**Module 2** **28 March 2015**

# Use of global tree cover and change datasets in REDD+ Measuring, Reporting and Verifying (MRV)

## *1 Introduction*

The Methods and Guidance Document (MGD) published by the Global Forest Observations Initiative (GFOI) describes the integrated use of remotely sensed and ground-based data to estimate greenhouse gas emissions and removals associated with REDD+ activities. This module discusses possible use of global datasets together with the MGD methods which are freely available via the GFOI web-site[1]. Technical terms used in this module are explained in an Annex.

Global maps of land cover, including tree cover, are now publically available. Work led by the University of Maryland (UMD) [2], provides tree cover, and cumulative tree cover gains and annual losses. The maps are updated annually, and there are plans to produce annual tree cover maps. The maps have 30m x 30m resolution and are based on Landsat data. They have the potential to provide countries with change maps where suitable maps do not already exist for their territories. This module discusses issues and trade-offs that may arise in using global datasets in conjunction with the MGD. It covers area estimation, and the relationship to national forest definitions. Tree cover is typically only one aspect of forest definition and so is not sufficient by itself to define forest. In addition, tree cover loss is not necessarily deforestation, e.g. in the case of managed forests or areas affected by significant disturbance (see Section 3).

## *2 Role of reference observations*

Reference observations (see the Annex) are high-quality statistically valid sample data that can be used to produce area estimates without expected bias[3]. Reference data can be used by themselves, or jointly with remotely sensed data used for mapping. Joint use of reference data and maps, whether nationally or globally produced, allows correction for the estimated effects of bias due to classification error in the map, and can improve precision by reducing the standard errors of area estimates. Given the same number of high quality reference observations, nationally produced land cover maps would generally be expected to produce area estimates with better precision than if a global map product were used[4]. National mapping is better able to take national circumstances into account, which should translate into a more accurate map. However, use of additional reference data points with a globally produced map can compensate for the larger standard errors that would

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[1] The MGD is at http://www.gfoi.org/methods-guidance-documentation

[2] M C Hansen et al, *High-resolution global maps 21st-century forest cover change*, Science, **342** Nov. 15, 2013. The data are also available via the World Resources Institute Global Forest Watch web-site, at http://www.wri.org/our-work/project/global-forest-watch. The data are relative to 2000 and at the time of writing cover the period 2001-2012. Other maps of this type may become available in future. For a review of global data sets see Tsendbazar, N.E., et al. (2014) Assessing global land cover reference datasets for different user communities. ISPRS J. Photogram. Remote Sensing, http://dx.doi.org/10.1016/j.isprsjprs.2014.02.008. Other data sets are the ESA Land Cover CCI at 300m: http://www.esa-landcover-cci.org/,the Global Land Cover dataset at 30m from China for 2000 and 2010: http://www.globallandcover.com/, and Do-Hyung Kim et al, *Global, Landsat-based forest-cover change from 1990 to 2000*, Remote Sensing and the Environment **155, (**2014), 178-193.

[3] Technically, this is possible by using *unbiased estimators* with suitable data sets – see Annex

[4] Losses of forest are more easily detected than changes in forest cover or gains in forest area, so the need for national mapping is likely to increase in the case of degradation and the plus activities of REDD+.

otherwise be expected from global maps. This applies to overall area and area change estimates rather than to the accuracy of site specific mapping (section 6 below). In this context, global mapping has the potential for considerable savings where national mapping capacity does not already exist; at least until national mapping capacity is developed to improve precision, and for other reasons discussed below.

*3 Relationship to national forest definitions*

Common inconsistencies between global data and national forest definitions are related to the minimum canopy cover thresholds, detailed consideration of land use (e.g. the status of shifting cultivation, oil palm or other plantations), the minimum size of forest patches, and the minimum tree height required by the definition. The global maps available from UMD indicate three main characteristics: (i) percentage crown cover for vegetation over 5 metres in height[5], (ii) tree cover loss (areas where tree cover has been removed entirely) and (iii) tree cover gain (areas where tree cover has been established where previously there was no tree cover).

Rules to map the extent of the minimum percentage crown cover[6] specified in the national forest definition (the first map product identified in Table 6 of the MGD) could be implemented automatically in the case of the UMD data, because percentage crown cover is a pixel-level attribute. Other criteria to define forest, such as a different height specification, or specific land use requirements, imply the need for supplementary national mapping (with associated cost) to correct for areas either erroneously included or excluded by the global maps. To achieve this, the national forest monitoring system (NFMS, see MGD section 1.4), or other institutional arrangement responsible for land use, could identify areas that would otherwise meet the forest definition, but are under predominantly agricultural or urban land use, and identify ecosystems where trees do not meet the height definition.

Use of 30m x 30m pixel-based data, whether produced on a global or local scale, should also take account of minimum area of forest land use where specified as part of the national definition. Accommodating the area requirement of a forest definition is non-trivial with pixel-based maps. Pixel elimination and aggregation rules must be applied for consistency with the applied definition, which may degrade the spatial resolution of the map and involve complicated averaging methods to estimate percent canopy cover for the aggregated units. In practice, to date, this has seldom been done[7].

Global map products indicating areas where tree cover has been removed entirely could be used to help produce the second map product in MGD Table 6 (Forest/non-forest change)[8]. However, as is the case also with national mapping, areas where complete overstorey removal is indicated will not necessarily correspond to deforestation in accordance with the national forest definition, because:

[5] In the case of the UMD data the mapping is tuned to detect tree cover about 5 m height. Tree height measurement by remote sensing requires interpretation of stereoscopic images or a returned signal from radar or LiDAR which are not commonly available.

[6] The relative performance of global and national classification methods may be a function of the crown cover threshold used in the national forest definition

[7] The Australian National Greenhouse Gas Inventory approach to reporting land use, land use change and forestry applies such methods.

[8] At the time of writing the UMD data do not yet provide updated global forest cover maps.

- deforestation, consistent with the national forest definition, entails land use change and occurs when areas previously meeting the forest definition fall below the minimum tree cover, height or area thresholds without prospect of recovery. This is not necessarily the same as complete removal of tree cover.
- tree cover may fall temporarily to zero (or below the minimum specified in the national forest definition) because of harvest or natural disturbance, but this does not indicate a change from forest land use if replanting or regeneration will take place.
- disturbances (e.g. fire, wind, disease or landslides) may reduce forest cover below the minimum threshold, or to zero, but this does not indicate deforestation if forest according to the national definition will be re-established by natural or assisted regeneration.

Use of global datasets to estimate deforestation therefore needs to take account of factors other than simply using the global analysis of removal of tree cover below the minimum level that can be estimated by the global data set classification algorithm. This is likely to require identification of areas subject to harvesting where replanting will take place, and information on the extent of any disturbances, and whether they have been followed by land use change, or not. The auxiliary information required should be obtained by interaction with stakeholders via the NFMS or other institutional arrangement responsible for land use. Modifications introduced via auxiliary data need to be treated consistently over time, or significant error may be introduced into mapping and area estimation.

Reference observations consistent with the national forest definition can be used with unmodified global mapping to adjust for estimated bias as discussed in section 2. Alternatively auxiliary information could be used as part of the processing to produce maps from the global data which correspond to the national forest definition. The second alternative would probably be undertaken to reduce the number of reference observations needed to achieve a specified precision expressed as specified standard error.

*4 Forest stratification*

Stratification is a step in estimating greenhouse gas emissions and removals using the gain-loss method[9] as described in section 2.2 of the MGD. Information such as stocking densities (e.g. volume, biomass or carbon), site class, topography, aspect, dominant tree species or species clusters are commonly used for this stratification. Percentage crown cover from global datasets could be used to estimate uniform carbon density for stratification purposes. Such information can also improve the precision of estimates where the stock difference method is used. It is necessary that strata are sufficiently distinct to be identifiable, using remotely sensed data, aerial imagery or specialized map layers such as soils, forest type or others. Estimation of forest degradation, and enhancement of carbon stocks (the 'plus' of REDD+) may require finer resolution data (both spatially

[9] Section 2.2 of the MGD describes use of IPCC guidance to estimate directly emissions and removals associated with REDD+, rather than estimating them as the difference in carbon stocks at two points in time, which requires a National Forest Inventory or equivalent. Section 2.2 therefore describes gain-loss estimation, consistent with the defining equations 3.2.2 in the IPCC 2003 Good Practice Guidance, or 2.4 in Vol 4 of the IPCC 2006 Guidelines. MGD Section 2.1 has a discussion of the choices involved.

and temporally) than are currently available as pre-processed global datasets, and development of national capacity will help take advantage of technical developments as they become available[10].

*5 Site specific accuracy*

The methods for using reference data in bias correction, referred to in section 2 above and described in Section 3.7 of the MGD, yield area estimates of land classes (e.g. forest, non-forest, forest loss and forest gain) that are adjusted for estimated bias. However these methods are not designed to determine which pixels are misclassified[11]. This means that the act of area (or area change) estimation with reference observations does not improve site-specific mapping accuracy (at the level of individual pixels or minimum mapping units). Consequently if maximum site-specific accuracy is needed (e.g. for interacting with stakeholders, identifying drivers of deforestation[12], or associating ground-based with remotely sensed data for development of emission factors) it may be better to develop national mapping using classification methods designed for national circumstances[13]. Achieving a particular accuracy in either case is likely to require an initial trial followed by additional reference observations sampling or improvements to the classification technique until the desired result is obtained.

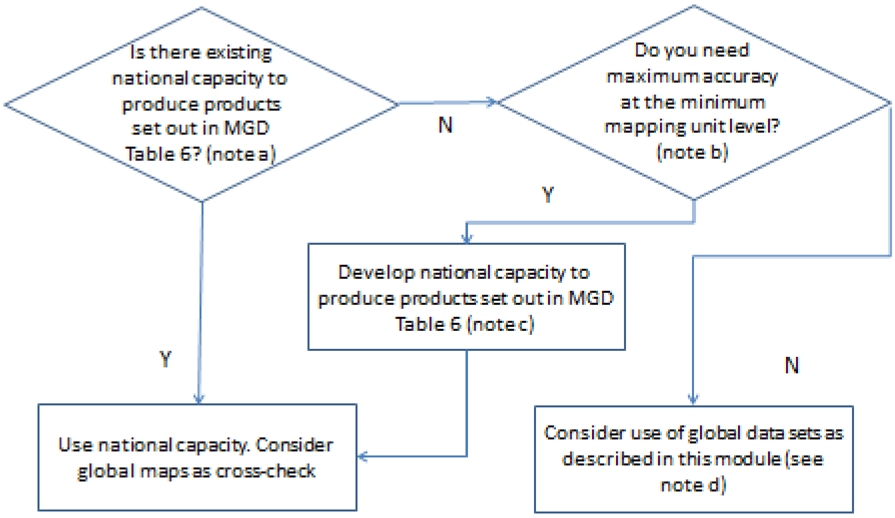
*6 Summary*

Decisions on possible use of available global datasets to generate national level estimates of forest area and change are related to:

- whether national mapping capacity already exists
- accuracy achieved by global datasets
- cost relativities (e.g. the cost of collecting more reference observations versus establishing a national mapping capability, and costs of establishing the relationship between global maps and national forest definitions)
- specific national needs for a land cover map (e.g. related to forest definition and land cover classifications, for integration with domestic planning)
- preferences for national ownership of the process, to respond to technical developments.

The choices are summarized in the decision tree below.

[10] As discussed in the MGD, it is currently challenging to detect changes in canopy cover associated with degradation. In October 2013 GFOI and GOFC-GOLD held a workshop on degradation monitoring and a report of the meeting is available at http://gfoi.org/sites/default/files/GFOI-GOFCGOLD_RDExpertWS2_Report.pdf
[11] Misclassification of individual pixels or other sampling units corresponding to the reference sample can be determined, although these will generally be a very small proportion of the study area.
[12] Or other REDD+ activities
[13] See MGD Section 3.5 for discussion of image classification.




Notes:
a) All cases assume joint use of mapped and reference data.
b) E.g. for interacting with stakeholders, identifying drivers or associating remotely sensed and ground-based data.
c) Use of global datasets could be an interim step while national capacity is developed.
d) Factors identified in the text include preferences for national ownership, cost relativities of national mapping or global datasets plus increased reference sample size, and ability to respond to technological developments.

**Annex – Explanation of Technical Terms**

| Term | Explanation |
|---|---|
| Accuracy | How closely an estimate corresponds to the corresponding underlying true value |
| Bias | Tendency to produce over- or under-estimates. Section 3.7 of the MGD discusses these points further and describes two methods for using reference observations (see below) to correct for estimated bias. Other possibilities exist these are described in a module currently in preparation |
| Estimator | A rule for producing an estimate of an underlying true value from suitable data. An estimator is said to be *unbiased* if it does not, on average, under- or over-estimate the true value. |
| Precision | How closely estimates of an underlying true value from different samples agree with each other |
| Reference observations | The best available assessment of conditions on the ground for a given location or spatial unit. Reference observations can be used to estimate areas and associated standard errors based on sampling. Reference observations are also used to assess the accuracy of maps made using remote sensing and to correct for estimated bias. Reference observations may be accurately co-georeferenced ground data or finer resolution or more accurately classified remotely sensed data, which are available for a probability sample of the data-points with sufficient representation of classes of interest (e.g. changes associated with deforestation). The reference observations referred to in this module should be independent of any data used to train or develop the classification algorithm used to produce the maps. Section 3.7 of the MGD discusses these points further. |

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|---|---|
| Resolution | The pixel size of satellite imagery. |
| Standard error | A quantification of the uncertainty of an estimate, e.g. the uncertainty is attributable to the fact that a different sample of reference observations would yield a different estimate. The standard error quantifies how much the estimate would vary over different samples that could have been selected. |


*This module was prepared by:*

Martin Herold – Wageningen University

Erik Lindquist – Food and Agriculture Organization of the United Nations

Ronald McRoberts – U.S. Forest Service

Erik Næsset – Norwegian University of Life Sciences

Pontus Olofsson – Boston University

Jim Penman – University College London

Christophe Sannier - Systèmes d'Information à Référence Spatiale, France

Pete Watt Indufor (Asia-Pacific)



*Taking into account, with thanks, review comments from*[14]*:*

Danny Donoghue - University of Durham

Simon Eggleston – Global Climate Observing System

Carly Green – Environmental Accounting Services

Matt Hansen – University of Maryland

Nancy Harris – World Resources Institute

Russell G. Congalton - University of New Hampshire

Kenneth G. MacDicken - Food and Agriculture Organization of the United Nations

Douglas M. Muchoney – U.S. Geological Survey

Maria Sanz-Sanchez – Food and Agriculture Organization of the United Nations

Charles T. Scott – U.S. Forest Service


[14] The final text represents the views of the authors, taking review comments into account.

Stephen V. Stehman – State University of New York

Kiyoto Tanabe – Technical Support Unit, IPCC National Greenhouse Gas Support Programme

Rob Waterworth - Australian National University

Sylvia Wilson – U.S. Geological Survey

Curtis Woodcock –Boston University