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Contents

SYMBOLS AND ACRONYMS

AGB	Above-Ground Biomass
ATBD	Algorithm Theoretical Basis Document
CCI	Climate Change Initiative
ECV	Essential Climate Variables
REDD	Reducing Emissions from Deforestation and Degradation
SAR	Synthetic Aperture Radar

1. Introduction

1.1. Purpose and scope

This document provides a summary of the products from the Climate Change Initiative (CCI) Biomass project. Its main content is contained in two summary tables relating to a) Above Ground Biomass (AGB) products and b) the AGB change product. Although the AGB products are well-specified, there have been only preliminary discussions about the desired properties of the change product or what it should comprise. Hence this document should still be regarded as an interim summary.

1.2. Applicable documents

Table 1. Applicable documents

ID	TITLE	ISSUE	DATE
RD-1	User Requirements Document	V3.0	30.08.22

2. The AGB product

Our current understanding of the AGB products to be generated in CCI-Biomass is given in Table 1 and is consistent with the major recommendations from the climate and carbon cycle modelling communities as expressed during the Second User Workshop and set out in the User Requirements Document (RD-1). The spatial resolution required for the Reducing Emissions from Deforestation and Degradation (REDD+) community is not a target for CCI-Biomass, though in most other respects the proposed products are acceptable to them.

A potentially difficult issue for the AGB products is provision of information on bias (which is a concern for almost all Essential Climate Variables; ECVs). This is strongly related to the validation component of the project and cannot be considered independently of spatial resolution, since bias could vary with resolution. The precision of the products is easier to estimate but is of less concern to the modellers since many of them are principally interested in grid-cell values. In this case, pixel averaging can be used to provide more precise estimates of the mean. Note that for most modellers, the locations of sub-grid-cell AGB estimates within a grid-cell are not needed. However, for models using age or biomass cohorts, the histogram of AGB values within a grid-cell is of major interest. Currently we have no specification of how accurate the histogram would need to be, or what the appropriate accuracy measure would be.

Table 2: Product specifications for AGB products.

Product	Map of forest aboveground biomass (AGB; Mg ha^{-1}). Maps of precision for both products
Spatial Coverage	Global
Pixel spacing	100 m x 100 m
Temporal Extent	Multiple time periods: 2005/07, 2010, 2015/16, 2017-2022
Reference System	Lat-Long, WGS-84
Accuracy	Accuracy should be higher than existing maps. AGB estimates should be unbiased but if this cannot be achieved with current sensors, information on likely bias will be provided.
Data format	netcdf GeoTIFF, LZW compression, unsigned 16-bit integer
Delivery mode	CCI Open Data Portal
Product support	• Fully documented mapping methods (i.e., the ATBD) • Robust and standardised validation scheme with documented protocol • Full reporting of validation results and implications for possible product bias and precision • Metadata available for the data used to estimate AGB and validation • Free and open access

3. The AGB change product

Changes in AGB are of major importance for climate as increases are associated with carbon sinks and sources and hence the net change in atmospheric carbon dioxide. However, measurement of change using any form of remote sensing data (including Synthetic Aperture Radar; SAR) is not well developed because of sensor, data and algorithm deficiencies. For SAR, two suggested approaches are to (i) generate and difference AGB maps and (ii) measure differences in the SAR signal and establish a link with AGB change.

Differencing AGB maps was studied during the GlobBiomass project and in Phase 1 of CCI Biomass, where it was noted that quantifying the error statistics in the AGB difference product is crucially dependent on knowledge of the distribution of the error statistics of the AGB product itself. The precision of the AGB difference will be given by the square root of the sum of the variances of the individual AGB measurements, so will be larger than the precision of either of the two input AGB values. The bias will be the difference of the biases in the two AGB measurements, so can be larger or smaller than either of the two individual biases. The ability to calculate confidence intervals on the AGB difference depends on whether the precision in the individual AGB measurements varies with AGB. Hence, progress with describing the accuracy of AGB change measured using AGB differencing relies on the findings from the validation element of CCI-Biomass.

Measuring differences in the SAR signal and establishing a link with AGB change is statistically much more firmly based, as there has been extensive work on detecting and measuring changes in both single and multi-channel radar signals. The difficulty is then to attribute signal change to AGB change and the size of that change, and these issues have not been extensively studied.

Changes in AGB over annual (2017 to 2018) and decadal (2010-2017 or 2018) periods can be associated with a range of natural events and processes and human activities that have occurred over these periods. Based on a new globally-relevant change taxonomy (Lucas et al., 2022) that supports CCI Biomass, **AGB gains** are associated with increases in the extent and/or amount of vegetation, including afforestation, reforestation (both natural and plantations), recovery from wildfires, revegetation, vegetation encroachment and restoration and succession. Most of these processes take place over multi-year timeframes and are often difficult to discern through annual comparisons of Earth observation data or derived products. **AGB losses** come from decreases in the amount of vegetation, often associated with specific events, which are sometimes followed by recovery. Events include those that are natural (storm (wind) damage, wildfires or dieback following storms) or human induced (e.g., deforestation, selective logging, thinning). Reducing processes include dieback (from storms, sea level fluctuation, inundation, droughts, insects, pathogens or herbivory) and desertification. Natural events and human activities are often easier to detect through annual comparisons (i.e., 2017 to 2018 in the context of CCI Biomass) but processes may be best detected through multi-annual or decadal comparisons (i.e., 2010 to 2017/18). Each of these change events and processes (whether leading to a loss or gain in AGB) will be detectable to differing degrees using the SAR data and current efforts are being made to better define these and the extent to which these can be mapped.

In the above, AGB change has been treated as a quantity to be estimated at each pixel, but for modelling it may be more useful to consider changes in the histogram of AGB values within a grid-cell. Such an approach has attracted little attention up to now and its development needs both provision of methods and interaction with the modelling community to establish the best way forward.

It is against this background that Table 2 summarises our current understanding of the AGB change products to be generated in CCI-Biomass.

Table 2: Current product specifications for AGB change products.

Global AGB change product specifications		
	Threshold (minimum) Requirements	Target Requirements
Product	Maps of forest AGB change (Mg ha^{-1})	Maps of forest AGB change
Spatial Coverage	Global	Global
Pixel spacing	1 km x 1 km or at grid-cell level	100 m x 100 m or at grid-cell level
Temporal Extent	Changes for three time intervals: • Decadal (e.g. 2010-2020) • 5 yearly (e.g. 2010-2015/16) • Annual (e.g. 2017-2018)	As for threshold.
Reference System	Lat-Long, WGS-84	Lat-Long, WGS-84
Accuracy	Currently not specified and may need different specifications for pixel values and grid-cell histograms. Estimates of AGB change should be unbiased, which has different meanings for pixel values and grid-cell histograms. Methods to validate the product are currently undefined.	As for threshold, but validated products are required.
Data format	netcdf GeoTIFF, LZW compression, unsigned 16-bit integer	netcdf GeoTIFF, LZW compression, unsigned 16-bit integer
Delivery mode	CCI Open Data Portal	CCI Open Data Portal
Product support	• Fully documented change mapping methods (i.e., the ATBD) • Validation scheme with documented protocol • Full reporting of validation results and implications for possible product bias and precision • Metadata available for the data used to estimate validate biomass change. • Free and open access	• Fully documented change mapping methods, • Robust and standardised validation scheme with documented protocol • Full reporting of validation results and implications for possible product bias and precision • Metadata available for the data used to estimate validate biomass change. • Free and open access • Access to underlying data

4. Conclusions

Many of the properties of the final CCI-Biomass AGB product are well specified but there are still critical uncertainties related to spatial resolution and accuracy that will only become clear as the project develops, and the algorithm development and validation components become more consolidated. The specification of the AGB change product is less clear, as currently the meaning of AGB change (i.e., whether based on pixels or grid-cell histograms) in the context of climate and carbon models needs more discussion and interaction with the modellers and this is ongoing with the different interest communities. This will have major impact on the methods to be adopted and the description of error metrics. For the pixel-based approach, there is still uncertainty about whether approaches based on differencing AGB estimates or measuring signal change and attributing this to a quantitative value of AGB change will be more effective. Information from the validation WP of the CCI-Biomass project will be crucial for specification of the accuracy of both AGB and AGB change products.

5. References

Lucas, R.M., German, S., Metternicht, G. et al. (2022). A globally relevant change taxonomy and evidence-based change framework for land monitoring. Global Change Biology, 28(21), 6293-6317.