that lead to changes in degradation levels globally and potentially help to prioritise resources, to address regions of pressing need, for example.

The aggregation of national level data into a regional or global dataset has inherent limitations relating to precision, completeness and consistency. Simple averaging of national degradation proportions at regional scales may indicate the relative overall degradation levels regionally, but may skew the representation upwards in cases such as where smaller countries with larger proportions of degradation occur in the region. Conversely, weighting degradation levels by country area may understate the importance of significant degradation in smaller countries. Ultimately the method of aggregation must consider the reporting objectives of the aggregation.

One method for reporting regional and global land degradation status from national reports on Indicator 15.3.1 draws on the long historical experience of the FAO Forest Resource Assessment (FRA)[8]. Land degradation status and trends are calculated from the overall indicator values, and not at the sub-indicator level. For the trend analysis only complete time series are considered and countries displaying missing values for one or more of the reference years are excluded from the analysis. Missing values should not be estimated.

The primary analytical categories of the regional/global reporting of the results are aligned with those of the FAO FRA as follows:

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[8] The Global Forest Resources Assessment (FRA) has worked with governments since the mid-1940s to prepare and assemble a global view of how the world's forests are changing.

1. **Global:** as this implies, the global analysis makes use of all reported values. Where values are missing, list-wise deletions were made for the calculation of the trends for incomplete time series;
2. **Sub-regional**: countries are grouped into 12 sub-regions for finer-scale global analyses;
3. **Climatic domains:** Climatic domains, defined by the dominant climatic domain per country, provide a useful approach of discriminating and understanding where land degradation is occurring. Iremonger and Gerrand (2012) describe 20 ecological zones (**Error! Reference source not found.**) aggregated into five domains: Tropical, Sub-tropical, Temperate, Boreal and Polar (**Error! Reference source not found.**).
4. **Income categories:** the per capita income of national economies can be used to evaluate possible relationships with land degradation indicators. The income categories, as defined by the World Bank[9], provide a reasonable measure of land degradation across income groups. Analyses by income category may provide unique insights into where land degradation is concentrated, where change is occurring and where the challenges for reducing land degradation are greatest.

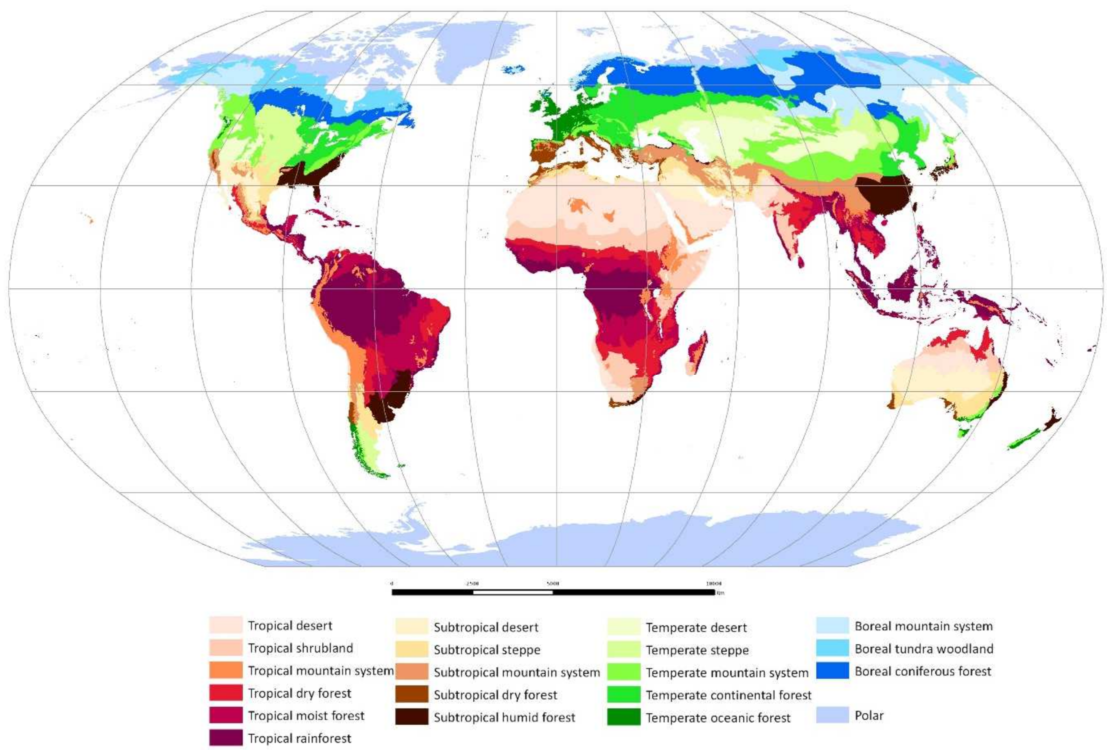

Figure 3. Global Ecological Zones (data available at http://foris.fao.org/static/data/fra2010/ecozones2010.jpg)

A range of other bases may also be preferred for aggregation at regional scales. Useful lists of countries grouped by regions and sub-regions and ecological domains are provided in Annex 4 of the FAO's FRA 2015 Process document (http://www.fao.org/3/a-br632e.pdf).

Understanding the precision of reported values instils an appropriate level of confidence in mean or summed values and allows variance-based analyses. Whilst this land degradation methodology does

[9] http://data.worldbank.org/about/country-and-lending-groups

not produce numbers with measures of variability around all reported values (similar to the FAO FRA dataset) it does not mean that national data necessarily originate from a source without estimates of precision. Many countries will adopt methods at Tiers[10] capable of generating sub-indicator estimates along with estimates of precision. The Tier designations within this methodology provide a measure of relative confidence in data at the sub-indicator level, even though measures of precision are not reported.

Table 5. FAO global Ecological Zoning framework for 2010 (Iremonger and Gerrand 2012).

EZ Level 1 – Domain		**EZ Level 2 – Global Ecological Zone**		
Name	**Criteria** *(Equivalent to Köppen-Trewartha Climatic groups)*	**Name** *(Reflecting dominant zonal[a] vegetation)*	**Code**	**Criteria** *(Approximate equivalent of Köppen – Trewartha Climatic types, in combination with vegetation physiognomy and one orographic zone within each domain)*
Tropical	All months without frost: in marine areas over 18°C	Tropical rain forest	TAr	Wet: 0 – 3 months dry[b]. When dry period, during winter
		Tropical moist forest	TAwa	Wet/dry: 3 – 5 months dry, during winter
		Tropical dry forest	TAwb	Dry/wet: 5 – 8 months dry, during winter
		Tropical shrubland	TBSh	Semi-Arid: Evaporation > Precipitation
		Tropical desert	TBWh	Arid: All months dry
		Tropical mountain systems	TM	Approximate > 1000 m altitude (local variations)
Subtropical	Eight months or more over 10°C	Subtropical humid forest	SCf	Humid: No dry season
		Subtropical dry forest	SCs	Seasonally Dry: Winter rains, dry summer
		Subtropical steppe	SBSh	Semi-Arid: Evaporation > Precipitation
		Subtropical desert	SBWh	Arid: All months dry
		Subtropical mountain systems	SM	Approximate > 800-1000 m altitude
Temperate	Four to eight months over 10°C	Temperate oceanic forest	TeDo	Oceanic climate: coldest month over 0°C
		Temperate continental forest	TeDc	Continental climate: coldest month under 0°C
		Temperate steppe	TeBSk	Semi-Arid: Evaporation > Precipitation
		Temperate desert	TeBWk	Arid: All months dry
		Temperate mountain systems	TeM	Approximate > 800 m altitude
Boreal	Up to 3 months over 10°C	Boreal coniferous forest	Ba	Vegetation physiognomy: coniferous dense forest dominant
		Boreal tundra woodland	Bb	Vegetation physiognomy: woodland and sparse forest dominant
		Boreal mountain systems	BM	Approximate > 600 m altitude
Polar	All months below 10°C	Polar	P	Same as domain level

[a] Zonal vegetation: resulting from the variation in environmental, i.e. climatic, conditions in a north south direction.

[b] A dry month is defined as the month in which the total of precipitation P expressed in millimeters is equal to or less than twice the mean Temperature in degrees Centigrade.

3.4 Reporting frequency

The recommended frequency of reporting for SDG 15 (Life on land) is every five to six years, which aligns with the publication of the UN Environment Programme's flagship report (UNDG Sustainable Development Working Group 2016). However, the frequency at which meaningful measurements of change in the sub-indicators can be calculated is a function of data availability, of the rate and

[10] This land degradation method adopts a set of tier categories similar to those used by both the Intergovernmental Panel on Climate Change (IPCC) and the FAO FRA. Countries are asked to assign a Tier value to each of the sub-indicator metrics. Specific definitions for each tier are provided in (Section 2.1).

magnitude of change in the sub-indicator and the level of uncertainty in the methods. For example, land productivity is assessed using a composite of high frequency measurements aggregated over the growing season, and it can be reported annually for the previous growing season. NPP is influenced by many environmental factors including environmental and human influences, however, and annual assessments of changes in the trajectory of NPP over time are more prone to influence by these factors than assessments over multiple years for instance. The availability of frequently updated land cover data is increasing and annual reporting of land cover change may soon be possible and meaningful. Conversely, SOC changes at a much slower rate, and therefore reporting more frequently than every 10 years may not be warranted nor able to detect changes within shorter time frames given the sensitivity of the methods used.

3.5 Minimum reporting requirements

Consistency in methodologies and definitions improves the interpretation of results and the ability to detect and understand real changes in the extent of degradation over time. Sufficient information must be reported to enable third parties to assess whether methods have been implemented correctly and consistently, and that reporting requirements have been met.

It is recommended that the following elements be included in Indicator 15.3.1 reports:

- Descriptions of, and justifications for the use of, relevant metrics for each of the sub-indicators at the National scale.
- Details of data sources, calculations, spatial disaggregation, and the basis for identifying changes in land cover, land productivity and carbon stocks.
- A land cover legend and transition matrix that maps land cover change to degradation processes and description of how the land cover classes are being used consistently throughout the time series.
- A land cover transition matrix showing the area of land cover types that have transitioned from one class to another during the assessment period. Accuracy statistics including an error matrix for classifications, and confidence intervals for all relevant assessments in each epoch of the assessment.
- Maps showing degraded areas as identified in each of the sub-indicator analyses at National scale.
- Justification for any areas that have been identified as degraded in one of the sub-indicators but are not reported as degraded at the overall Indicator level. Such justification may include "explainable anomalies" or "false positives".
- A descriptive review of all areas identified as degraded including the dominant land cover transitions, and possible drivers of degradation resulting in reduced land productivity and carbon stocks.

4 Rationale and Interpretation

Knowledge of the initial land degradation status is necessary for calculating SDG indicator 15.3.1[11] making use of the UNCCD land-based progress indicators and their associated metrics (e.g., land cover/land cover change; land productivity/NPP; carbon stocks/SOC)[12] to make this determination.

This good practice guidance documentation provides a global context for countries to consider their specific circumstances in addressing land degradation. However, it does not provide all the country-specific information necessary to fully understand and address specific land degradation problems, therefore it should be seen as complementary to other national efforts particularly those related to other reporting frameworks including the LDN Framework, the United Nations Framework Convention on Climate Change (UNFCCC) and the Convention on Biological Diversity.

Monitoring the *proportion of land that is degraded over total land area* differs from monitoring for LDN, which is focused on the monitoring of neutrality, that is, ensuring that the net area of significant new negative changes (losses) are counterbalanced with new significant positive changes (gains) in the same land type. However, the same data sets could be used to support current and future land degradation assessments to report on both SDG indicator 15.3.1 and LND.

Figure 2 illustrates how the initial land degradation assessment and monitoring of the indicators enables reporting on both SDG 15.3.1 and the LND framework; showing only scenarios where land is classed as degraded at time t_1. Any land that in not degraded at time t_0, and remains stable, or land that is degraded at t_0 but shows a gain in the indicators at t_1, is excluded from the calculation of proportion of degraded land.

While the three global indicators (land cover, land productivity, carbon stocks) address key aspects of land-based natural capital, additional indicators may be required to fully assess trends in land-based ecosystem services. Therefore, the global indicators should be supplemented by national (or sub-national) level indicators to provide full coverage of the ecosystem services associated with the land (Orr et al. 2017). Countries should identify complementary indicators which address their national and sub-national specificities and which will strengthen the interpretation of the global indicators. Examples may include indicators/metrics for other SDGs[6] or other national indicators/metrics, such as biodiversity assessed through the Red List Index (Bubb et al. 2009) and national Red Lists, and indicators that address locally-relevant issues such as heavy metal contamination.

[11] This differs from LDN monitoring, which is focused on the monitoring of neutrality, that is, ensuring that net area of significant new negative changes (losses) are counterbalanced with new significant positive changes (gains) in the same land type.

[12] See section 7.11 of the Scientific Conceptual Framework for Land Degradation Neutrality for more details on the important difference between using trends or absolute values to assess land degradation.

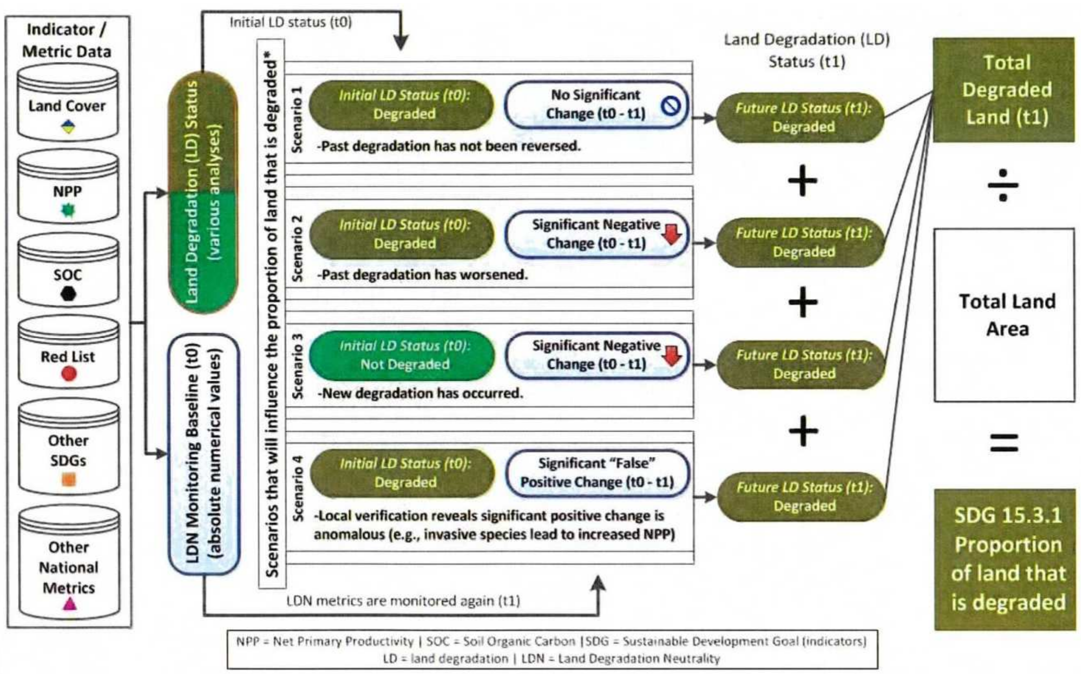

Figure 4: Conceptual diagram of the relationship between the initial land degradation assessment of SDG 15.3.1 and LDN monitoring (Orr et al. 2017).

5 Data Sources

The primary sources of information upon which the determination of degradation is made comes from the sub-indicator analyses. Data sources required for each sub-indicator are detailed in the relevant sub-indicator Annex to this report.

Datasets that complement and support existing and new national data and information are likely to come from multiple sources, including statistics and estimated data for administrative or national boundaries, ground measurements and Earth observations. Datasets with a 10-15 year archive of historical data, and for which an analogue is likely to be available into the foreseeable future, are best able to provide consistent data for this assessment.

Data required to derive the land cover and the carbon stocks sub-indicators are currently included in other multilateral reporting processes such as the greenhouse inventories under the UNFCCC. Therefore data acquisition will not necessarily require a new burden nor should it be interpreted as additional, but rather it will add consistency to existing reporting processes.

In the absence of, or as a complement to, national data, these guiding principles advocate that global and regional data sets must be validated with information at the national and, where possible, the subnational level. The most common approach involves the use of site-based data to assess the accuracy of the sub-indicators derived from Earth observations and geo-spatial information. Another approach uses site-based data to calibrate and validate Earth observation indices and measures where the remote sensing variable is used to predict the same biophysical variable on the ground. A mixed-methods approach, which makes use of multiple sources of information and combines quantitative and qualitative data, can also be used.

6 Comments and Limitations

6.1 One-out, all-out integration approach

The 1OAO rule can be considered a rigorous approach to the precautionary rule, in an ideal world where the status based on each indicator can be measured without error (Borja et al. 2014). In practice, the uncertainty associated with monitoring and assessment for each indicator/descriptor leads to issues of probable underestimation of the true overall class. Hence, if the error associated with the method used to assess the status of each indicator/descriptor is high the 1OAO approach is not advisable.

In practice the 1OAO approach results in very conservative assessments (Ojaveer and Eero 2011) and is recommended where indicators to be integrated are sensitive to different pressures (Caroni et al. 2013). Aggregation approaches would mask the changes detected in the individual indicators, and prevent the interpretation of individual measures at the national level based on local knowledge. Gains in one of these indicators therefore cannot compensate for losses in another because all are complementary, not additive, components of land-based natural capital (Orr et al. 2017).

Whilst the 1OAO approach is very conservative, consistently incorporating informed and well documented steps to address potential false positives and explainable anomalies will improve the confidence in the application of this aggregation approach. Including these well documented steps with any identified exclusions will help to maintain the integrity of the estimates reported against Indicator 15.3.1.

6.2 Comparative analysis

This good practice guidance document presents methodological approaches at three tiers to enable countries to report against Indicator 15.3.1 within their national circumstances. In the development of these country reports, National governments will adopt a wide variety of approaches in measuring, monitoring and regulating land degradation drawing on widely divergent levels of globally and nationally available data.

Whilst relatively frequent assessments of land degradation at National scales will enable country level trends in the *proportion of land that is degraded over total land area* to be established, the varying data quality and precision of the data used in the development of country reports pose limitations when making comparisons between countries and when aggregating the data into a global dataset.

Requiring transparency in reporting of the nationally adopted methods, tiers and data sources in generating estimates to report against Indicator 15.3.1 will enable improved interpretation of reported estimates and informed comparisons to be made.

Despite these challenges relating to comparative analysis, this reporting framework will lead to an increase in the awareness of global land degradation which can I turn provide an informed foundation for improved land management decisions and action.

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