Above-Ground Carbon Stock

Indicator name **Above-Ground Carbon Indicator (AGCI)**

Indicator unit The above-ground carbon (AGC) is expressed in Mg (megagrams or tonnes) of carbon per km^2. It corresponds to the carbon fraction of the oven-dry weight of the woody parts (stem, bark, branches and twigs) of all living trees, excluding stump and roots, as estimated by the GlobBiomass project (globbiomass.org) with 2017 as the reference year.

Area of interest The AGCI has been calculated at the country level, terrestrial ecoregion level and for all protected areas and is provided for each country, each terrestrial ecoregion and each terrestrial and coastal protected area of size ≥ 1 km^2.

Related targets

Sustainable Development Goal 13 on climate action

Sustainable Development Goal 15 on life on land

Aichi Biodiversity Target 11 on protected areas

Aichi Biodiversity Target 15 on contribution to carbon stocks

Policy question There are two main policy questions to which AGCI is relevant:

- How do protected areas contribute, through the conservation of vegetation resources, to the health and productivity of the ecosystems and to the sustainability of the local communities that depend on these resources? The persistent loss of AGC can indicate a degradation of the forest vegetation canopy, and can happen through unsustainable management practices and through detrimental land use and land cover changes.
- How do protected areas contribute to carbon storage and hence to offset the impacts of fossil fuel emissions and to climate change mitigation? Forests represent one of the largest terrestrial organic carbon reservoirs, and significantly contribute to the regulation of the global carbon cycle. Changes in land use and land cover can cause AGC decreases and related carbon emissions, which are one of the largest sources of human-caused carbon emissions to the atmosphere. Protected areas may contribute to biomass and carbon retention and hence to the reduction of net emissions of greenhouse gasses responsible for climate change.

Use and interpretation

Tree carbon stocks are relevant for quantifying terrestrial carbon storage and carbon sinks as well as for estimating potential emissions and removals from land cover changes (deforestation, reforestation, afforestation) and from biotic (pests, diseases) and abiotic (e.g. forest fires, windstorms) disturbances. Forests in particular have a key role in the global carbon cycle and are considered large and persistent carbon sinks thanks to the CO_2 fixed by photosynthesis into organic matter, such as wood. Therefore, spatially explicit data and assessments of forest biomass and carbon are of paramount importance for the design and implementation of effective sustainable forest management options and forest related policies.

The AGCI provides useful information about the tree carbon stocks and condition in protected areas, which can contribute to identify potentially degraded areas, evaluate the conservation performance of protected areas, set restoration targets, and assess the contribution of protected areas to reduce net global carbon emissions.

In the assessment of AGCI, water bodies, urban areas, permanent snow/ice and bare area land cover classes mapped by the Climate Change Initiative – Land Cover map (Land Cover CCI, 2017) have been masked out for preventing distortions and potentially biased estimates that unvegetated areas, or areas with very low canopy cover, can cause in the assessment (Quegan *et al.* 2017).

Key caveats

The AGCI was obtained by converting biomass to carbon using a conversion factor of 0.5 applied to the above-ground biomass (AGB) data provided by the global terrestrial biomass map derived from Earth Observation data in the framework of the GlobBiomass project (http://globbiomass.org) funded by the European Space Agency (ESA). The AGB estimates in the GlobBiomass project were derived from spaceborne SAR (ALOS PALSAR, Envisat ASAR), optical (Landsat-7), LiDAR (ICESAT) satellite data and auxiliary datasets using multiple estimation procedures.

Overall, the GlobBiomass approach seems to be performing appropriately in estimating AGB in all biomes, as assessed over a significant set of locations with independent in situ reference data (Rozendaal *et al.*, 2017). The validation confirmed the quality of the AGB estimates and indicated reliability even in the wet tropics, which was initially considered to be beyond the capability of the EO datasets and algorithms available. The estimates, however, are not free from errors (local biases and substantial uncertainties), primarily in regions where the remote sensing data available had limited capability to resolve forest structures or in areas not sufficiently characterized in terms of wood density and biomass expansion factors. For all biomes, AGB predictions strongly agreed with the observations in the lower biomass range. In the temperate and subtropical zone, AGB was underestimated for reference values ≥ 150 Mg/ha, while in the tropics and in the boreal ecozone the agreement between predicted and observed AGB was remarkable. We refer to the documentation of the GlobBiomass project (Quegan *et al.*, 2017; Rozendaal *et al.*, 2017) for a detailed discussion about the main strengths and limitations of the product.

Trees are the main stock of terrestrial vegetation biomass and carbon but, in certain biomes, other vegetation types such as shrubs or herbaceous plants can provide also significant contributions to AGB, which are not considered by the AGCI.

AGB estimates were generated in the GlobBiomass project for each point on Earth for which EO data were available. However, areas with no or very low canopy cover (typically, water, urban, permanent snow and ice and bare soil) have been masked out and are not considered in the assessment.

The biomass to carbon conversion factor of 0.5 here used is a good approximation of the typical carbon content in the biomass of terrestrial vegetation, and is consistent with the Good Practice Guidance in LULUCF by the IPCC (2003) and with other related assessments (Baccini et al., 2017; Zarin et al., 2016; Achard et al., 2014; Baccini et al., 2012; Saatchi et al., 2011; Gallaun et al., 2010). There is however some variation of this biomass to carbon conversion factor for different tree species, different components of a tree or a stand and age of the stand, which may be accounted for in more detailed assessments (Ruesch and Gibbs, 2008; Thurner et al., 2014).

Because the AGCI is computed within the boundaries for each protected area, results will be affected by the accuracy of the available protected area boundaries (see Figure 1).

Indicator status The Above Ground Biomass map, developed by ESA's GlobBiomass project, is publicly available for download at https://catalogue.ceda.ac.uk/uuid/bedc59f37c9545c981a839eb552e4084 (Santoro *et al.*, 2019) and is described in detail in Quegan *et al.* (2017). The assessment of the AGCI in protected areas is not yet published.

Available data and resources

Data available AGCI values are provided for each protected area of size ≥ 1 km^2, and can also be compared at country and ecoregion levels, on the DOPA Explorer website: http://dopa-explorer.jrc.ec.europa.eu/dopa_explorer/.

Data updates Planned with each update of DOPA.

Codes Standard GIS operations applied to vector and raster data.

Methodology

Methodology The AGCI is based on the information provided by the global terrestrial biomass map developed by the GlobBiomass project, which estimates, with a spatial resolution of 100 m and for the reference year 2017, the amount of AGB (Mg/ha) considering the oven-dry weight woody parts (stem, bark, branches and twigs) of all living trees excluding stump and roots. The AGB values have been here converted to carbon content (AGCI) using the conversion factor of 0.5 (Mg C / Mg dry matter), which is consistent with the approach in the Good Practice Guidance in LULUCF by the IPCC (2003) and within the range of values (0.47 -

0.51) used in the related literature (Ruesch and Gibbs, 2008; Thurner *et al.*, 2014).

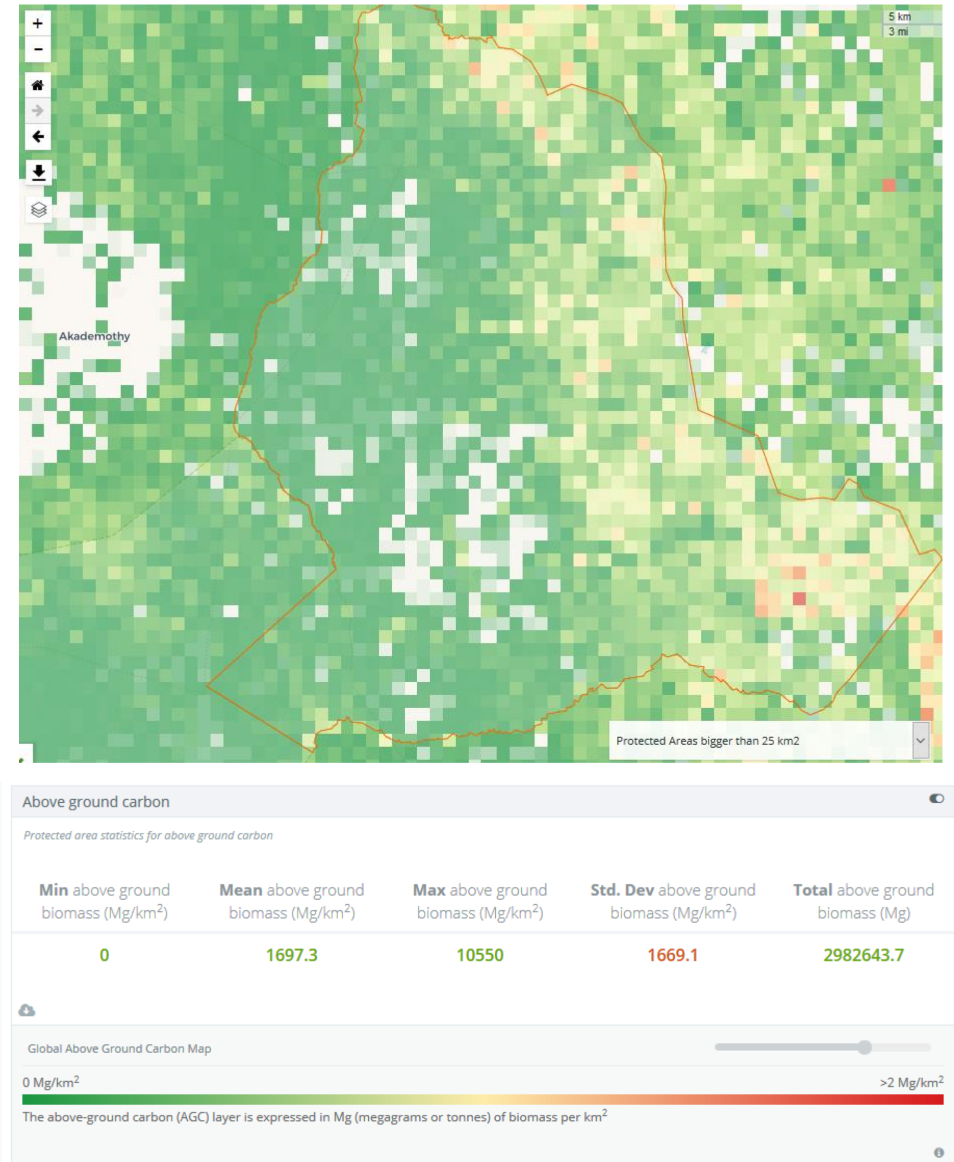

Figure 1. Screen capture of the above ground carbon content as presented in DOPA Explorer for a protected area, here the Matheniko wildlife reserve in Uganda.

The GlobBiomass map has been developed through a synergistic mapping approach and multiple estimation procedures combining spaceborne SAR (ALOS PALSAR, Envisat ASAR), optical (Landsat 7) and LiDAR (ICESAT) datasets, further supported by auxiliary products derived from earth observation (land cover, land surface temperature etc.) and in situ information. The earth observation data were used to estimate the Growing Stock Volume (GSV) of trees. GSV accounts for the volume of all living trees with more than 10 cm in diameter at breast height measured over bark from ground or stump height to a top stem diameter of 0 cm and excludes smaller branches, twigs, foliage, flowers, seeds, stump and roots (definition of FAO). Then, AGB was obtained from GSV with a set of biomass expansion and conversion factors, derived from ground estimates of wood density and stem-to-total biomass expansion factors. See Quegan *et al.* (2017) for a detailed description of the algorithms and methods used in the production of the GlobBiomass map.

The AGB map data, with a spatial resolution of 100 m, were overlaid with the boundaries of each country, terrestrial ecoregion and terrestrial or coastal protected area to calculate the minimum, maximum, mean of AGCI (as density, in Mg C/km^2) and the total AGC stored (Mg) within each country, terrestrial ecoregion and protected area. UNESCO Biosphere Reserves were discarded as well as protected areas with known areas but undefined boundaries.

Input datasets

The indicator uses the following input datasets:

Protected Areas

- WDPA of January 2021 (UNEP-WCMC & IUCN, 2021).
  - Latest version available from: www.protectedplanet.net

Country boundaries

Country boundaries are built from a combination of GAUL country boundaries and EEZ exclusive economic zones (see Bastin *et al.*, 2017).

- Global Administrative Unit Layers (GAUL), revision 2015.
  - Latest version available online: http://www.fao.org/geonetwork/srv/en/metadata.show?id=12691
- Exclusive Economic Zones (EEZ) v9 (2016-10-21)
  - Latest version available from: http://www.marineregions.org/downloads.php

Terrestrial Ecoregions of the World

- TEOW (Olson *et al.*, 2001)
  - Latest version available from: https://www.worldwildlife.org/publications/terrestrial-ecoregions-of-the-world

Above-Ground Biomass

- GlobBiomass global map of forest above-ground biomass (Santoro *et al.*, 2019).

  The global above-ground biomass map is available for download, in the form of 40° x 40° tiles, at:
  - https://catalogue.ceda.ac.uk/uuid/bedc59f37c9545c981a839eb552e4084

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