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

Annex 1: Land cover and land cover change

DRAFT

Executive Summary

This Good Practice Guide is a living document that describes the methods available for evaluating land cover and land cover change as a sub-indicator for the Sustainable Development Goal 15, "promoting sustainable life on land". It will be revised based on feedback from international experts and agencies implementing methods for reporting progress against the SDG 15.3 target at the national level. The purpose of the document is to provide national agencies with a list of considerations that will help them determine how best to measure and map land cover and land cover change in order to implement national reporting against the sole indicator for SDG 15.3, i.e. indicator 15.3.1, "proportion of land that is degraded over total land area".

Key aspects of good practice for monitoring land cover are outlined in Section 3. This includes the development of national approaches to land cover mapping and the definition of degradation in terms of transitions between land cover classes (Section 3.1). Good practice is also specified for the reporting of land cover change and the evaluation of degradation based on these changes (Section 3.2), which will be integrated with other sub-indicators for reporting of the overall SDG 15.3.1 indicator. In terms of the development of a national method it is *good practice* to:

i. Define a spatial disaggregation scheme, as outlined in the Good Practice Guide for the overall indicator 15.3.1.
ii. Formulate a land cover map legend with classes that are unambiguous, exhaustive and complete.
iii. Generate a land cover class transition matrix that identifies the important processes (flows) of land cover change.
iv. Specify the product or method for generating a national land cover map including the source data, pre-processing, the classification algorithm and the accuracy assessment procedure.
v. Evaluate the performance of any new classification algorithm or existing product to be used in terms of:
    a. The availability of complete and temporally consistent national coverage;
    b. Their ability to capture the thematic detail defined in the legend;
    c. An ability to capture classes at a high level of thematic accuracy;
    d. Spatial resolution that is at least as detailed as the global default data (300m2);
    e. The ability to generate, or availability of, a land cover baseline going back to at least the year 2000, which corresponds to the start of the global default data time series.
vi. Specify when interim reporting will occur (ideally annually).

With respect to regular reporting of the land cover and land cover change sub-indicator, it is *good practice* to:

i. Provide two national land cover datasets, one which defines the baseline state (t_0) and one that defines the land cover state for the reporting date.
ii. Generate land cover change data including:
    a. Gridded change data which identify the flows for each grid cell.
    b. A table that identifies the total area for each major land cover flow.
    c. Data specifying if change is degradation or not degradation for each grid cell in the source land cover data.

    d. A map that indicates the probability of degradation, based on the land cover sub-indicator, for each spatial feature defined by the national disaggregation approach.

iii. Perform and report on validation of the land cover flows for any areas identified as degraded since the previous reporting period.

iv. Explain why any spatial features identified as degraded in the land cover change data should not to be included in the overall indicator calculation.

v. Explain why any spatial features not identified as degraded in the land cover change data should be included in the overall indicator calculation.

vi. Assess change for interim and final reporting periods with respect to the land cover baseline (t_0).

No dataset is expected to be the ideal source for rigorous land cover change detection and monitoring. However, the development of national methods for quantitative and repeatable land cover mapping provide the best basis for objective assessment of land cover change relevant to monitoring degradation in the context of SDG 15. This is particularly true when the methods are combined with extensive and accurate calibrated and validated data.

Although some consensus regarding good practice for monitoring land cover and land cover change may be reached, decisions made at the national level will always take precedence, as they are more likely to account for specific land cover types and change processes relevant to their situation. It is also recognised that data availability, the level of expertise and the resources available for reporting will vary immensely between countries and that this guide should not increase the reporting burden on national agencies. Rather it should be aligned and find application as guiding principles for meeting existing national and international reporting strategies which require assessment of land cover and land cover change.

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1 Definition and Concepts

1.1 Land Cover

Land cover refers to "*the observed physical and biological cover of the Earth's surface and includes natural vegetation and abiotic (non-living) surfaces*" (United Nations Statistical Commission 2012). 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 selection of woody and non-woody species arranged in a complex way both horizontally and vertically. Land cover, in this sense, is the description of these components in a way that has some logical meaning at the spatial unit of interest and in the thematic context being considered.

1.2 Land Cover Classification System

A *land cover classification system* is a framework to define and organize the land cover types or classes used in a specific application (Di Gregorio & O'Brien 2012). The framework should use consistent, unique and systematically-applied principles for classification. The framework should use objective "logical" class definitions, rather than subjective "cognitive" definitions of land cover. In this sense, logical classes are defined by the actual (bio) physical elements present, their arrangement and their properties. It should also be capable of describing the whole gamut of earth surface features.

The Land Cover Meta Language (LCML) (ISO 19144-2: 2012) is a framework for land cover classification which is formalized using the Unified Modelling Language (UML). While UML has traditionally been used in software engineering to define object-oriented software, in this application the UML classes represent *concepts*: specifically a framework for land cover elements and their attributes, arranged in a structured way, to ensure that classes can be clearly understood and readily compared within and between user groups and communities.

1.3 Spatial Feature

In the context of a classified landscape represented as a thematic map, a *feature* is an individual landscape element which is labelled as a member of a class from the classification system or map legend. Features may be abstract regions defined by a grid (pixels) or a polygon, or may be a logical unit defined by a political or natural boundary. Within a landscape the set of features should be spatially exhaustive, such that the entire region of interest (e.g. country) can be classified according to the legend in use.

A feature is often a contiguous unit that is assigned to a single class. However, a feature may be considered heterogeneous and information may be recorded about the proportions of all land cover types present. The degree of homogeneity of features depends on the classification system in use. Given uncertainty in the data, features may be labelled using the most probable class, with one or more other likely classes also recorded.

1.4 Land Cover Element

The basic components in the landscape that make up a given land cover type (or class) are referred to as *land cover elements* (ISO 19144-2: 2012). Elements may be abiotic such as water, soil, rock and man-made surfaces, or vegetation such as grasses, shrubs, bushes and woody plants. A particular land cover type (or class) may include one or many elements, depending on the complexity of the land cover and on the spatial unit being considered.

1.5 Land Cover Class

A land cover class is a single category or type of land cover within a broader set of classes, defined within a classification system. Its specification will generally describe the elements that constitute the class, and what properties these elements may have. For example, the definition of a forest class may include woody and non-woody vegetation, while some criteria for the cover and height of the woody elements may also be specified.

The decision about what classes might be defined depends on the purpose for which land cover mapping is being carried out. In the context of land degradation, decisions regarding what classes that need to be defined can be thought of in two ways:

1. Based on the need to define land cover types which identify important natural and degraded states of the land;
2. Based on the need to define the prior and post states for degradation processes that are important to monitor, mitigate and remediate.

1.6 Land Cover Class Definition

In the simplest approach, a land cover class is defined using a unique identifier (class name) and description. This is sufficient for land cover types that are simple to describe, but may be inadequate for those that are complex, requiring a definition that includes multiple elements and properties. Simple textual definitions also tend to lead to more cognitive than logical descriptions (Di Gregorio & O'Brien 2012) that are not necessarily well understood in different regions or across different disciplines.

For more rigorous and scalable class definitions a schema written in a mark-up language such as xml, json or rdf may be used. This can fully describe the criteria for the presence and arrangement of elements, as well as the range of acceptable properties for these elements. Because it is based around UML conventions, the LCML can be used to produce such a metadata classification schema that exactly specifies the criteria for classes in a machine readable format.

1.7 Land Cover Legend

A land cover classification legend is the set of classes which have been defined using the classification system and which will be incorporated into a given measurement, mapping, monitoring or reporting exercise. The classes constituting a suitable legend should be:

1. **unambiguous**: being mutually exclusive and unique;
2. **complete:** in terms of spatial coverage for the region of interest;

3. **exhaustive**: providing complete thematic coverage of all states of land cover of interest.

The level of detail for a given legend may depend on the application of the classification exercise and the thematic and spatial accuracy of available data. Instances of land cover legends range from course thematic detail such as the six-class IPCC land use legend (Penman et al. 2003), to more complex hierarchical legends such as the 36-class European Space Agency's Climate Change Initiative Land Cover (CCI-LC) dataset (Defourny et al. 2012).

1.8 Land Cover Flows

The transition from one land cover class to another is referred to as a land cover flow (Di Gregorio et al. 2011). The word flow is used (as opposed to transition) to recognise the gradual processes which often cause land cover change. In the case of land degradation, flows can occur rapidly as a result of significant environmental disturbances, natural disasters or human interference, but there may also be gradual processes of decline such as gradual changes in soil fertility, herbivory or climate.

In theory, flows can occur between any two classes (though some transitions may be improbable or are not possible instantaneously or without intermediate states). For example, a transition from a forest class to pasture may be referred to as deforestation, while a transition from a grassland to a water body may be defined as inundation. To formalize the complete set of flows, they may be organized in a matrix of class transitions, in which the two axes refer to the initial and final classes from the legend. However, some flows between different class pairs classes are due to a similar process, so the matrix may be simplified into a smaller number of unique flows.

2 Introduction

The 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 these 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 is to protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss. There are 12 targets that are considered critical to achieving the SDG 15 goal. Target 15.3 states the following:

"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 47th session of the United Nations Statistical Commission agreed to a draft global indicator framework as a starting point to review progress towards SDG targets. The UN Convention to Combat Desertification (UNCCD) has taken responsibility for developing a framework for monitoring this target 15.3 and has convened an Inter-Agency and Expert Group (IAEG) that has proposed a sole indicator for 15.3, being the:

"Proportion of land that is degraded over total land area."

They also proposed three sub-indicators that can be monitored by countries and used in concert to quantify the proportion of degraded land. These sub-indicators are:

1. Land cover
2. Land productivity
3. Carbon stocks above and below ground.

The way that sub-indicators can be combined to provide a total estimate of the proportion of land that is degraded is described in a separate Good Practice Guidance document.

The following document provides a summary and recommendations on how countries can access or measure land cover data, which can be used to monitor land cover change in the context of quantifying the area of degraded land. Countries are best placed to make their own decisions regarding the best method to measure, map and monitor national land cover. This Good Practice Guidance document seeks to set out general principles for how this can be achieved, drawing on existing methodologies that have been implemented or have been recommended in the broader literature.

While the intention of this Good Practice Guidance document is to describe how land cover can be measured, monitored and reported in the context of the SDG 15.3 target, it is recognised that land cover has applications beyond SDG target 15.3. This includes within other SDGs and fulfilling a role in other international and national-level reporting obligations. For these reasons, a national decision regarding the best method for monitoring land cover will, as far as possible, exploit existing data and methods so as not to increase burden on national agencies. It is also recognised that to be an effective tool in helping countries achieve SDG 15, land cover data must be relevant in the context of policy setting such as prevention, mitigation and restoration of degraded land into the future.

3 Method of Computation

The methodology suggested for assessing land cover and land cover change draws on the guiding principles for the overall SDG 15.3.1 indicator for land degradation (see separate Good Practice Guide for the overall SDG 15.3.1 Indicator). The method of computation used is a national decision and this guidance merely sets out considerations for national agencies in implementing their own measurement, validation and reporting approaches.

The method of computation for land cover and land cover change is described in two phases: (3.1) the development and approval of the national method, and (3.2) the interim and final (2030) reporting of the sub-indicator. Approval of the land cover method is done as a component of the approval of the national method for the overall indicator. From the perspective of the land cover sub-indicator, it is important to ensure that the method conforms to good practice, is an objective assessment of land cover change and can be aggregated to report on land degradation at the global scale. The reporting phase concerns the identification and reporting of land that has degraded since the initial date for the target, January 2016. Such reporting involves integration of the sub-indicator with other sub-indicators (net primary productivity and carbon stocks), as described in a separate document outlining good practice for the overall SDG 15.3.1 indicator.

3.1 Definition of National Method

The national method identified to map land cover change should be described in detail and be included with the first interim report against the SDG 15.3 target. This definition should include a baseline land cover map from which future change and degradation can be assessed. It is possible that the method adopted may change as additional expertise, resources and data become available. Such a change should be reported in the next interim report against the target and include reprocessing and submission of the new baseline land cover data. The definition of the method of computation should address the following *good practice* principles.

- It is *good practice* to define and justify a spatial disaggregation scheme. This scheme will specify the spatial features within which land cover and land cover change will be reported. It will also be used to stratify the assessment and reporting of other sub-indicators. Methods of stratification and their applicability for assessing and reporting land cover change are discussed in the good practice guide for the overall indicator SDG 15.3.1.
- It is *good practice* to define a land cover map legend with classes that are unambiguous, exhaustive (they can be used to map all land area) and complete (transitions capture the major land degradation processes). The capacity of country to utilise existing expertise and available data to support accurate mapping and validation of classes across the country must also be considered. Criteria for evaluating the legend will be that important degradation processes can be identified via transitions between classes. The use of a structured land cover classification system is encouraged to assist in harmonising classes at the global scale.
- It is *good practice* to generate a land cover class transition matrix that identifies the processes that are involved in causing a transition between land cover classes. This will assist in determining if the correct classes have been used in the legend and that all major land cover change processes (flows) have been captured. The major flows identified in the matrix

should be listed and identified as either degradation, stable or improvement in terms of the value of land capital.

- It is *good practice* to clearly specify the method selected for generating a national land cover map. This should include the source data, any pre-processing, the classification algorithm and the accuracy assessment procedure. A national subset of a default global land cover map will be made available by the agency responsible for the SDG 15.3 target. This will include only the 6 IPCC land cover classes. Other global, regional and national land cover products are available (see Section 4.2) and could be used to supplement or as an alternative to this default dataset.
- It is *good practice* to evaluate (quantitatively where possible) the performance of any new classification algorithm or existing product to be used in terms of:
    - The availability of complete and temporally consistent national coverage;
    - The use of time series data to assess when transitions in land cover occur and to identify these transitions through the analysis of spectral change;
    - Their ability to capture the thematic detail defined in the legend;
    - Ability to capture classes at a high level of thematic accuracy;
    - A spatial resolution that is at least as detailed as the global default data (300m2, see Section 4.1)
    - The availability of or ability to generate or a baseline map for January 2016.
- It is *good practice* to define as baseline (t_0) from which changes in land cover will be assessed. Nominally this baseline would be the most common (mode) class specified in land cover maps over the period 2000 to 2010. The use of shorter or more recent baseline periods may be required depending on the base land cover data being used.
- It is *good practice* to specify when interim reporting of the SDG 15.3.1 indicator will occur. This should occur annually from the start of reporting to January 2030, but may be less frequent depending on data availability and resources. As far as possible, the method of generating the land cover product for these future reporting dates should be the same as the baseline. Any issues in generating future land cover maps that are comparable with the baseline map should be identified.

3.2 Reporting of the Sub-Indicator

Interim reporting of the overall indicator (SDG 15.3.1), including the land cover change sub-indicator, can occur after the national method has been defined and described. Reporting of the sub-indicator will identify areas where land cover has changed significantly relative to the baseline (t_0). Reporting should be detailed enough so that national stakeholders and the agency responsible for SDG target 15.3 can recognise the location, type and level of change that has occurred. This requires the following *good practice* principles to be considered.

- It is *good practice* to provide two gridded national land cover datasets, one for t_0 and one for the reporting date. These should be generated at the same grid spacing (spatial resolution) and using the same approved land cover classification approach. This should be accompanied by an accuracy assessment for each map, including a confusion (error) matrix with accuracy and confidence intervals as described in Section 3.8.

- It is *good practice* to generate land cover change information based on the reporting date and baseline (t_0). This will include
    - Gridded change data which identifies the flows for each grid cell in the land cover data.
    - A table that identifies the total area of land that is associated with each major land cover flow.
    - Gridded degradation data that specifies if change is degradation or not degradation for each grid cell in the land cover data.
    - A map that indicates the probability of degradation within spatial features that are based on the approved national disaggregation approach. Significant degradation can be identified according to the equations in Section 3.9.
- It is *good practice* to perform qualitative assessments of areas identified as degraded. This assessment should specify the dominant land cover flows occurring within the region, the expected rate of degradation (in hectares per year) and proposed remediation approaches.
- It is *good practice* to justify why any spatial features identified as degraded in the land cover change data should not be included in the overall indicator calculation. This should be based on the identification of false positives, where change in the land cover data is due to stable or improved land capital.
- It is *good practice* to justify why any spatial features not identified as degraded in the land cover change data should be included in the overall indicator calculation. This should include a proposed improvement to the land cover classification approach or legend so that such degradation processes are captured in future assessment periods.
- It is good practice to assess change for interim and final reporting periods with respect to the baseline land cover data product (t0). This will ensure that land defined as degraded, from a land cover change perspective, will remain in the degraded category unless it is improved relative to the land cover baseline. Rationale and Interpretation.

3.3 Land Cover Baseline

The baseline for the 15.3 target (t_0) should be considered over an extended period, as opposed to a single date or land cover mapping epoch. Nominally this baseline period is from January 2000 to January 2010 and it is good practice to consider the most common land cover type (the mode) as the appropriate baseline value. In cases where multiple classes have equal highest frequency, the most recent of these classes should be considered the appropriate baseline value.

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. The baseline is referred to as t_0 and interim reporting dates (ideally annually) 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 and if the sub-indicator implies that the target has been achieved.

National agencies should consider the specific period for assessing the baseline (t_0) in the context of the rate of land cover change in their country. For example, a shorter period selected for the baseline could be used to ensure the baseline better reflects land cover state at the start of the SDG process (January 2016), but will be more subject to spurious values in the land cover time series.

Earlier periods (e.g. using 2000-2010 as opposed to 2005-2015) will provide more opportunity to assess land degradation after the baseline, but will have a tendency to show greater degradation as a proportion of land area for a given reporting date.

3.4 Defining the Legend

Land degradation can be defined differently depending on the characteristics of the environment and the values of those assessing it. Some of the ways degradation can be considered include:

1. A decline in the actual or potential productive capacity of the land, through a loss of biomass or a reduction in vegetative cover and soil nutrients.
2. A reduction in the land's capacity to provide resources for human livelihoods.
3. A loss of biodiversity or ecosystem complexity.
4. Increased vulnerability of the environment or people to destruction or crisis.

National agencies must determine what processes (flows) are considered to degrade their natural land capital. This may include the identification of specific processes that are of concern such as deforestation, desertification and urbanisation. Identification of specific flows will help to ensure a **complete** set of land cover classes required to monitor and map land degradation at the national scale.

Land cover classes should also be **exhaustive**, such that all of a country's land area can be attributed to a specific class at t_0 and monitored over the period to t_n. The identification of an exhaustive set of classes may reinforce or supplement classes identified as part of an analysis of land degradation flows. While national agencies are best placed to determine the exact classes to include in a legend to quantify land degradation, the six classes included in the IPCC land use change legend (Penman et al. 2003) should be considered a minimum set. National agencies are encouraged to extend this minimum set to enhance their ability to identify and map important land degradation processes occurring in their country. The UN Statistical Commission's System of Environmental and Economic Accounting (United Nations Statistical Commission 2012) defines 14 land cover types that are considered to best capture the state of natural capital in a country (see Table 1). The FAO GLC-SHARE Land cover dataset adopts 11 of these classes by aggregating SEEA cropland classes (Latham et al. 2014). The hierarchical structure of the GLC-SHARE legend is shown in Figure 1.

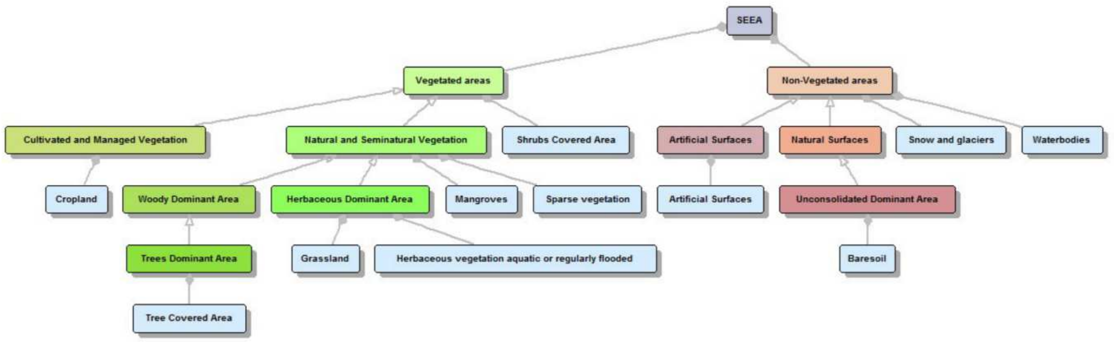


Figure 1: The SEEA based legend used by GLC-SHARE and defined using the LCML (Latham et al. 2014).

Clear and **unambiguous** definition of classes is imperative in order to ensure that flows can be identified and degradation processes are understood by all parties. While not the only method for defining clear and unambiguous classes, LCML provides a structured approach to class definition. In the case of an existing legend, Gregorio & Jansen (2000) provide guidance on how to translate from conventional descriptive class definitions to a LCML-based schema.

At the coarse (thematic) scale, land cover elements have a natural hierarchy defined within the LCML. In more complex classes, land cover types may be defined using multiple elements that occur in detailed (horizontal) patterns and (vertical) strata. Examples of LCML class definitions are shown in Figure 2 and Figure 3. Tools that form part of the LCCS allow users to take land cover classes and store them in a hierarchical structure that groups the classes according to the main land cover type. While the FAO provides software tools to help in harmonising non-LCML classes, these tools do require some prior understanding of the object based structure of the meta-language. An examples of the relationship between classes that form part of three important land cover legends (IPCC, GLC-SHARE, SEEA, and the ESA CCI Land Cover) are shown in Table 1.

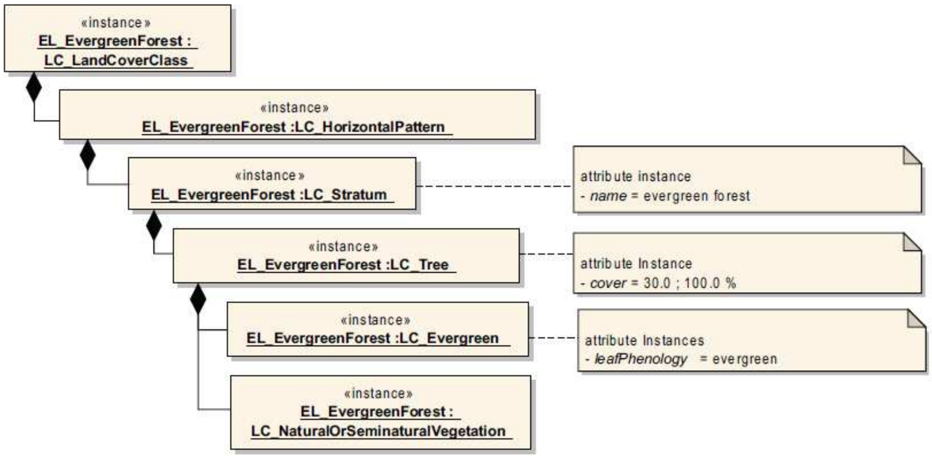


Figure 2: LCML implementation of the CORINE Evergreen forest class (ISO 19144-2: 2012)

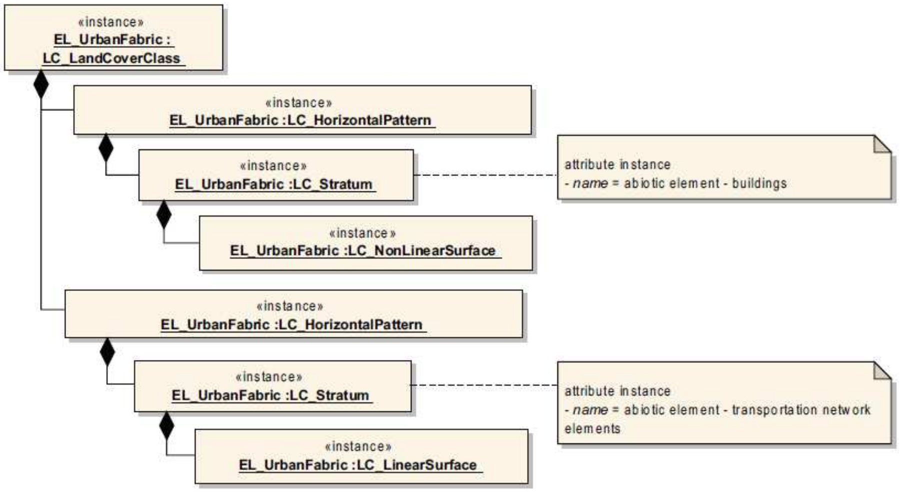


Figure 3: LCML implementation of the CORINE Continuous Urban Area class (ISO 19144-2: 2012)

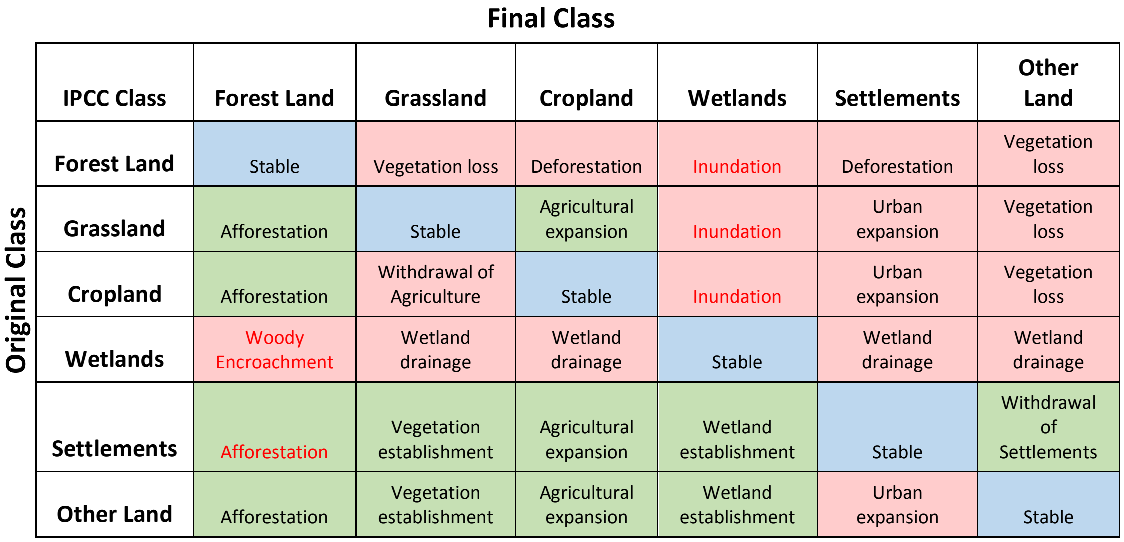
Table 1: Mapping between land cover classes used in various legends. The final "National Legend" column is left blank to indicate the desire to be able to harmonise nationally defined legends to common global standards.

IPCC	GLC-Share	SEEA	ESA CCI-LC classes (and codes)	National Legend
Forest Land	Tree Covered Areas	Forest tree cover	Tree broadleaved evergreen, Tree broadleaved deciduous, Tree needle leaved evergreen, Tree needle leaved deciduous, Tree mixed leaf type, Mosaic tree, shrub / herbaceous cover, Tree flooded, fresh water	
Grassland	Grassland Shrub Covered Areas Sparse Vegetation	Pasture and natural grassland Shrubland, bushland, heathland Sparsely vegetated areas Natural vegetation associations and mosaics	Mosaic natural vegetation / cropland, Mosaic herbaceous cover / tree, shrub, Scrublands, Grassland, Lichens and mosses, Sparse vegetation	
Cropland	Cropland	Medium to large fields of rain-fed herbaceous cropland Medium to large fields of irrigated herbaceous cropland Permanent crops, agriculture plantations Agriculture associations and mosaics	Cropland rain fed, Herbaceous cover Tree or shrub cover Cropland, irrigated or post-flooding, Mosaic cropland / natural vegetation	
Wetlands	Herbaceous Vegetation, aquatic and regularly flooded Mangrove	Open wetland	Tree cover, flooded, saline water, Shrub or herbaceous cover, flooded Water bodies	
Settlements	Artificial Surfaces	Urban and associated developed areas	Urban areas	
Other land	Bare soil Snow and Glacier	Barren land Permanent snow and glaciers	Bare areas, Permanent snow and ice	
	Water Bodies	Inland water bodies Coastland Water bodies Sea		

3.5 Defining Flows

It is good practice to define a matrix of flows that include all classes in the national legend. Using the IPCC legend (Penman et al. 2003) as a simple example, the 6 classes can be used to define 6 x 5 (30) possible land cover changes. An example of how these class changes might be classified according to major change processes is shown in Figure 4 and includes 11 unique land cover flows. These flows are then listed in

Table 2.



Final Class

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

Figure 4: Graphical summary of the land cover change matrix for the 6 IPCC classes (30 possible transitions). Unlikely transitions are highlighted in red text. Major land cover processes (flows) are identified and boxes colour coded as improvement (green), stable (blue) or degradation (red).

Table 2: Descriptions of major land cover change processes identified as flows in Figure 4.

FLOW ID	FLOW PROCESS DESCRIPTION	DEGRADATION
LCF1	Deforestation	Yes
LCF2	Urban Expansion	Yes
LCF3	Vegetation Loss	Yes
LCF4	Inundation	Yes
LCF5	Wetland drainage	Yes
LCF6	Withdrawal of agriculture	Yes
LCF7	Stable	No
LCF8	Afforestation	No
LCF9	Agricultural Expansion	No
LCF10	Vegetation establishment	No
LCF11	Wetland Establishment	No

Transitions between classes will not always be logical or probable (Gómez et al. 2016; Wehmann & Liu 2015). The identification of illogical or improbably flows in the transition matrix will assist in validation of land cover change maps. A comprehensive approach would be to specify the probability of all transitions in the matrix. This may be incorporated into automated classifications schemes (e.g. using Bayesian priors) to improve the accuracy of subsequent land cover maps.

The attribution of flows for a reporting period can only be done using two epochs of corresponding classified features. In the case of land cover, features will generally be a spatial unit and the attribution of flows to these spatial units result in a new spatial dataset. In the case of the SDG 15.3 target, this spatial dataset is used to identify the location and aggregated area of degraded land. The presumption is that flows can be used to determine if an area is either degraded or not degraded, based on the net change natural land capital.

3.6 Earth Observation Source Data

Land cover mapping is often based on surface reflectance products derived from earth observation data. These products attempt to minimise, normalise or remove some or all of the following:

- Sensor to sensor spectral radiometric variations;
- Atmospheric attenuation and obscuration by cloud; and
- Surface bi-directional reflectance distribution function (BRDF) variations.

In addition to the above, identification of land cover change requires consecutive epochs of land cover to be overlayed precisely. The removal of geometrical distortions such as projection of native swath data to an established spatial (or coordinate) reference system (ISO 19111: 2007) and the removal of topographic distortions are important steps for ensuring that land cover change is not incorrectly identified.

Products such as the MODIS Nadir BRDF Adjusted Reflectance (Schaaf et al. 2002) and MERIS surface reflectance (Defourny et al. 2012) provide good examples of the required pre-processing of earth observation data prior to attribution of land cover classes. Further refinement of these products using compositing, including best available pixel approaches (White et al. 2014), have resulted in the availability of annual global cloud free surface reflectance composites that are a strong basis for generation of land cover maps . However, knowledge of the timing of any measurement is important for understanding change and it is good practice to record, interrogate and understand pixel observation dates in any composite product before land cover is attributed.

While the spectral properties of some classes within a legend may be quite distinct (e.g. vegetation, water, urban), other classes may be less easy to distinguish using conventional spectral methods at a given spatial resolution (e.g. deciduous and evergreen forests), particularly when using annual image composites. In such cases, assessment of spectral change metrics is required and may provide a means of increasing classification accuracy (Gómez et al. 2016; Fuller et al. 2003).

Spatial and temporal resolution of EO source data are key factors which can determine the value of derived land cover products. A broad survey of the user community conducted as part of the implementation of the CCI-LC (Herold et al. 2010) suggests there is a need to move towards finer spatial resolution (e.g. from 1km towards 30m) and towards finer temporal coverage (from 1 year to seasonal or monthly) in order to better detect land cover change.

While high quality cloud free imagery are an important basis for land cover classification, the native spatial resolution of the observation also has a significant impact on the type of land cover and the change processes that can be detected. Sub-pixel change processes are less likely to be identified, the larger the pixel size to change area ratio. This has led to a call for increased spatial resolution in land cover products (Herold et al. 2010) and is an emerging opportunity for moderate resolution sensors on board Landsat (Franklin et al. 2015) and Sentinel (Malenovský et al. 2012).

Since trade-offs between spatial and temporal resolution are required to achieve an acceptable "signal to noise ratio" for satellite observations, data fusion algorithms (e.g. Gao et al. 2006; Hilker et al. 2009) may provide some advance toward the required data to underpin accurate and timely land cover classification.

3.7 Land Cover Datasets

While national and regional programs to monitor and map land cover have been in existence for decades, the first global land-cover product, DISCover based on AVHRR data, was not released until the early 1990s (Loveland et al. 1999). Increased spectral information available via the MODIS and SPOT-VEGETATION instruments allowed for more detailed legends (Bartholomé & Belward 2005; Friedl et al. 2002). Recently, medium resolution sensors, MERIS and SPOT-VGT, have allowed an increase in the spatial resolution achievable for global land cover maps like the CCI-LC (Bontemps et al. 2013; Defourny et al. 2012).

Many countries have systems in place that regularly collect quantitative data to assist in mapping land cover. The three tiered structure outlined by the IPCC (IPCC 2006) for data and methods is a useful model. These tiers order the methods from least to most detail. For example, in the case of the land cover sub-indicator for 15.3.1 these tiers might include:

1. **Tier 1:** Global or regional land cover products based on earth observation data, but not calibrated at the national scale;
2. **Tier 2:** Nationally derived land cover products based on earth observation data and with specifically designed legends and calibration for local conditions;
3. **Tier 3:** National land cover products based on the integration of earth observation data, modelling and ongoing validation programs including manual interpretation of high resolution imagery and in-situ observations and measurements.

These tiers are not meant to be exclusive, rather building on each other to best utilise the data and expertise available at the national level. Specific sources of data at the global and regional level are described under "Sources and Data Collection".

As part of the SDG 15.3.1 target reporting process a dataset will be nominated and made available for use as a default for reporting on the land cover and land cover change sub-indicator. While thematic detail, geographic coverage and temporal range are all factors that should be considered at the national level, at this time, the European Space Agencies (ESA) Climate Change Initiative (CCI) land cover dataset (CCI-LC) is the preferred product for use as the global default. Specifically, national subsets of the CCI-LC baseline (most common land cover class over the period 2000-2010) from which land cover change can be evaluated.

Both automated and semi-automated classification methods have been developed for the generation of land cover maps based on earth observation data. Although unsupervised methods with post-classification labelling have frequently been used (Loveland et al. 1999; Bartholomé & Belward 2005), supervised methods have become more common. These include both parametric (generally Gaussian) and non-parametric methods. In a meta-analysis of relevant literature, Khatami et al. (2016) present a list of most accurate to least accurate algorithms for land cover classification as follows:

1. Support Vector Machines;
2. Neural Networks;
3. Random Forests;
4. Traditional (non-ensemble) Decision Trees;
5. Maximum likelihood.

In addition to variations in the performance of specific classification algorithms, Khatami et al. (Khatami et al. 2016) found that the inclusion of additional variables (beyond raw spectral data) into the algorithm can yield improvements in the classification accuracy (Table 3). Specifically the inclusion of spatial, directional and temporal context, along with other orthogonal variables such as topography and geology, generally provide a means of improving accuracy.

Table 3: Improvements in the mean accuracy of land cover products after inclusion of additional data (in additional to raw spectral bands), based on the meta-analysis by Khatami et al. (2016).

Input Data	Mean Accuracy Improvement
Textural indices	12.1%
Topographic, geological, radar, lidar	8.5%
Multi-angular data	8.0%
Time-series data	6.9%
Spectral Indices	2.4%

Although Khatami et al. (2016) provide guidance based on 15 years of published research, the best algorithm and variables for a specific case will depend on the classes that need to be discriminated and the characteristics of the data being employed. National agencies will be best placed to make decision regarding these methods once legends and source data are established. However, if land cover products other than the default data are used, it is good practice to show how these provide a quantitative advantage over the global default.

Fuller et al. (2003) argues that the differencing of two distinct land cover maps as a means of determining land cover change requires classification accuracy that is not generally achieved using remote sensing. They advocate an approach which draws on broader knowledge of the directions, patterns and scale of change. In the context of the SDG 15.3, this somewhat of a circular argument, in that accurate mapping of land cover requires identification knowledge of land cover change processes, while this knowledge is change processes are often derived from differences in land cover mapping. To address this circularity, it is good practice to use methods of land cover mapping that not only use static indices (e.g. Table 3), but also the trajectory of these indices over time to determine what the final state of land cover is. This method helps to identify illogical or improbable changes (Gómez et al. 2016) to support the final land cover class specification.

3.8 Training and Validation

Good practice for collecting training and validation data, and assessing accuracy are described in a recent FAO publication (Finegold et al. 2016). Optimum training and validation data depend on the classification legend and the classification method employed. The most common non-parametric methods of classification require training data that best describes class boundaries as opposed to parametric methods which require the location and spread in the input data space (Gómez et al. 2016).

The size of the training dataset will depend on the thematic detail of the legend and on the spatial variability of the land cover. It is difficult to specify appropriate field sample size since it depends on information that is not known a priori (Finegold et al. 2016). However, it was estimated that around 1000 samples were required for adequate training and validation of the GLC-Share global land cover product (FAO 2014), while the CCI-LC product made use of 2600 sampling points (Defourny et al. 2012). For the Australian Dynamic Land Cover Map, more than 25,000 field validation sites were used (Lymburner et al. 2011). It is good practice to define a spatial stratification approach to help guide selection of samples.

Ideally the distribution of each variable for each land cover class needs to be captured. In some cases, ground sampling for training and validation data may be impractical. Alternative approaches to data collection may include the manual interpretation of:

- High resolution imagery (e.g. airborne, satellite, Google Earth or via Collect Earth)
- High temporal resolution data (e.g. NDVI time series for the feature of interest)

Expert knowledge and training may be required to ensure that such data accurately captures the spatial and thematic variability in the data.

Methods for assessing a reporting error in land cover classification are well established and generally begin with a confusion (or error) matrix, which is a cross-tabulation of map classes (rows) and validation classes (columns; Table 4). The number of samples that appear along the diagonal show those samples that are correctly classified, while those that appear off the diagonal are errors. Confidence intervals should be reported for each of the accuracy measures in the confusion matrix. The formula for these can be found in Olofsson et al. (2014).

Table 4: Example of a three class confusion matrix and accuracy statistics.

	Validation Class 1	Validation Class 2	Validation Class 3	Commission Error
Map Class 1	p_{11}	p_{12}	p_{13}	$p_{11} / \sum p_{1i}$
Map Class 2	p_{21}	p_{22}	p_{23}	$p_{21} / \sum p_{2i}$
Map Class 3	p_{31}	p_{32}	p_{33}	$p_{31} / \sum p_{3i}$
Omission Error	$p_{11} / \sum p_{i1}$	$p_{12} / \sum p_{i2}$	$p_{13} / \sum p_{i3}$	$\sum p_{ii}$

3.9 Reporting Change

For any features that are identified as being degraded at t_1, it is good practice to provide some ground truth to validate that changes indicated by the data are realistic and that flows have actually degraded the natural land capital. Some discussion of significant changes at the scale of individual features will be useful for understanding national trends and planning policy responses. Justification should also be provided for not including any areas that have been identified as degraded in the data, but are considered not degraded based on more detailed validation studies.

It is good practice to report on the degraded area and proportion for each land cover type in addition to the total proportion of land degraded at the national level. If all spatial features are considered homogeneous at t_0 and at t_1, then the baseline land cover specific area is calculated by:

$$A_{i,0} = \sum_{j=1}^{n} a_j \, X_{i,0} \qquad (1)$$

where a_j is the area of the jth feature (e.g. pixel or polygon) and $X_{i,0} \to \{0,1\}$ is an indicator function that takes the value one if features are of land cover type i at time t_0. At t_1 the area of land cover class i that is degraded at t_1 is:

$$A_{i,1} = \sum_{j=1}^{n} a_j \, X_{i,1} \qquad (2)$$

where $X_{i,1} \to \{0,1\}$ is the indicator function taking the value one when features are originally of land cover class i and have transitioned to a degraded class before t_1. The proportion of land cover type *i* that is degraded is then given by:

$$P_{i,1} = \frac{A_{i,1}}{A_{i,0}} \qquad (3)$$

The total area of degraded land at the national scale is the accumulation across the *m* land cover classes defined within the legend:

$$A_1 = \sum_{i=1}^{m} A_{i,1} \qquad (4)$$

and the total proportion of degraded land, as specified in the SDG 15.3.1 target is given by:

$$P_1 = \frac{A_1}{\sum_{i=1}^{m} A_{i,0}} \qquad (5)$$

If features are not considered homogeneous at either t_0 or t_1 then significant change can be specified when $p > \alpha$ when p is calculated using the equation:

$$p = \sum_{i=1}^{m} \left| P_{i,0} - P_{i,1} \right| \tag{6}$$

Nominally $\alpha = 0.10$, while $P_{i,0}$ and $P_{i,1}$ are the initial and final proportions of each of the m land cover types. The baseline land cover specific area at t_0 is these proportions as follows:

$$A_{i,0} = \sum_{j=1}^{n} a_j P_{i,0} \tag{7}$$

At t_1 the area of land cover class i that is degraded is only accumulated over those features where change has been shown to be significant:

$$A_{i,1} = \sum_{j=1}^{n} a_j P_{i,1} X_{i,1} \tag{8}$$

where the indicator function $X_{i,1} \rightarrow \{0,1\}$ takes the value one for features where p indicates significant change. The proportion degraded for land cover type, the total area degraded and the total proportion of land degraded are again based on Eq. 3-5. A template for reporting land cover change is shown in Table 5.

Table 5: Template for reporting degraded area and proportion by land cover class

Class	Class Area at t_0	Area Degraded at t_1	Proportion Degraded at t_1
C_1	$A_{1,0}$	$A_{1,1}$	$P_{1,1}$
C_2	$A_{2,0}$	$A_{2,1}$	$P_{2,1}$
…	…	…	…
C_m	$A_{m,0}$	$A_{m,1}$	$P_{m,1}$
Total			P_1

4 Sources and Data Collection

4.1 Global Default Data

The land cover sub-indicator is used to detect land cover change, but also as a means of stratifying the analysis of the other sub-indicators (productivity and carbon stocks). The UNCCD has established a partnership with ESA to provide interested countries with extractions of global CCILC data (Herold et al. 2010). This provides 22 land cover classes defined using the LCML, at 300m resolution based on moderate resolution satellite data (ENVISAT MERIS, MODIS, SPOT VGT and PROBA-V). Annual updates of the CCI-LC product are currently available from 1992 to 2015. A default baseline (t_0) product base on the most common land cover type of the period 2000 to 2010 will also be generated. Additional years will be made available as soon as they are finalized by ESA.

While the CCI-LC data provides 22 classes at level 1, these will also be provided in aggregated IPCC classes (see Table 1) to assist in harmonising between existing classifications systems. The CCI product follows good practice principles by detecting change relative to a land cover baseline based on a time series of annual global classifications generated from AVHRR HRPT (1992 - 1999), SPOT-Vegetation (1999 - 2012) and PROBA-V (2013 - 2015). Analysis of the temporal trajectory of each pixel allows identification of change processes. This approach avoids independent classification of annual updates, ensuring temporal and spatial consistency between successive maps.

The national subsets of the CCI-LC data will be provided to countries at the native $300m^2$ spatial resolution for t_0. This can be used at interim reporting dates to determine the land cover change as additional annual updates become available. Other options at the tier 1 to 3 level are described under Section 4.2 and these should be evaluated to determine if these data are better suited to identifying flows associated with degradation processes that are important at the national scale, or if they can be used to supplement existing default or national datasets.

4.2 Additional Data Sources

Many reviews of land cover data products have been published (Hansen & Loveland 2012; Xie et al. 2008; Congalton et al. 2014; Gómez et al. 2016). Such reviews date quickly as new data and classification methods emerge. A recent review of land cover data conducted by Diogo & Koomen (2015) included 27 global, regional and national land cover datasets. They discussed source data, spatial resolution, time periods available, accuracy, geographic extent and the classification system employed. They make the following points relevant to the most appropriate data for identifying land cover change:

- Land cover data with a reasonable continuity of regular epochs should be preferred as there is more impetus and demonstrated capability to continue generating these into the future.
- Country specific data benefits from the knowledge of local experts, including the generation of legends which are appropriate at the national scale.
- Higher spatial resolution is generally preferred in order to capture finer scale land cover change such as urban sprawl and other landscape fragmentation.

A list of global land cover datasets is shown in **Error! Not a valid bookmark self-reference.**. Some practical limitations of these products are outlined below:

- GLC-SHARE: The Global Land Cover-SHARE (GLC-SHARE) is a 1km resolution global land cover product created by FAO’s Land and Water Division in partnership with various partners and institutions (Latham et al. 2014). No specific date is associated with the product as it is derived from a broad set of a combined and harmonised products, including national, regional and global land cover datasets. Thus it provides a useful bassline from which land cover change might be measured as opposed to a dynamic product that could be used to determine change in and of its self.
- FROM-GLC: The FROM-GLC dataset is a 30 m resolution global land cover map produced using Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) imagery, with source data centred around 2006 (Gong et al. 2013). While there is significant value in increasing the spatial resolution of land cover mapping, as with GLC-SHARE, the product is not regularly updated and thus may provide a useful baseline but requires additional product epochs to be generated in order to determine change.
- MODIS Land Cover: The MODIS land cover product is generated using a supervised artificial neural network classification and decision tree classifier, exploiting a global database of

training sites interpreted from high-resolution Landsat TM imagery in association with ancillary data (Friedl et al. 2002). The latest collection of the products (Collection 5) includes processes to reduce year-to-year variability not associated with land cover change due to poor spectral–temporal separability in MODIS data (Friedl et al. 2010). MODIS land cover products use the IGBP classification system and are available for every year in the period 2000 to 2014 at 500m spatial resolution.

Diogo & Koomen (2015) suggest that it is not clear if any currently available data sources are adequate to produce robust information about land cover changes. For this reason new and emerging data and methods should be investigated and the most appropriate integration of earth observation, manual interpretation of high resolution imagery and ground based surveys should be determined. This will vary depending on the land cover types and the degradation processes present at the national scale.

While regional land cover products do not provide the geographical coverage to act as a default product for the SDG 15.3 target, they may have advantages at the individual country scale as a means of better characterising land important land cover classes specific to that region. Two important regional datsets are summarised in Table 7 and dicussed below:

- CORINE Land Cover: The CORINE Land Cover product includes coverage of the 28 European Union member states and other European countries. The prodiuct is based primarily on the manual interpretation of Landsat ETM+. National land cover maps are assembled into a seamless European map, resulting in a complete and consistent dataset across Europe. The datasets are distributed in at a 100 m pixel resolution, including 44 classes organised in three hierarchical levels, combining both land cover and land use concepts. Land cover maps are available for 1990, 2000, 2006 and 2012.

North American Land Change Monitoring System (NALCMS): The NALCMS is a harmonised land cover product based on MODIS data, which can be applied across North America at 250m spatial resolution. The classification legend is designed in three hierarchical levels using the FAO-LCCS system. There are currently two series available for the year 2005 and 2010.

Table 6: Summary of existing global, regional and national land cover data available, as reviewed by Diogo & Koomen (Diogo & Koomen 2015).

Product	Measurement method	Reported accuracy	Geographical coverage	Spatial resolution	Time periods available	Thematic resolution
Global Land Cover Characterization	Based on AVHRR satellite imagery	81%-90% (training data)	Global (aggregated dataset)	1o, 8km and 1km	Only available for 1984	Land cover (IGBP)
Global Land Cover Classification (GLCC)	Based on AVHRR satellite imagery	65%-82%	Global (aggregated dataset)	1 km	Only available for 1992-1993	Land cover (IGBP)
GLC 2000	Based on SPOT 4 satellite imagery	66%- 69%	Global and regional (aggregated dataset)	1 km	Only available for 2000	Land cover (FAO-LCCS)
MODIS Land Cover	Based on MODIS satellite imagery	2005: 75%	Global (mosaics and aggregated dataset)	500m (mosaics) or 5’ and 0.5o (aggregated global dataset)	Every year between 2001-2012	Land cover (IGBP)
SYNMAP	Merging of GLCC, GLC 2000 and MODIS 2001	-	Global (aggregated dataset)	1km	Only available for (circa) 2000	Land cover (SIMPLE)
GlobCover	Based on MERIS satellite imagery	2005: 73% 2009: 68%	Global (aggregated dataset)	300m	2005 and 2009	Land cover (FAO-LCCS)
CCI-LC	Based on MERIS and SPOT-Vegetation satellite imagery	2008-2012: 74%	Global (aggregated dataset)	300m	1998-2002, 2003-2007 and 2008- 2012	Land cover (FAO-LCCS)
Global Land Survey	Satellite imagery collected from Landsat sensors	-	Global (mosaics)	30m	1975, 1990, 2000, 2005 (LTCCF and LFCC only available for 2000 and 2005)	HR satellite imagery, Tree cover, Forest cover change
FROM-GLC 30m	Based on Landsat TM/ETM+ satellite imagery	64%-66%	Global (mosaics)	30m	Only available for 2006	Land cover (compatible with IGBP and FAO-LCCS)
GlobLand30	Based on Landsat TM/ETM+ and HJ-1 satellite imagery	2010: 79%	Global (mosaics)	30m	2000 and 2010	Land cover (GlobLand30 legend)
GLC-Share	Harmonisation of national, regional and global databases	0.8	Global (aggregated dataset)	30 arc-second (~1km)	-	Percentage of each land cover per grid cell and dominant land cover (SEEA)

Table 7: Summary of existing regional land cover data available, as reviewed by Diogo & Koomen (Diogo & Koomen 2015).

Product	Measurement method	Reported accuracy	Geographical coverage	Spatial resolution	Time periods available	Thematic resolution
CORINE Land Cover	Based on SPOT, Landsat TM and MSS satellite imagery, complemented with ancillary data available at the country level	2000: 87%	EU-28, Albania, Bosnia and Herzegovina, Macedonia, Iceland, Kosovo Liechtenstein, Montenegro, Norway, Serbia, Switzerland, and Turkey	1:100,000 (vector) or 100m (raster)	1990, 2000, 2006 (2012 foreseen)	Land cover and land use (CORINE, based on FAO-LCCS)
North American LCMS	Based on MODIS satellite imagery	Canada 2005: 59%-69%	Canada, Mexico and the United States	250m	2005 and 2010	Land cover (FAO-LCCS)

Many countries produce their own land cover mapping products that service both national and international reporting requirements. A selection of these have been reviewed by Diogo & Koomen (2015) and are listed in Table 8. These data are considered to have precedence over global and regional products for monitoring land cover change in the context of SDG 15. This is because class legends can be designed to include specific land cover types and to capture important land cover change processes that are important within a specific country. However, National land cover mapping products vary greatly in terms of the underlying data used, spatial and temporal resolution, classification algorithms employed and the level of validation applied. In order for National land cover mapping approaches to best serve the needs of monitoring the SDG 15.3 target, care should be taken to incorporate good practice in terms of class definition, legend design, classification approaches and the extent and approach to validation.

Table 8: Summary of existing national land cover data available, as reviewed by Diogo & Koomen (Diogo & Koomen 2015).

Product	Measurement method	Reported accuracy	Geographical coverage	Spatial resolution	Time periods available	Thematic resolution
PNECO	Based on MODIS TERRA and LANDSAT TM satellite imagery	Not reported	Argentina		2006-2007	Land cover (FAO-LCCS)
National Dynamic Land Cover	Based on MODIS EVI composites	Not reported	Australia	250m	2000-2008 Time series with a dataset for each year between 2000 and 2010 is expected to be released	Land cover (FAO-LCCS)
ALUMP	AVHRR imagery, land use information and simulation of agricultural crops allocation	Not reported	Australia		1992-1993 1993-1994 1996-1997 1998-1999 2000-2001 2001-2002 2005-2006 2010-2011	Land use (ALUMC)
Mapeamento Sitemático do	Based on Landsat ETM+	Not reported	Brazil (mosaics, incomplete)		2003 and 2007, but not for all	Land use (inspired in

Product	Measurement method	Reported accuracy	Geographical coverage	Spatial resolution	Time periods available	Thematic resolution
Uso da Terra	satellite imagery				mosaics	CORINE)
Land Cover of Canada	Based on AVHRR satellite imagery	Not reported	Canada (merged with Vegetation Map of Alaska dataset)	1km	1998	Land cover (Alaska Interim)
Canada Land Cover circa 2000	Based on Landsat 5 and Landsat 7 satellite imagery	Not reported	Canada	Not reported. Based on data with 30m resolution	2000	Land Cover (EOSD)
Catastro de los Recursos Vegetacionales Nativos de Chile	Initially based on panchromatic aerial photography, currently based on SPOT 5 and FORMOSAT-2 satellite imagery	Not reported	Chile (mosaics of 15 regions)		1997, 2001, 2007 and 2011	Land cover, land use, property rights, forest category, forest establishment and reforestation, biomass, carbon, forest fires, forestry resource extraction
China Land Cover	Based on Landsat TM/ETM satellite imagery	Not reported	China		1990, 1995, 2000, 2005, 2008	Land cover and land use (unknown classification)
National Land Numerical Information	Based on Landsat, TERRA and ALOS satellite imagery	Not reported	Japan (1km mosaics)	100m (1/10) mesh	1976, 1987, 1991, 1997, 2006 and 2009	Land use (classes differ per year)
Uso del Suelo y Vegetacion	1976: aerial photography interpretation. 1993, 2000 and 2007: based on Landsat TM satellite imagery	Not reported	Mexico		1976, 1993, 2000 and 2007	Land cover (IFN2000)
LUCAS LUM	Based on Landsat and SPOT satellite imagery	2012: 95%	New Zealand	Not reported. Based on data with the following resolution: 1990 – 30m 2008 – 10m 2012 – 10m	1990, 2008 and 2012	Land cover (FAO-LCCS)
National Land Use and Cover		-	South Africa		-	Land use (CSDM)
Land Categories Map of the U.S.S.R.	Compilation of different sources from land cadastre inventory	Not reported	Former U.S.S.R.		1991	Land cover (IIASA-LUC Former U.S.S.R.)
National Land Cover Database	Based on Landsat TM satellite imagery	2001:79% 2006: 78%	United States	30m	1992, 2001, 2006 and 2011	Land cover (modified Anderson LCCS)

5 Comments and Limitations

The purpose of the document is to outline key considerations that may assist in implementing national scale monitoring of the sub-indicator in order to implement national reporting against SDG indicator 15.3.1. It draws on existing knowledge of good practice with respect to land cover and land cover change mapping. However, as it precedes the implementation of the monitoring of SDG 15.3.1 it will benefit from ongoing revision based on feedback from international experts and agencies implementing these strategies at the national level.

A suggested by Diogo & Koomen (Diogo & Koomen 2015), no earth observation dataset has yet proven to be adequate for rigorous land cover change detection. However, the adoption of a quantitative and repeatable process for land cover mapping will provide an objective method for detecting change that can be assessed using more detailed manual interpretation of high resolution imagery or ground based surveys.

Although it is hoped that broad consensus will be reached regarding some aspects of good practice, decisions made by individual countries that take into account their specific land cover types and change processes will be more effective in providing a basis for setting policy responses to help address the SDG 15. It should also be recognised that the level of data, expertise and resources available for reporting against SDG 15.3.1 will vary immensely and that it is not the intention of this guide to increase the reporting burden on national agencies. Rather it is hoped that the SDG 15.3.1 land cover sub-indicator can be aligned and find application as a tool for national reporting and to meet other international reporting obligations.

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