



Food and Agriculture
Organization of the
United Nations



Investing in rural people

TECHNICAL GUIDE

FOR THE ADAPTATION, BIODIVERSITY
AND CARBON MAPPING TOOL

ABC-Map

THIRD EDITION

TECHNICAL GUIDE

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AND CARBON MAPPING TOOL

ABC-Map

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Chemical formulae and elements, units of measurement

CH ₄	methane
CO ₂	carbon dioxide
CO ₂ -e	carbon dioxide equivalent
N ₂ O	nitrous oxide

°C	degree Celsius
g	grams
ha	hectare
t	metric tonnes
tC	tonnes of carbon
tCO ₂ -e	tonnes of carbon dioxide equivalent
Int\$	international dollars

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ABC-Map is developed by FAO and the International Fund for Agricultural Development (IFAD). The Agence Française de Développement (AFD) and the Bundesministerium für Ernährung und Landwirtschaft (BMEL) have kindly provided financial support for the development of ABC-Map.

Abbreviations

ABC-Map	Adaptation, Biodiversity, and Carbon Mapping Tool
AFOLU	agriculture, forestry and other land use
Aoi	area of interest
CBD	Convention on Biological Diversity
CCI	Climate Change Initiative
CRTB	Climate Risk Toolbox
CWB	climatic water balance
ESA	European Space Agency
ESVD	Ecosystem Services Valuation Database
FAO	Food and Agriculture Organization of the United Nations
GIS	geographic information systems
GLOBIO	global biodiversity model for policy support
IFAD	International Fund for Agricultural Development
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
JRC	Joint Research Centre (European Commission)
KBA	key biodiversity areas
MSA	mean species abundance
NEXT	The Nationally Determined Contributions Expert Tool
NDC	nationally determined contributions
SOC	soil organic carbon
THI	temperature-humidity index
UNCCD	United Nations Convention to Combat Desertification
UNFCCC	United Nations Framework Convention on Climate Change
UNEP-WCMC	United Nations Environment Programme's World Conservation Monitoring Centre
WDPA	World Database on Protected Areas

About these guidelines

This technical guidance has been developed to provide users with an overview of ABC-Map, including the methodologies and data sources it utilizes.

The content of this document is divided into three key sections that do not have to be read in sequential order:

- **Part I** provides an overview of ABC-Map, including its purpose, required inputs, and expected outputs.
- **Part II** provides details on the indicators that make up ABC-Map, their methodologies and sources.
- **Part III** provides details on the overarching methodologies common to multiple indicators.

These guidelines will be updated periodically, according to new features of the tool.

Part I: Overview of ABC-Map



Context and purpose

Biodiversity loss, climate change and land degradation are interconnected issues that require a holistic approach. While the scientific community and policy-making bodies recognize these interconnections, in practice, they have been largely considered and addressed in isolation. This separation risks missed opportunities for coordinated action, or implementation of actions that inadvertently harm one or more of the other issues. For example, an action taken to mitigate climate change may not necessarily be beneficial for biodiversity, and vice versa.

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To develop effective solutions, it is necessary to consider climate, biodiversity, and land degradation as part of the same problem, ensuring strategies avoid maladaptation and maximize positive outcomes.

Whilst there are various existing tools and technologies to analyse one or two of these areas in depth, there is a lack of accessible tools that enable assessment of possible synergies and trade-offs between climate, biodiversity, and land restoration actions in the agriculture, forestry and other land use (AFOLU) sector. ABC-Map seeks to address this gap.

WHAT IS ABC-MAP?

ABC-Map is a geospatial tool that allows users to holistically assess the environmental impact of projects, policies and investments in the AFOLU sector. It is available online at abc-map.fao.org

WHO IS THE TOOL FOR?

ABC-Map is designed for non-commercial use. Users may include, but are not limited to, project designers and managers, departments or agencies supporting climate, environment and agriculture sectors, agricultural public development banks, planners and focal points in governments in relevant units, and farmer organizations.

Importantly, users do not need to have prior knowledge or experience of geographic information systems (GIS) or remote sensing to use the tool. However, while not essential, familiarity with the topics covered by the tool's indicators may help in the interpretation of results.

HOW CAN THE TOOL BE USED?

ABC-Map is designed to support ex-ante analyses of projects, policies and investments in the AFOLU sector. Additionally, ABC-Map seeks to guide users towards other specialist tools, and in this way can be seen as a first step to highlight areas where in-depth analyses may be needed, especially in situations where time or resources are limited.

The tool can be used flexibly depending on the different users and desired outcome of use. The use of information generated by the tool can provide important inputs to support, for example:

- Risk screening for a new project or investment through identification of climatic and geophysical risks and projecting future crop and livestock suitability.
- Preliminary screening of an investment opportunity and comparison of site selection options through assessing and evaluating potential impacts of planned actions on biodiversity and carbon.
- Biodiversity safeguarding through identifying protected areas and Key Biodiversity Areas.
- Balancing of gains and losses at project level through identifying possible synergies and trade-offs between adaptation, mitigation and biodiversity actions.
- Tracking of nature-positive finance by conducting ex-ante analysis to conform with the Multilateral Development Bank Common Principles for tracking nature-positive finance (World Bank, 2023).
- Improving understanding of a project or investment area through showing past trends in land use, climate, biodiversity and carbon, supporting collection of information for planning.

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WHO DEVELOPED THE TOOL?

ABC-Map was developed by the Food and Agriculture Organization of the United Nations (FAO) and the International Fund for Agricultural Development (IFAD), with financial support from Agence Française de Développement and the Bundesministerium für Ernährung und Landwirtschaft.

A pilot version of ABC-Map was launched in 2022, after which the tool was refined and officially released in February 2024.

RELATED TOOLS

As part of its holistic approach, ABC-Map was developed in the context of other FAO tools, in particular:

- **The Nationally Determined Contributions (NDC) Expert Tool (NEXT)** – A greenhouse gas account tool to monitor past and ongoing climate actions and estimate the mitigation potential of planned actions (see [Box 9](#) on page 32 for more details).
- **The NDC Tracking Tool** – An excel-based tool to facilitate data collection of the information necessary to track NDC implementation and achievement.
- **Climate Risk Toolbox (CTRB)** – The CRTB is an open-access resource that utilises climatic, geographical, social, and economic geospatial information to help identify the climate-related risk in any area of interest worldwide. It allows users to map the individual factors contributing to hazards, exposure, vulnerability, and adaptive capacity of a region. The CRTB can be accessed through the FAO Hand-in-Hand Geospatial Platform (2025a).
- **Earth Map** – Earth Map is a free, open-access tool by the FAO. It enables countries, researchers, farmers, and the public to monitor land using satellite imagery and global datasets on climate, vegetation, fires, biodiversity, and more. With an easy-to-use interface, it requires no prior GIS or remote sensing expertise. ABC-Map was initially developed as a follow-on tool from Earth Map to enable ex-ante analysis.

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Part I
Overview of
ABC-Map



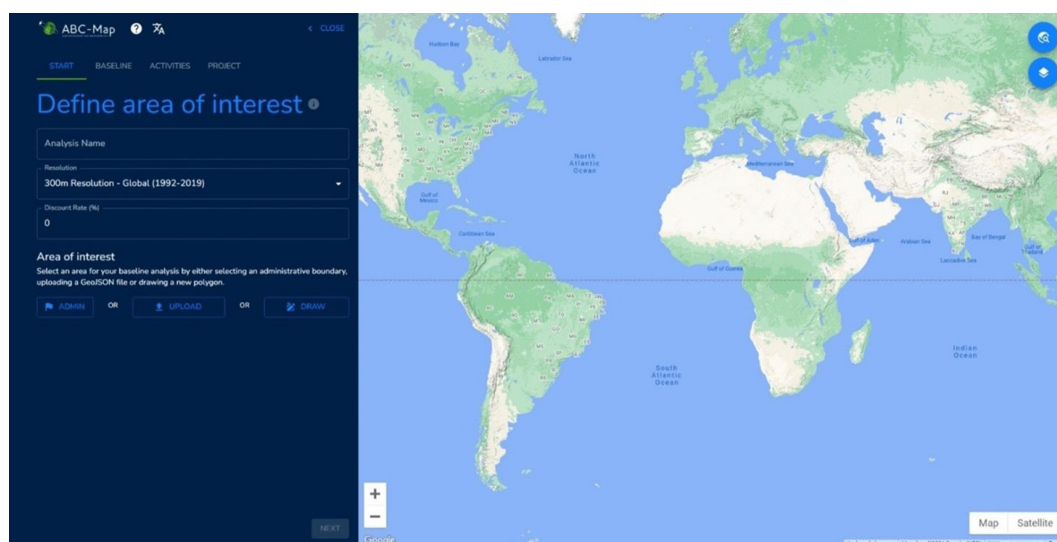
Box 1. The NDC Toolbox

Together with NEXT and the NDC Tracking Tool, ABC-Map is part of the **NDC Toolbox**, which aims to support countries to achieve their commitments under the United Nations Framework Convention on Climate Change (UNFCCC) and enhance synergies with the Convention on Biological Diversity (CBD) and the United Nations Convention to Combat Desertification (UNCCD).

Main structure, inputs and outputs

Visually the interface is divided into a dashboard on the left and a map on the right, and as shown in **Figure 1**. The dashboard is where the user inputs information to generate an analysis and views outputted graphs. The map displays geo-spatial data generated by both the baseline and project assessment.

Figure 1. ABC-Map's initial interface, showing the dashboard (left) and the map (right)



Note: Refer to the disclaimer on page ii for the names and boundaries used in this map.
Source: ABC-Map screenshot, ABC-Map. 2025. Adaptation, Biodiversity and Carbon Mapping Tool. Cited 8 January 2025. abc-map.fao.org

Box 2. ABC-Map and Google Earth Engine

ABC-Map runs on Google Earth Engine, a Google Cloud Platform that makes it easy to access high-performance computing resources for processing very large geospatial datasets. Google Earth Engine is designed to help researchers easily disseminate their results to other researchers, policymakers, non-governmental organizations, field workers, and the general public (Gorelick et al., 2017).

OUTPUTS GAINED

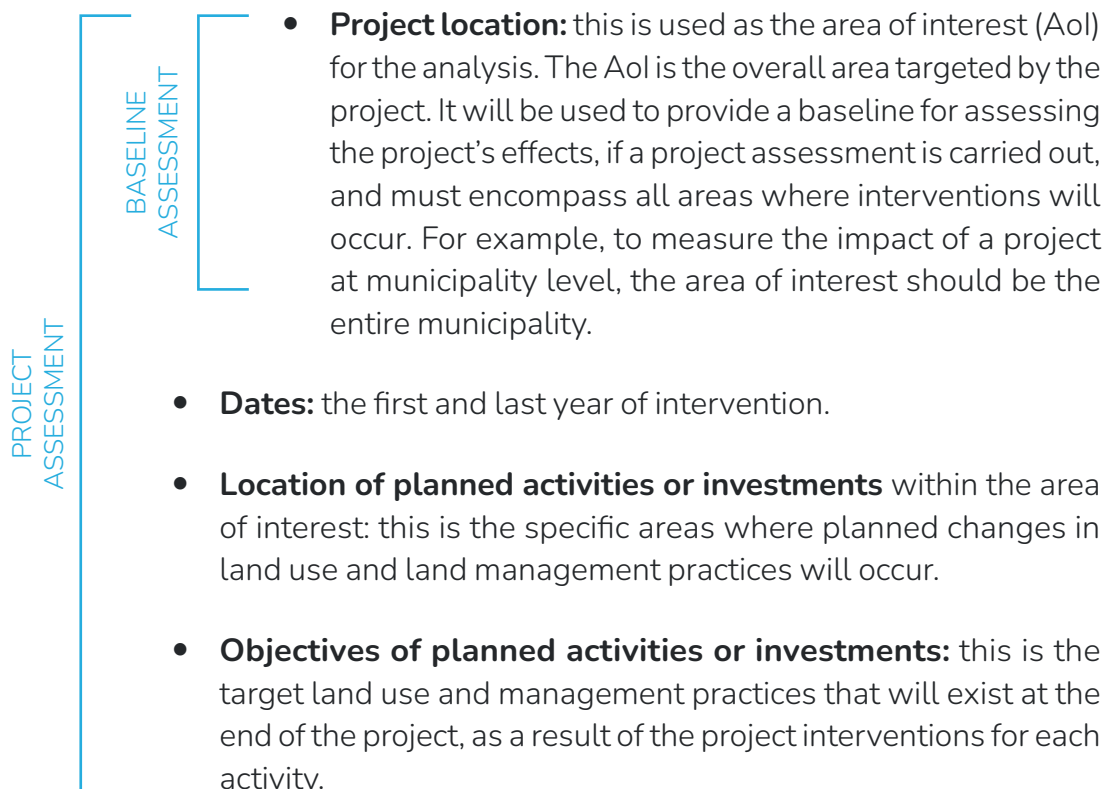
ABC-Map has two key steps to performing assessments, which means that outputs can be obtained for two periods: the baseline and the project assessment, which can be used separately or in combination.

- The **baseline assessment** provides an overview of past and present trends in adaptation, biodiversity and carbon. It can be used to better understand the characteristics of the project area and perform a risk screening.
- The **project assessment** estimates the future impact of the project activities on the project area. It can be used to compare potential activities, and identify synergies between adaptation, biodiversity and carbon.

Full details on all indicators provided by ABC-Map are provided in part II of these guidelines.

INPUTS REQUIRED

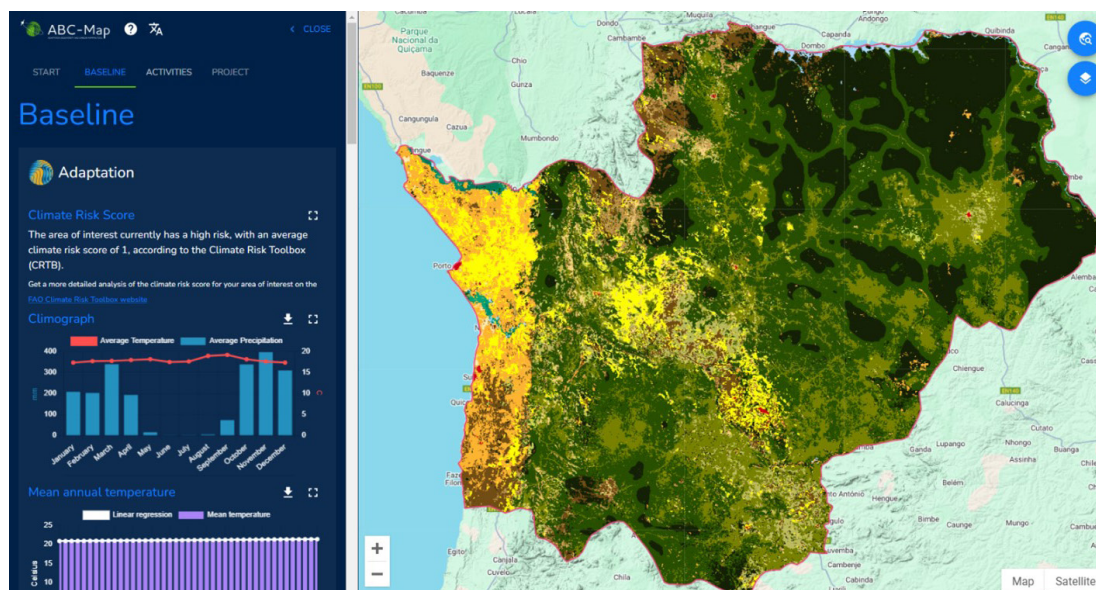
The inputs required depend on whether the user wishes to conduct only a baseline assessment, or also a project assessment:



The user can also select the land cover product and discount rate to be used in their analysis. If no values are explicitly chosen, ABC-Map provides default values (see Part III for details). A full step-by-step [user guide](#) and [guidance video](#) is available online.



Figure 2. Example of a baseline assessment on ABC-Map's interface



Note: Refer to the disclaimer on page [i] for the names and boundaries used in this map.

Source: ABC-Map screenshot, ABC-Map, 2024. Adaptation, Biodiversity and Carbon Mapping Tool. Cited 8 January 2025. abc-map.fao.org

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INTRINSIC LIMITATIONS TO THE USE OF ABC-MAP

Technical Guide
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Biodiversity and
Carbon Mapping Tool
ABC-Map

ABC-Map has been designed to be used flexibly in a range of contexts. However, users should be aware of certain limitations when using the tool.

To conduct a project assessment, there must be planned activities with land use or land management changes relevant to the AFOLU sector. However, a baseline analysis can still be performed without these inputs.

ABC-Map uses multiple land cover datasets, each with varying resolutions and accuracies (see Part III for dataset details). While there is no strict minimum area size of an assessment, it is not recommended to analyse areas that are similar to or smaller than the resolution of the land cover product. Although there is no absolute maximum size for an assessment, some of ABC-Map's indicators may not run on very large areas, or areas with complex geometry.

Additional limitations stem from the datasets underlying some indicators. Despite efforts to use the best available data, global datasets derived from remote sensing inherently contain inaccuracies. As improved datasets become available, they will be integrated into the tool where appropriate.

Part II: Indicator-Specific Methodologies



The following sections detail the methodologies underlying ABC-Map’s indicators. Indicators are listed by section: adaptation, biodiversity, and carbon. Some shared logic, common to multiple indicators, is presented in Part III.

Table 1. All indicators in ABC-Map

ADAPTATION	BIODIVERSITY	CARBON
Climate risk score		
Climograph		
Mean annual temperature		
Total annual precipitation		
Days of extreme heat	Land use and land use changes	
Frost days	Mean species abundance	Total carbon stock
Dry days	Natural capital	Social value of carbon
Days of extreme precipitation	Key Biodiversity Areas	
Elevation	Protected areas	
Slope		
Water occurrence		
Crop climatic suitability		
Livestock heat stress		

Source: Authors' elaboration



Adaptation Section

The adaptation section of ABC-Map has been designed to give an overview of climatic and geophysical data relevant to planning agricultural adaptations to climate change. It includes information on climatic and geophysical data, climate risk, crop climatic suitability, and on livestock heat stress. All indicators are available at the baseline level, and crop climatic suitability and livestock heat stress are available at project level.

CLIMATE RISK SCORE

The climate risk score provides aggregated data on hazards, vulnerability, exposure and adaptive capacity, based on the most up-to-date definition of risk from the Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2022).

The climate risk score provided in ABC-Map is a simplified version of the climate risk analysis available in the Climate Risk Toolbox (CRTB) (FAO, 2025b). This indicator allows to identify areas subject to climate risks and guides users towards the full version of the CRTB for a more detailed screening. The full version of the CRTB is accessible on the FAO Hand-in-Hand Geospatial Platform and provides detailed information on individual hazard, exposure, vulnerability and adaptive capacity factors contributing to the aggregated risk score (FAO, 2025a).

ABC-Map provides an average climate risk score over the Aol for the baseline period (1981-2010), as well as near-term (2021-2040) and mid-term (2041-2060) future. The near-term and mid-term projections are available for two shared socioeconomic pathways: a low-emission scenario (SSP1-2.6) and a high-emission scenario (SSP5-8.5).

Methodology

Climate risk results from the interaction of climatological, hydrological, and meteorological hazards, with the geographical exposure of human and natural systems, together with human and natural systems' vulnerability to climate hazards. The adaptive capacity component modulates the level of observed and projected risk.

Hazards, exposure, vulnerability and adaptive capacity are first calculated separately following a convergence of evidence method. For each component, a list of variables is defined (9 for baseline climate hazards 6 for future climate hazards under each scenario, 11 for exposure, 9 for vulnerability and 7 for adaptive capacity). Each variable is associated to geospatial data and reclassified into a “Low”, “Moderate”, “High”, and “Very High” contribution to the overall climate risk, based on quantile thresholds or manual breaks classifications. Since the Hazards, Exposure, and Vulnerability variables increase the level of risk, they are reclassified as Low (pixel value: 1), Moderate (pixel value: 2), High (pixel value: 3), and Very High Risk (pixel value: 4). Conversely, since Adaptive Capacity modulates the final risk, negative values are given to the Adaptive Capacity layers, and where -1 represents a Low Adaptive Capacity and -4 a Very High Adaptive Capacity.

For example, to calculate the climate hazards component, one variable is “Extreme high temperatures: annual number of days with maximum temperatures above 35°C”, where areas with 0 days exceeding the threshold of average daily maximum temperatures (35°C) are categorized as “Low”, areas with up to 0.5 days are categorized as “Moderate”, areas with up to 18.6 days are categorized as “High”, and areas with up to 256.4 days are categorized as “Very High”, based on a quantile distribution of values for each pixel worldwide. The same procedure is repeated for all 9 variables to compute the cumulative hazard index in the baseline, as well as for future periods, exposure, vulnerability, and adaptive capacity components.

The aggregated climate risk score is then calculated as the interaction of cumulative hazards, exposure, vulnerability and adaptive capacity, to identify different levels of climate risks within a chosen geographic area:

Equation 1.

$$climateRisk = \sum(hazards * 0.3) + \sum(exposure * 0.3) + \sum(vulnerability * 0.4) - \sum(adaptiveCapacity * 0.3)$$

The complete methodology and details of each geospatial layer are available in the Climate Risk Toolbox guidelines document (FAO, 2025b).



Box 3. Climatic data in ABC-Map

ABC-Map includes a set of indicators, displayed as charts, that show the climatic properties of a selected Aol and how they have changed for the past 40 years. These climatic indicators have been selected due to their relevance for agricultural production.

To help assess past trends, climatic indicators are associated with a p -value derived from a linear regression over the entire baseline period. A p -value lower than 0.05 indicates a statistically significant increasing or decreasing trend, whereas a p -value higher than 0.05 indicates no statistically significant trends.

Box Table 1: Units of measurements and sources of the climatic indicators in ABC-Map

INDICATOR	UNIT	SOURCE
Climograph	Celsius (°C) and millimetres (mm)	ERA5-Land Monthly Aggregates (Copernicus Climate Change Service, 2019)
Mean annual temperature	Celsius (°C)	
Total annual precipitation	Millimetres (mm)	
Days of extreme heat	Number of days	ERA5-Land Daily Aggregates (Copernicus Climate Change Service, 2019)
Frost days		
Dry days		
Days of extreme precipitation		

Note: The climatic datasets are updated on ABC-Map annually, once a complete year of data is available.

Source: Authors' elaboration

CLIMOGRAPH

This indicator displays data on the average precipitation and temperature for each month of the year. These averages are calculated using monthly data from 1981 up to the most recent complete year. These are two useful metrics that provide an overview of the basic climate for the selected Aol.

MEAN ANNUAL TEMPERATURE

This indicator calculates the mean annual temperature since 1981.

TOTAL ANNUAL PRECIPITATION

This indicator calculates the total annual precipitation since 1981. Total annual precipitation is defined in ABC-Map as the sum of monthly aggregates.

DAYS OF EXTREME HEAT

This indicator calculates the number of days annually where the maximum temperature exceeded 35 °C since 1981. This threshold is used as it aligns with those referenced by the IPCC (IPCC, 2023).

FROST DAYS

This indicator calculates the annual number of days with potential for frost since 1981, i.e. the total of the number of days in a year where the minimum temperature is below 0 °C. This threshold is used as it aligns with those referenced by the IPCC (IPCC, 2023).

DRY DAYS

This indicator calculates the annual number of days where the total daily precipitation is below 1 mm since 1981. The IPCC does not specify a threshold for dry days, but 1 mm is commonly used in literature (Rivoire *et al.*, 2019).

DAYS OF EXTREME PRECIPITATION

This indicator calculates the annual number of days since 1981 where the total precipitation exceeded 50 mm. This threshold is set as suggested by the IPCC (IPCC, 2023).

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Part II
Indicator-Specific
Methodologies



Box 4. Geophysical data in ABC-Map

ABC-Map includes a set of indicators that show the geophysical properties of a selected Aol. These indicators have been selected due to their relevance to agricultural viability and environmental risks.

Box Table 2: Units of measurements and sources of the geophysical indicators in ABC-Map

INDICATOR	UNIT	SOURCE
Elevation	Meters	NASA STRM Digital Elevation 30m (Farr <i>et al.</i> , 2007)
Slope	Degrees	

Note: These datasets do not have a regular update schedule and are updated on ABC-Map once new versions are available.

Source: Authors' elaboration

ELEVATION

The elevation indicator provides elevation statistics on average elevation, maximum elevation, minimum elevation. ABC-Map provides a chart of the elevation distribution and a map displaying the elevation across the Aol.

The elevation statistics section uses the NASA SRTM Digital Elevation 30 m to calculate the average, maximum and minimum elevation, as well as an elevation distribution chart for the selected Aol. While the entire Aol is considered for the elevation statistics, for visualization purposes, water bodies (identified using JRC Global Surface Water Mapping Layers, v1.4 [Pekel *et al.*, 2017]) are not displayed on the map.

SLOPE

The slope indicator provides statistics on the average slope, maximum slope, and minimum slope. ABC-Map provides a chart of the slope distribution and a map displaying the slope across the Aol.

The slope statistics section uses the NASA SRTM Digital Elevation 30 m to calculate the slope gradient statistics and map. The local gradient is computed using the four-connected neighbours of each pixel in degrees. After calculating the gradient, ABC-Map uses the categorized slope gradient (in percentage) definitions used by the Canadian Government on their National Soil Database (Government of Canada, 2013), as described in [Table 2](#).

While the entire Aol is considered for the slope statistics, for visualization purposes, water bodies (identified using JRC Global Surface Water Mapping Layers, v1.4 [Pekel *et al.*, 2017]) are not displayed on the map.

Table 2. Landform slope classes

CLASS	DESCRIPTION
Little or none	Little or no slope: 0–3% gradient.
Gentle	Gentle slopes: 4–9% gradient.
Moderate	Moderate slopes: 10–15% gradient.
Steep	Steep slopes: 16–30% gradient.
Extremely steep	Extremely steep slopes: 31–60% gradient.
Excessively steep	Excessively steep slopes: > 60% gradient.

Source: Government of Canada. 2013. Landform Slope Class. Cited 7 October 2024. https://sis.agr.gc.ca/cansis/nsdb/slc/v3.2/ldt/lf_slope.html

WATER OCCURRENCE

The water occurrence distribution statistics use the JRC Global Surface Water Mapping Layers, v1.4 dataset to calculate the categorical classification change between the first (1984) and last year (2021) of observation for the Aol.

The JRC Global Surface Water Mapping Layers, v1.4 defined nine possible categories:

1. Unchanging permanent water surfaces.
2. New permanent water surfaces - conversion of a no water place into a permanent water place.
3. Lost permanent water surfaces - conversion of a permanent water place into a no water place.
4. Unchanging seasonal water surfaces.
5. New seasonal water surfaces - conversion of a no water place into a seasonal water place.
6. Lost seasonal water surfaces - conversion of a seasonal water place into a no water place.
7. Conversion of seasonal water into permanent water.
8. Conversion of permanent water into seasonal water.



9. Ephemeral permanent water - no water places replaced by permanent water that subsequently disappeared within the observation period.
10. Ephemeral seasonal water - no water places replaced by seasonal water that subsequently disappeared within the observation period.

ABC-Map aggregates all the areas that have the same classification and calculates the corresponding percentage and provides a chart displaying the distribution of water occurrence.

CROP CLIMATIC SUITABILITY

The crop climatic suitability indicator provides a chart with an estimate of the climatic suitability for 30 crops¹ for four periods: historical (1994-2014), near-term (2015-2040), mid-term (2041-2060) and far-term (2060-2100). Projected data for the near-term, mid-term and far-term is presented for two different scenarios: SSP2-4.5 and SSP5-8.5.

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Methodology

Calculations of the crop climatic suitability follow the methods detailed in Mombo *et al.* (2025). The following section provides an overview of the methods to calculate the suitability for a given crop and a given year.

Temperature and precipitation data are retrieved from the W5E5 v2.0 (Lange *et al.*, 2021), for historical observations, and ISIMIP3b (Lange and Büchner, 2021), for climatic projections. For the projections, the ensemble median of five global circulation models (GFDL-ESM4, MPI-ESM1-2-HR, IPSL-CM6A-LR, MRI-ESM2-0, and UKESM1-0-LL) is computed.

The relationship between temperature and precipitation is represented by the climatic water balance, i.e. the difference between precipitation and reference evapotranspiration. Precipitation is obtained from W5E5 v2.0 and ISIMIP3b data, and reference evapotranspiration is calculated using the Hargreaves & Samani (1985) equation:

¹ Arabica coffee, banana, barley, bean, cassava, cocoa, coconut, cotton, cowpea, groundnut, lentil, maize, other pulses, pearl millet, pigeon pea, plantain, potato, rice, robusta coffee, sesame seed, sorghum, soybean, sugarbeet, sugarcane, sunflower, sweet potato, tea, tobacco, wheat, yams.

Equation 2.

$$CWB_{i,d}(P_{i,d}, T_{i,d}) = P_{i,d} - ET_{0,i,d}(Tmin_{i,d}, Tmax_{i,d}, R_{i,d})$$

Where:

- $CWB_{i,d}$ is the climatic water balance in pixel i for day d , in millimetres;
- $P_{i,d}$ is the total precipitation in pixel i for day d in millimetres;
- $Tmin_{i,d}$ and $Tmax_{i,d}$ are the minimum and maximum temperature in pixel i for day d in °C; and
- $ET_{0,i,d}$ is the reference evapotranspiration in pixel i for day d , in millimetres, calculated using the equation from Hargreaves & Samani (1985) equation as a function of $Tmin_{i,d}$, $Tmax_{i,d}$ and $R_{i,d}$ the radiation.

The overall climatic water balance, named CWB_i , is then defined as the sum of daily climatic water balances over the entire crop growing cycle.

The suitability of the overall climatic water balance, denoted as S' , is determined based on the overall climatic water balance CWB_i itself. If CWB_i is within a range of optimal conditions (noted CWB_{opmin} , CWB_{opmax}), the suitability S' is equal to 1. Outside of this range, and as conditions drift away from optimal conditions, S' decreases towards 0.

The values of CWB_{opmin} and CWB_{opmax} are calculated using yield data from the Spatial Production Allocation Model (SPAM). First, areas of rainfed agriculture within the 90th percentile of yields are identified. For each pixel inside of these areas, the value of CWB_i is calculated. CWB_{opmin} and CWB_{opmax} then correspond respectively to the first and third quartile of CWB_i in areas with high yield.



Equation 3.

$$S'(CWB_i) = \begin{cases} \frac{\overline{CWB}_{opmin}}{CWB_i} & \text{if } CWB_i < CWB_{opmin} \\ 1 & \text{if } CWB_i \in [CWB_{opmin}, CWB_{opmax}] \\ \frac{\overline{CWB}_{opmax}}{CWB_i} & \text{if } CWB_i > CWB_{opmax} \end{cases}$$

Where:

$$\begin{aligned} \overline{CWB}_{opmin} &= CWB_{opmin} + \phi \\ \overline{CWB}_{opmax} &= CWB_{opmax} + \phi \\ \overline{CWB}_i &= CWB_i + \phi \\ \phi &= -\frac{CWB_{opmin} + CWB_{opmax}}{2} \end{aligned}$$

Where:

- S' is the suitability of the overall climatic water balance;
- CWB_i is the overall water balance in pixel i ;
- CWB_{opmin} is the lower bound of the optimal suitability range of the overall climatic water balance; and
- CWB_{opmax} is the upper bound of the optimal suitability range of the overall climatic water balance.

To ensure that the suitability conditions for temperature are respected, the suitability of the overall climatic water balance S' is multiplied by the suitability of the temperature S_T to obtain the final crop climatic suitability S'' :

Equation 4.

$$S''(CWB_i, T_i) = S'(CWB_i) * S_T(T_i)$$

Where S_T is defined following Ramirez-Villegas *et al.* (2013), as detailed in equation 5, the optimal ranges of precipitation and temperature are obtained from the EcoCrop database (FAO, 2000).

Equation 5.

$$S_T(x) = \begin{cases} 1 & \text{if } x \in [T_{opmin}, T_{opmax}] \\ \frac{T_{max} - x}{T_{max} - T_{opmax}} & \text{if } x \in [T_{opmax}, T_{max}] \\ \frac{x - T_{min}}{T_{opmin} - T_{min}} & \text{if } x \in [T_{min}, T_{opmin}] \\ 0 & \text{elsewhere} \end{cases}$$

Where:

- x is the value of the average temperature over the growing period;
- T_{opmin} is the minimum optimal temperature or precipitation for a given crop;
- T_{opmax} is the maximum optimal temperature or precipitation for a given crop;
- T_{min} is the minimum marginal temperature or precipitation for a given crop; and
- T_{max} is the maximum marginal temperature or precipitation for a given crop.

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LIVESTOCK HEAT STRESS

The temperature-humidity index (THI) estimates the heat stress caused by the combined effects of air temperature and humidity. It is one of the most widely used indices among practitioners for assessing heat stress in livestock (Habeeb *et al.*, 2018). Extensive research has applied THI to quantify the impact of the historical and projected climate change on different livestock's health (Lallo *et al.*, 2018; Carvajal *et al.*, 2021; Rahimi *et al.*, 2021). Given the significant effects of heat stress on livestock welfare and productivity, THI can be used to assess the historical and future suitability of a region for livestock production (Carvajal *et al.*, 2021; Rahimi *et al.*, 2021).

ABC-Map provides a chart with an estimate of the degree of heat stress for six species of livestock (dairy cattle, beef cattle, sheep, goats, poultry and swine). The degree of heat stress is categorized into four groups based on THI values: no stress, mild stress, moderate stress, and severe stress/danger.

Data on heat stress is provided for four periods: historical (1994-2019), near-term (2020-2040), mid-term (2041-2060) and far-term (2060-2100). Projected data for the near-term, mid-term and far-term is provided under two climate scenarios: SSP2-4.5 and SSP5-8.5.

Methodology

Calculation of the THI follows the methodology detailed in Rahimi *et al.* (2021). Based on Stull *et al.* (2011), a modification was incorporated to estimate the wet-bulb temperature. Additionally, following Lallo *et al.* (2018), Carvajal *et al.* (2021) and Rahimi *et al.* (2021), the daily maximum temperature, $T_{\max,i,d}$ (°C) is used instead of the dry-bulb temperature $T_{db,i,d}$ (°C).

Temperature and humidity data are retrieved from W5E5 v2.0 (Lange *et al.*, 2021) for historical observations, and ISIMIP3b (Lange and Büchner., 2021) for climatic projections. For the projections, the ensemble median of five global circulation models (GFDL-ESM4, MPI-ESM1-2-HR, IPSL-CM6A-LR, MRI-ESM2-0, and UKESM1-0-LL) is computed.

The THI for the six livestock species is calculated based on the below equations:

Equation 6.

$$THI_{cattle,i,d} = (1.8T_{db,i,d} + 32) - [(0.55 - 0.0055RH_{i,d}) \cdot (1.8T_{db,i,d} - 26.8)]$$

$$THI_{small\ ruminants,i,d} = T_{db,i,d} - [(0.31 - 0.0031RH_{i,d}) \cdot (T_{db,i,d} - 14.4)]$$

$$THI_{poultry,i,d} = 0.6T_{db,i,d} + 0.4T_{wb,i,d}$$

$$THI_{swine,i,d} = 0.25T_{wb,i,d} + 0.75T_{db,i,d}$$

Where:

- $THI_{livestock,i,d}$ is the temperature humidity index for a livestock species in pixel i for day d . Cattle represents dairy and beef cattle. Small ruminants represent goats and sheep;
- $T_{db,i,d}$ is the daily dry-bulb temperature in pixel i for day d in °C. Daily maximum temperature, $T_{\max,i,d}$ (°C) is used instead of $T_{db,i,d}$ (°C);
- $T_{wb,i,d}$ is the daily wet-bulb temperature in pixel i for day d in °C, calculated using the empirical equation from Stull *et al.* (2011) as a function of the daily temperature $T_{i,d}$ (°C) and the daily relative humidity $RH_{i,d}$ in percent; and
- $RH_{i,d}$ is the daily relative humidity in pixel i for day d in percent.

For each livestock species, the obtained daily $THI_{livestock,i,d}$ is classified into four degrees of heat stress, each degree being dependent on the livestock species (**Table 3**):

- No stress: livestock do not experience heat stress and are at optimum productive and reproductive performance;
- Mild stress: livestock experience heat stress but body chemical and physical processes are able to control the impact;
- Moderate stress: body temperature increases and can negatively impact the livestock's performance; and
- Severe stress/Danger: events that result in significant decreases in productive and reproductive performances.

Additional details on the impact of each degree of heat stress are provided in **Table 4**.

For each pixel, daily data on THI is then aggregated per period to obtain the total number of days under each degree of heat stress. ABC Map, using the area-weighted mean of this total days per degree of heat stress in the selected Aoi, computes and provides the proportion (i.e. percent) of each degree of the heat stress for each period (e.g. 50 percent in degree "No stress" for period "Historical" means that 50 percent of the days in period "Historical" were classified as degree "No stress").



Table 3. Degree of heat stress with corresponding THI value for different livestock species

LIVESTOCK SPECIES	NO STRESS	MILD STRESS	MODERATE STRESS	SEVERE STRESS/ DANGER
Dairy Cattle	THI ≤ 72	72<THI ≤ 78	78<THI ≤ 88	88<THI
Beef Cattle	THI ≤ 75	75<THI ≤ 81	81<THI ≤ 91	91<THI
Sheep	THI ≤ 25	25<THI ≤ 30	30<THI ≤ 35	35<THI
Goat	THI ≤ 27	27<THI ≤ 32	32<THI ≤ 37	37<THI
Poultry	THI ≤ 27.8	27.8<THI ≤ 28.8	28.8<THI ≤ 30	30<THI
Swine	THI ≤ 23.3	23.33<THI ≤ 26.11	26.11<THI ≤ 28.88	28.88<THI

Source: Adapted from Rahimi, J., Mutua, J.Y., Notenbaert, A.M.O., Marshall, K. & Butterbach-Bahl, K. 2021. Heat stress will detrimentally impact future livestock production in East Africa. Nature Food, 2(2): 88–96. <https://doi.org/10.1038/s43016-021-00226-8>

Table 4. General impacts of each degree of heat stress on livestock

	GENERAL IMPACTS OF EACH DEGREE OF HEAT STRESS
No stress	<ul style="list-style-type: none"> Both productive and reproductive performance are optimal
Mild stress	<ul style="list-style-type: none"> Livestock experience heat stress but body chemical and physical processes are able to control the impact. Livestock seek for shade. Increase in rectal temperature and respiration rate. Dilation of blood vessels.
Moderate stress	<ul style="list-style-type: none"> Body temperature increases and productive/reproductive performances are expected to be severely affected. Significant increase of respiration rate. Expected decrease in dry matter intake and ratio of forage intake to concentrate intake. Significant increase in water intake.
Severe stress/ Danger	<ul style="list-style-type: none"> Significant increase of respiration rate and excessive saliva production. Significant decrease in productive and reproductive performances. Decrease in rumination and urination. In extreme cases, livestock may die.

Source: Adapted from Rahimi, J., Mutua, J.Y., Notenbaert, A.M.O., Marshall, K. & Butterbach-Bahl, K. 2021. Heat stress will detrimentally impact future livestock production in East Africa. Nature Food, 2(2): 88–96. <https://doi.org/10.1038/s43016-021-00226-8>



Biodiversity Section

The biodiversity section of ABC-Map is designed to give an overview of the status of, and pressures on, biodiversity. The biodiversity section provides information on land use, protected areas and Key Biodiversity Areas, mean species abundance and natural capital, all available at baseline and project level.

LAND USE AND LAND USE CHANGES

ABC-Map provides an overview of current and past land uses over the entire Aol and over protected areas and Key Biodiversity areas specifically.

Methodology

ABC-Map allows users to select the land cover product to be used during the analysis. Several products with varying resolutions and time frames are proposed:

- European Space Agency (ESA) Climate Change Initiative (CCI) Land Cover (300m resolution, global coverage, annual maps for 1992-2022);
- PROBA V (100m resolution, global coverage, annual maps for 2015-2019); and
- MapBiomias (30m resolution, 11 countries covered with varying time frames).

More details on the land cover products available are detailed in Part III of these guidelines.

To generate a time series of land uses, ABC-Map retrieves data from the user selected land cover product and aggregates the available classes into the seven generic IPCC land uses; cropland, forest, grassland, settlement, wetland, water, other land. Definitions of these categories and the aggregations can be found in [Annex II](#). Conversion tables between each land cover product's classes and IPCC land uses are presented in [Annex I](#).

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MEAN SPECIES ABUNDANCE

In ABC-Map, the mean species abundance (MSA) indicator expresses the abundance of original species in disturbed conditions relative to their abundance in an undisturbed habitat. It acts as an indicator of the degree to which an ecosystem is intact, and varies between 0 and 1, where:

- MSA = 1, highlights an undisturbed ecosystem where all original species remain.
- MSA = 0, highlights a destroyed ecosystem with no original species left.

ABC-Map provides a map of the MSA value for the last year of the baseline and the last year of the project and a time-series showing the evolution of the aggregate MSA value over time within the Aol.

Methodology

The methodology of the MSA assessment is based on the global biodiversity model for policy support (GLOBIO) Version 3.5 developed by the Netherlands Environmental Assessment Agency (Schipper *et al.*, 2016). The GLOBIO model makes use of extensive terrestrial biodiversity databases to establish quantitative pressure-impact relationships. Six major taxonomic groups are covered by GLOBIO: mammals, birds, reptiles, amphibians, terrestrial invertebrates, and vascular plants.

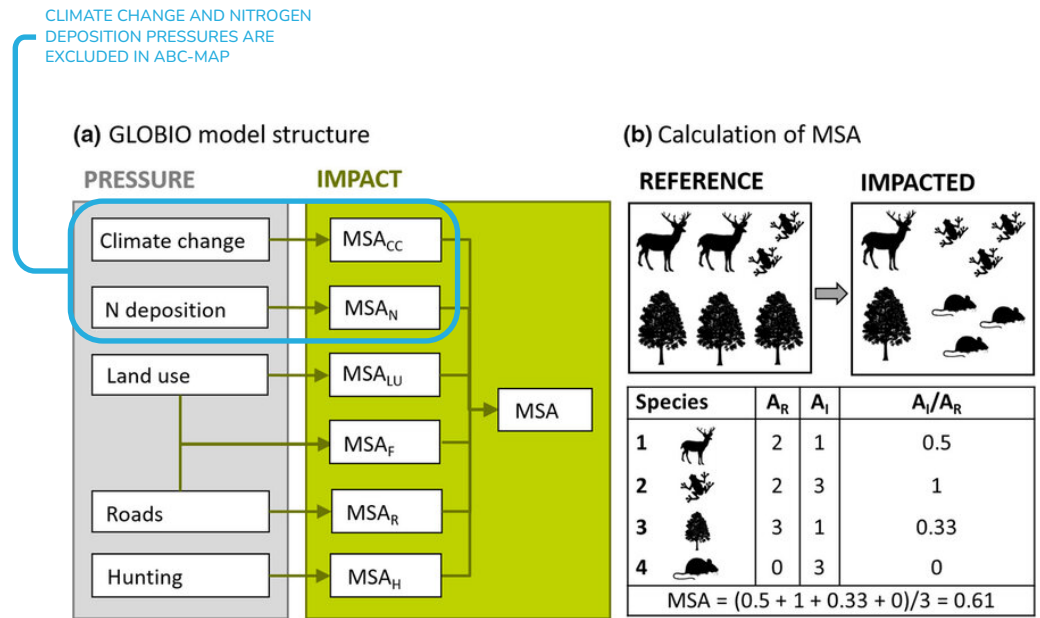
GLOBIO calculates MSA as a function of six anthropogenic pressures: land use, infrastructure (also referred to as 'road disturbance'), habitat fragmentation, human encroachment (also referred to as 'hunting'), atmospheric nitrogen deposition and climate change.

Adaptations were made to the GLOBIO methodology to fit the scope and objectives of ABC-Map. Unlike GLOBIO, which focuses on global-level assessments, ABC-Map assesses impacts from project-level activities. Additionally, while GLOBIO is used mainly for future impact estimates based on geo-spatialized trends data aggregated from a grid-cell level, ABC-Map is a spatially explicit land-based accounting system that aims to provide impact appraisals of expected project activities.

ABC-Map excludes the climate change and nitrogen deposition pressures used in GLOBIO's structure. Since the impact of greenhouse gas emissions on climate change is not limited to a restricted (project or investment) area, nor to a specific period, climate change is better addressed via the social value of carbon, which is an estimate of economic costs of emitting an additional tonne of CO₂ equivalent (tCO₂-e). Atmospheric nitrogen deposition puts an important

pressure on biodiversity, and it is the consequence of global emissions of oxidized nitrogen from fossil fuel combustion. Not only will it be difficult to obtain project or investment-specific data, but the critical load of atmospheric nitrogen deposition may not be directly linked to the project's or intervention's activities.

Figure 3. The GLOBIO structure and calculations of MSA values



Source: Adapted from Schipper *et al.*, 2016. The GLOBIO Model. A technical description of version 3.5. The Hague, PBL Netherlands Environmental Assessment Agency.

ABC-Map thus considers four anthropogenic impacts, or pressures, on biodiversity:

1. impacts of land use;
2. disturbance by infrastructure;
3. habitat fragmentation due to land use and infrastructure; and
4. human encroachment.

ABC-Map provides information on individual pressures as well as an aggregate MSA value, which summarizes the overall impact of all four pressures. Data on the aggregate MSA is provided in the form of a map and a time-series showing the evolution of the average aggregate value over the Aol across baseline and project years. Data on individual pressures is presented as an average value over the Aol for the last year of the baseline and the last year of the project.

The MSA values for individual pressures are first calculated separately for each pixel, as explained in the following sections. Then, the aggregate MSA value for each pixel is determined by multiplying the individual MSA values. Finally, the aggregate MSA for the entire Aol is calculated as the area-weighted mean of the aggregate pixel values.



Equation 7.

$$msaAggregate_t = \frac{\sum_{i=1}^n (msaLU_{i,t} * msaF_{i,t} * msaHe_{i,t} * msaI_{i,t}) * pixelArea_i}{\sum_{i=1}^n pixelArea_i}$$

Where:

- $msaAggregate_t$ is aggregate mean species abundance (MSA) for the area of interest for year t ;
- $msaLU_{i,t}$ is the land use MSA value in pixel i for year t ;
- $msaF_{i,t}$ is the habitat fragmentation MSA value in pixel i for year t ;
- $msaI_{i,t}$ is the infrastructure MSA value in pixel i for year t ;
- $msaHe_{i,t}$ is the human encroachment MSA value in pixel i for year t ;
- $pixelArea_i$ is the the area of pixel i ; and
- n is the the number of pixels within the Aol.

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Impact of land use (MSA_{LU})

GLOBIO defines 16 land use classes and assigns to each a MSA_{LU} value based on literature review of cause-and-effect relationships between land use and species composition. For example, natural undisturbed forests have a MSA_{LU} of 1, whereas urban areas have a MSA_{LU} of 0.05.

ABC-Map land uses (see Part III) are matched with GLOBIO land uses to generate a map of GLOBIO land use classifications. Each pixel is then assigned the MSA_{LU} value corresponding to its land use class. Finally, the area-weighted mean of pixel values is calculated to determine the average MSA_{LU} for the entire Aol.

Correspondence between GLOBIO and ABC-Map land use classes are shown in [Annex I](#), together with the MSA_{LU} values assigned to each land use class.

Impact of habitat fragmentation (MSA_F)

Habitat fragmentation is assumed to be induced by roads, cropland, and urban areas. The mean species abundance due to the fragmentation MSA_F , is related to the size of non-fragmented natural area, as shown in [Table 5](#).

Table 5. GLOBIO MSA values by size range of non-fragmented natural area

NON-FRAGMENTED NATURAL AREA (KM ²)	MEAN SPECIES ABUNDANCE (MSA_F)
0–1	0.35
1–10	0.45
1–100	0.65
100–1 000	0.90
1 000–10 000	0.98
>10 000	1.00

Source: Schipper et al., 2016. The GLOBIO Model. A technical description of version 3.5. The Hague, PBL

To estimate the MSA_F , ABC-Map first calculates the area of non-fragmented natural areas. To do so, the map of ABC-Map land uses is transformed into a categorical map with pixel values equal to 1 if the land use is natural (e.g. forest, natural grassland) or 0 if the land use is artificial (e.g. urban area, cropland).

All connected (i.e. eight-connected) natural pixels are then grouped into fragmentation groups. The area of each fragmentation group will determine the value of the MSA_F for all natural pixels contained within the group.

For artificial pixels, it is considered that the impact of artificialization is already accounted by the MSA_{LU} , and the MSA_F is assigned a value of 1.



Equation 8.

If pixel i is artificial, then $msaF_{i,t} = 1$
Otherwise, pixel i is part of a fragmentation group l of area $fragmentationGroupArea_{l,t}$,
and for all pixels part of l :

$$\text{If } 0 \text{ ha} < fragmentationGroupArea_{i,t} < 100 \text{ ha,} \\ msaF_{i,t} = fragmentationGroupArea_{i,t} * \left[0.35 + \left(\frac{0.45 - 0.35}{100 - 0} \right) \right]$$

$$\text{If } 100 \text{ ha} < fragmentationGroupArea_{i,t} < 1e3 \text{ ha,} \\ msaF_{i,t} = fragmentationGroupArea_{i,t} * \left[0.45 + \left(\frac{0.65 - 0.45}{1e3 - 100} \right) \right]$$

$$\text{If } 1e3 \text{ ha} < fragmentationGroupArea_{i,t} < 1e4 \text{ ha,} \\ msaF_{i,t} = fragmentationGroupArea_{i,t} * \left[0.65 + \left(\frac{0.90 - 0.65}{1e4 - 1e3} \right) \right]$$

$$\text{If } 1e4 \text{ ha} < fragmentationGroupArea_{i,t} < 1e5 \text{ ha,} \\ msaF_{i,t} = fragmentationGroupArea_{i,t} * \left[0.90 + \left(\frac{0.98 - 0.90}{1e5 - 1e4} \right) \right]$$

$$\text{If } 1e5 \text{ ha} < fragmentationGroupArea_{i,t} < 1e6 \text{ ha,} \\ msaF_{i,t} = fragmentationGroupArea_{i,t} * \left[0.98 + \left(\frac{1 - 0.98}{1e6 - 1e5} \right) \right]$$

$$\text{Otherwise } msaF_{i,t} = 1$$

Where:

- $msaF_{i,t}$ is the mean species abundance due to fragmentation for pixel i for year t ; and
- $fragmentationGroupArea_{i,t}$ is the area of the fragmentation group of pixel i for year t .

Impact of infrastructure (MSA_i)

Biodiversity disturbance from infrastructure is assumed to be confined to an impact zone of 1 km² around infrastructural elements under GLOBIO. Both roads and railways are considered biodiversity disturbing infrastructure. ABC-Map uses the road density raster of the GRIP dataset to map roads (Meijer *et al.*, 2018).

The cause-and-effect relationship between infrastructure and MSA is quantified based on a meta-analysis (Benítez-López, Alkemade and Verweij, 2010), assigning the overall MSA_i for the 1-km impact zone as 0.78. As GLOBIO assumes that infrastructure does not cause additional MSA loss in urban areas and cropland except for the direct effect of land use, the MSA_i for urban areas and cropland is 1.

Equation 9.

If pixel i is artificial, then $msaI_{i,t} = 1$

Otherwise pixel i is natural and:

If $msaI_{i,t} = 1 - \left[\frac{(I_i^2)}{pixelArea_{i,t}} * (1 - 0.78) \right] < 0.78$ then $msaI_{i,t} = 0.78$

Else, $msaI_{i,t} = 1 - \left[\frac{(I_i^2)}{pixelArea_{i,t}} * (1 - 0.78) \right]$

Where:

- $msaI_{i,t}$ is the MSA value due to infrastructure for pixel i for year t ;
- I_i is the infrastructure (roads and railways) in pixel i in kilometres; and
- $pixelArea_i$ is the area of pixel i .

Impact of human encroachment

Human encroachment can be defined as anthropogenic activities in otherwise natural areas, comprising hunting, food and fuel gathering, recreation and human settlements. GLOBIO assumes that a proportion of cropland and urban area of 1.5 percent is sufficient to have the entire project area influenced by human encroachment, based on estimates from model simulations.

Based on GLOBIO, ABC-Map calculates the MSA_F as follows:

Equation 10.

If the cropland area surpasses 1.5 percent of the total Aol are, then for all pixels i

$$msaHe_{i,t} = 0.85$$

Otherwise

$$msaHe_{i,t} = 1$$

Where:

- $msaHe_{i,t}$ is the MSA value due to human encroachment for pixel i for year t .



Box 5. Area of Intact Biodiversity

Based on the MSA, ABC-Map provides the area of intact biodiversity (AIB), an additional indicator that supports users to interpret and visualise MSA values in context. The AIB corresponds to a surface area equivalent of the MSA value. For instance, an AIB of 500 ha corresponds to the value of biodiversity contained in 500 ha of a forest undisturbed by human activities.

The equation to calculate the AIB is as follows:

$$AIB = (1 - aggregateMsa_{Aol}) * area_{Aol}$$

Where:

- *aggregateMsa_{Aol}* is the average aggregate MSA over the Aol;
- and *area_{Aol}* is the area of the Aol.

NATURAL CAPITAL

In ABC-Map, the natural capital indicator expresses the sum, in monetary value, of the ecosystem services provided by the ecosystems in the Aol.

Ecosystems, both natural and managed, provide a wealth of benefits to society. These benefits are referred to as 'ecosystem services' and include provisioning services (e.g. food or water provisioning), regulating services (e.g. carbon sequestration or pollination), cultural services (e.g. recreation, inspiration, and cultural identity) and supporting services (e.g. life cycle maintenance).

Investment decisions which do not account for the positive and negative externalities associated with ecosystem services can lead to degradation of ecosystems and biodiversity loss. Measuring and utilising natural capital values supports the consideration of the economic and ecological benefits of ecosystem services in decision-making.

In ABC-Map, the natural capital indicator links ecosystem service values to geospatial data. ABC-Map provides a map of the natural capital for the last year of the baseline and the last year of the project and a time-series showing the evolution of the natural capital over time within the Aol.

Methodology

To calculate the natural capital, ABC-Map utilizes data from the Ecosystem Services Valuation Database (ESVD), a database gathering over 10 000 records of ecosystem service valuation studies (see [Box 6](#)). From the ESVD, summary values of ecosystem services per biome can be calculated.

Box 6: The Ecosystem Services Valuation Database

ABC-Map utilizes ecosystem service values from the 'Ecosystem Services Valuation Database' (ESVD), the largest database with standardized monetary values for all ecosystem services globally (Brander *et al.*, 2024). The ESVD synthesizes information from over 1 350 studies, which yield over 10 800 value estimates covering 15 biomes and 23 ecosystem services.

To enable the comparison and synthesis of values, estimates in the ESVD are standardised to a common set of units (Int\$/ha/year at 2020 price levels). These summary statistics can be understood as the average of all standardized values for a combination of a biome and an ecosystem service. A summary value reflects the availability of valuation studies, the interests of funding organizations, and the thematic expertise of the researchers involved.

FAO is collaborating with the Foundation for Sustainable Development, who developed and maintains the ESVD, to develop value functions that adjust summary values to be specific to local contexts. These value functions will be integrated into ABC-Map upon completion of this work.

The ABC-Map land cover categories (see Part III), climate zones data (Audebert *et al.*, 2021) and datasets on coral reefs (UNEP-WCMC *et al.*, 2021), wetlands and lake distribution (Lehner & Döll, 2004) are used to map the locations of different biomes. ABC-Map then assigns pixel values based on summary values from the ESVD, in Int\$/year/ha.

The summary value of each pixel is then multiplied with the pixel area to obtain values in Int\$/year. The total natural capital for the Aol is then obtained by taking the sum of all pixel values within the Aol and applying a discount rate.

Equation 11.

$$\mathit{naturalCapitalAggregate}_t = \frac{\sum_{i=1}^n \mathit{naturalCapital}_{i,t} * \mathit{pixelArea}_i}{(1 - r)^{t-2020}}$$

Where:

- $\mathit{naturalCapitalAggregate}_t$ is the total natural capital for the Aol for year t ;
- $\mathit{naturalCapital}_{i,t}$ is the natural capital value in pixel i for year t ;
- $\mathit{pixelArea}_i$ is the area of pixel i ; and
- r is the discount rate.



Box 7. Average natural capital per hectare

Based on the natural capital, ABC-Map also calculates the average change in natural capital per ha (ΔANC). The average natural capital per hectare corresponds to an average ecosystem service value for one hectare of land within the project intervention area. ABC-Map shows the difference in average natural capital per hectare between the last year of the baseline and the last year of project implementation.

The equation to calculate the ΔANC is as follows:

$$\Delta ANC = \frac{totalNaturalCapital_p - totalNaturalCapital_B}{area_{AOI}}$$

Where:

- $totalNaturalCapital_B$ is the total natural capital of the Aol for the last year of the baseline in Int\$/year/ha;
- $totalNaturalCapital_p$ is the total natural capital of the Aol for the last year of the project in Int\$/year/ha; and
- $area_{AOI}$ is the area of the Aol in hectares.

Box 8. Using the natural capital and mean species abundance together as a biodiversity proxy

While the natural capital and mean species abundance (MSA) assessments use innovative approaches to allow for accounting via geospatial data, it is important to note that there are also limitations stemming from both indicators. For this reason, these two indicators should be considered complementary, i.e. while MSA has limitations on differentiating the ecological value, natural capital does not, and while natural capital does not include degradation levels of ecosystems, MSA does.

Hence, when both indicators are used in a complementary way, they provide a good proxy to measure if biodiversity is improving or deteriorating (Audebert *et al.*, 2022). In this way, the International Fund for Agricultural Development (IFAD) have adopted the biodiversity section of ABC-Map as their biodiversity core outcome indication “Biodiversity improvements at ecosystem-level” (Audebert *et al.*, 2022).

KEY BIODIVERSITY AREAS

Key Biodiversity Areas (KBA) are sites that contribute to the global persistence of biodiversity (Birdlife International, 2024).

In ABC-Map the locations of KBAs are displayed on the map and a time-series of land uses within them is provided. The time series provided is based on the methodology described in Part III of these guidelines. In the time series ABC-Map land uses are aggregated into the seven generic IPCC land uses: cropland, forest, grassland, settlement, wetland, water, other land. Definitions of these categories and the aggregations can be found in [Annex II](#).

These areas are sourced from the World Database of Key Biodiversity Areas, managed by the KBA Partnership, a partnership of 13 global conservation organisations. KBAs are identified by applying the biological criteria and thresholds included in the “A Global Standard for the Identification of Key Biodiversity Areas” approved by the Council of the International Union for Conservation of Nature in April 2016 (IUCN, 2016). The World Database of KBAs includes areas identified under the Standard as well as other existing KBAs (e.g. Important Bird and Biodiversity Areas, Alliance for Zero Extinction sites, KBAs identified through the Critical Ecosystem Partnership Fund). This database is updated periodically and integrated into ABC-Map accordingly.

PROTECTED AREAS

A protected area is “a geographically defined area, which is designated or regulated and managed to achieve specific conservation objectives” (Article 2, Convention on Biological Diversity).

In ABC-Map the locations of protected areas are displayed on the map and a time-series of land uses within them is provided. The time series provided is based on the methodology described in Part III of these guidelines. In the time series ABC-Map land uses are aggregated into the seven generic IPCC land uses: cropland, forest, grassland, settlement, wetland, water, and other land. Definitions of these categories and the aggregations can be found in [Annex II](#).

These areas are sourced from the World Database on Protected Areas, which is managed by the World Commission on Protected areas, a voluntary network administered by IUCN’s Global Programme on Protected Areas (UNEP-WCMC, 2019). The database is composed of submissions from governments, non-governmental organizations, landowners and local organizations and communities that comply with the Protected Planet data standards (UNEP-WCMC, 2019). An updated version of this dataset is released monthly, which is then integrated accordingly into ABC-Map.



The WDPA categorizes different types of protected areas (UNEP-WCMC, 2019):

- 1a. strict nature reserve
- 1b. wilderness area
2. national park
3. natural monument
4. habitat/species management
5. protected landscape/seascape
6. protected area with sustainable use of natural resources

In ABC-Map, all types are aggregated under a single category, and simply considered protected areas.

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Carbon Mapping Tool
ABC-Map

Box 9. Key Biodiversity Areas and Protected Areas

The location and land uses within both Key Biodiversity Areas (KBAs) and protected areas are useful to understand the past and current status and context surrounding biodiversity. This information can also aid spatial planning. The identification of these areas also supports the application of biodiversity safeguards for many institutions (IFC, 2019).

Although KBAs and protected areas each have separate and distinct criteria for designation, they often overlap. However, for accurate interpretation, it is important that the distinction between them is well understood.

The identification of an area as a KBA highlights its significant values to the global persistence of biodiversity and implies that the area should be managed in a way that its biodiversity is maintained. However, KBA designation does not always imply that the area should become a protected area. Other management tools, such as community-managed areas, indigenous reserves, marine zones, or forest plans, or similar mechanisms may be the most appropriate form of effective management for a given site (KBA Partnership, 2017). Additionally, protected areas may be established for other conservation purposes beyond biodiversity conservation.

Further guidance on the relationship and distinctions between these areas are available through the Key Biodiversity Areas Partnership (KBA Partnership, 2017).

Carbon Section



The carbon section provides information on greenhouse gas sequestration and emissions. All indicators follow the methodology of the NDC Expert Tool (NEXT) (**Box 10**), which itself is based on IPCC Tier 1 methodologies for greenhouse gas inventories.

Currently, the carbon section contains two indicators: total carbon stocks and the social value of carbon, both available at baseline and project level.

Box 10. The Nationally Determined Contribution Expert Tool

The Nationally Determined Contribution Expert Tool (NEXT) is a greenhouse gas accounting tool developed by the Food and Agriculture Organization of the United Nations (FAO) to support annual environmental impact assessments in the agriculture, forestry and other land use (AFOLU) sector.

NEXT provides a 30-year time-series of annual and cumulated estimates of carbon removal and greenhouse gas emission reductions from climate actions made by Parties to the Paris Agreement. It was developed using the IPCC methodologies, and estimates can be made using the IPCC 2006 guidelines (IPCC, 2006) or the IPCC 2019 refinement to the IPCC 2006 (IPCC, 2019), which are both complemented by the IPCC 2013 wetlands supplement (IPCC, 2013).

The tool was designed to provide results that directly respond to the provisions of the Paris Agreement's enhanced transparency framework. It supports the tracking of nationally determined contributions (NDCs) as required by the modalities, procedures and guidelines.

NEXT provides a high temporal series of results and a wide set of indicators, including the social value of carbon. This provides a comprehensive environmental and economic overview of climate actions to achieve a mitigation target.

Finally, the tool helps countries interpret, track and scale up the ambition of their NDCs, which could ultimately feed into, and inform the global stocktake of the Paris Agreement in a harmonized manner.

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Part II
Indicator-Specific
Methodologies



TOTAL CARBON STOCKS

The total carbon stocks indicator of ABC-Map provides an estimate of the total carbon stored in all compartments (i.e. above- and below-ground biomass, soil, deadwood and litter). Total carbon stocks are calculated as an annual time series using a stock change approach.

ABC-Map provides a map of the total carbon stocks for the last year of the baseline and the last year of the project, and a time-series showing the evolution of carbon stocks over years within the Aol.

Methodology

Carbon stocks are calculated using the Tier 1 methodology laid out in the 2019 IPCC guidelines for national greenhouse gas inventories. They are defined as the sum of the soil organic carbon (SOC) and the carbon from the biomass. The biomass includes above-ground and below-ground biomass, and, for forest land only, deadwood and litter.

SOC stocks are calculated using default reference stock from the 2019 IPCC guidelines and the 2013 IPCC wetland supplement (IPCC, 2019; IPCC, 2013). The guidelines provide default estimates of stocks contained in the 0-30 cm layer, assuming reference vegetation. The values are disaggregated by IPCC major soil type and climate zone (Table 2.3, Chapter 2, Volume 4). For instance, in accordance with the 2019 IPCC Guidelines, high activity clay soils under a tropical montane climate have an average reference SOC stock of 51 tonnes of carbon per hectare (+/- 10 percent).

SOC stocks are then associated to SOC stock changes factors (Vol. 4, Ch. 2, Equation 2.25), including: (i) a land-use factor (F_{lu}) that reflects changes associated with the type of land use, (ii) a management factor (F_{mg}) that represents the principal management practice specific to the land-use sector (e.g. tillage practices in croplands), and (iii) an input factor (F_i) representing different levels of carbon input to soil.

The SOC values are dependent on the IPCC major soil type and the climate zone. Default biomass values and stock changes factors are dependent on the climate zone and land use class. The IPCC soil types map from Sinitambirivoutin *et al.* (2024) is used to map soil types. For climate zones, ABC-Map uses the map from Audebert *et al.* (2024). Land uses are detected from land cover products, as detailed in Part III.

The final equation of carbon stocks for a given year for pixel i is as follows:

Equation 12.

$$cStock_{i,t} = SOC_i * F_{lu_{i,t}} * F_{mg_{i,t}} * F_{i,t} + Biomass_{i,t}$$

Where:

- $cStock_{i,t}$ is the total carbon stocks observed in pixel i on year t , in tC/ha;
- SOC_i is the reference soil organic carbon for the soil type and climate associated with pixel i , in tC/ha;
- $F_{lu_{i,t}}$ is the land use factor for pixel i on year t , dimensionless;
- $F_{mg_{i,t}}$ is the management factor for pixel i on year t , dimensionless;
- $F_{i,t}$ is the input factor for pixel i on year t , dimensionless; and
- $Biomass_{i,t}$ is the sum of the total above-ground biomass and below-ground biomass for pixel i on year t , in tC/ha.

For natural forests, forest plantations and wetlands, a slightly different version of Equation 8 is used, excluding the management factor (Fmg) and the input factor (F_i), and adding an intactness factor:

Equation 13.

$$cStock_{i,t} = (SOC_i * F_{lu_{i,t}} + Biomass_{i,t}) * Intactness_i$$

Where:

- $cStock_{i,t}$ is the total carbon stocks observed in pixel i on year t , in tC/ha;
- SOC_i is the reference soil organic carbon for the soil type and climate associated with pixel i , in tC/ha;
- $F_{lu_{i,t}}$ is the land use factor (held constant at 1 for forests) for pixel i on year t , dimensionless;
- $Biomass_{i,t}$ is the sum of above-ground biomass, below-ground biomass, litter and deadwood for pixel i on year t ; and
- $Intactness_i$ is an adjustment factor for the degradation level of the forest (between 0 and 1), here for pixel i , dimensionless.



ABC-Map first calculates the carbon stocks in each pixel, measured in tonnes of carbon per hectare. These carbon stock values are then multiplied by the pixel area in hectares. The results are summed across the entire Aol to determine the total carbon stocks for a given year. Finally, the data for all available years are organized into a histogram.

As per the IPCC guidelines, soils are assumed to reach an equilibrium after a 20-year period. Consequently, in ABC-Map, stock changes consequent to projects are calculated over a minimum period of 20 years.

Equation 14.

$$totalCarbonStocks_t = \sum_{i=1}^n cStock_{i,t} * pixelArea_i$$

Where:

- $totalCarbonStocks_t$ is the total stock of carbon in the Aol on year t in tC;
- $cStock_{i,t}$ is the total carbon stock in pixel i on year t in tC/ha; and
- $pixelArea_i$ is the area of pixel i in hectares.

SOCIAL VALUE OF CARBON

The social value of carbon is the discounted monetary value of future climate change damages due to one additional tonne of CO₂-e emissions (Schiettecatte *et al.*, 2022). The social value of carbon can be used to help policymakers, financial institutions and other actors determine whether the costs and benefits of a proposed project, investment, or policy to curb climate change are justified. ABC-Map provides a time-series showing the evolution of the social value of carbon over time within the Aol.

Methodology

The social value of carbon is based on the carbon shadow prices outlined in the Report of the High-Level Commission on Carbon Prices by Stiglitz and Stern (2017), adjusted for their net present value based on 2017 prices. The Commission estimated that, in 2020, a shadow price range of USD 40–80 per tonne of CO₂ equivalent (tCO₂-e), rising to USD 50–110 per tCO₂-e by 2030, is consistent with the Paris Agreement’s goal of limiting global warming to 2°C, provided there is a supportive policy framework.

In line with the Commission’s recommendations, ABC-Map uses the minimum and maximum shadow prices for the 2020–2030 period. For years beyond 2030, the shadow price is extrapolated based on the annual growth rate of 2.25 percent observed between 2020 and 2030.

The social value of carbon is then calculated by multiplying the total carbon stock (as estimated by the total carbon stock indicator) with the shadow price of carbon, adjusted for its net present value relative to 2017 prices.

Based on Stiglitz *et al.* (2017), a minimum and maximum social value of carbon is calculated for each year:

Equation 15.

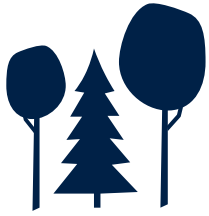
$$MAXsocialvalueofcarbon_t = - \frac{(74.908 \times \exp(0.023 \times (t-2017)) \times \Delta CO_{2,t})}{((1+r)^{(t-2017)})}$$

$$MINsocialvalueofcarbon_t = - \frac{(37.436 \times \exp(0.023 \times (t-2017)) \times \Delta CO_{2,t})}{((1+r)^{(t-2017)})}$$

Where:

- $MAXsocialvalueofcarbon_t$ and $MINsocialvalueofcarbon_t$ are, respectively, the maximum and minimum social value of carbon based on carbon shadow process, (Stiglitz *et al.*, 2017) from the reference or target scenario for a given year t ;
- ΔCO_2 is the carbon-balance of a climate action for a given year t ;
- r is the discount rate; and
- t is the year of the assessment.





Part III: Cross-Cutting Methodologies

The following section provides details on the overarching methodologies common to multiple indicators in ABC-Map.

ABC-Map Land cover

ABC-Map indicators make use of several land use classifications, originating from the land cover products used, from GLOBIO 3.6, and from the IPCC. Correlations were established between all categories and are detailed in [Annex I](#).

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On the 'Start' page, users must select a land cover product from a list of options. The selected product will determine both the resolution and the range of years available for the baseline analysis. The resolution and time period covered for each land cover product are listed below.

Indicators relying on land cover data establish a correlation between the classes from the selected land cover product and the ABC-Map land cover classes. ABC-Map land cover classes are correlated with the land use and land management options available in the IPCC Guidelines for National Greenhouse gas Inventories. For forest classes, the Forest Landscape Integrity Index is used to disaggregate forest land into three categories: high, medium and low integrity forest (Grantham *et al.*, 2020).

The following land cover products are available in ABC-Map:

ESA LAND COVER CCI V2.1

The European Space Agency (ESA) CCI-LC project delivers a global land cover map from satellite derived parameters at 300 m spatial resolution on an annual basis from 1992 to 2022 (Land Cover CCI Partnership, 2017).

CCI-LC identifies 22 classes that, for use in ABC-Map, are converted to the equivalent IPCC classes using Table 3.3 of the Land Cover CCI Product user guide (Land Cover CCI Partnership, 2017). CCI-LC reaches a reported accuracy of 74 percent.

COPERNICUS GLOBAL LAND COVER LAYERS (CGLS-LC100): COLLECTION 3

Copernicus Global Land Cover Layers (CGLS-LC100) Collection 3 map at 100 m resolution delivers a global land cover map at 100 m spatial resolution (Buchhorn *et al.*, 2020).

The CGLS-LC100 Collection 3 maps are provided for the 2015–2019 period over the entire globe and reach a reported accuracy of 80 percent.

CGLS-LC100 Collection 3 identifies 23 classes that, for use in ABC-Map, are converted to the equivalent IPCC classes using the conversion table in [Annex I](#).

MAPBIOMAS

MapBiomass provides national land cover maps at a 30 m resolution for 11 countries:

- Argentina (1998-2022), with an undefined accuracy (MapBiomass, 2025a);
- Bolivia (Plurinational State of) (1985-2022), with 66 percent accuracy (MapBiomass, 2025b);
- Brazil (1985-2023), with 89 percent accuracy (MapBiomass, 2025c);
- Colombia (1985-2022), with 91 percent accuracy (MapBiomass, 2025d);
- Chile (2000-2022), with an undefined accuracy (MapBiomass, 2025e);
- Ecuador (1985-2022), with an undefined accuracy (MapBiomass, 2025f);
- Indonesia (2000-2022), with 75 percent accuracy (MapBiomass, 2025g);
- Paraguay (1985-2022), with an undefined accuracy (MapBiomass, 2025h);
- Peru (1985-2022), with an undefined accuracy (MapBiomass, 2025i);
- Uruguay (1985-2022), with 78 percent accuracy (MapBiomass, 2025j); and
- Venezuela (Bolivarian Republic of) (1985-2022), with 78 percent accuracy (MapBiomass, 2025k).



The land cover classes available in MapBiomass vary depending on the country, from 12 classes available in Uruguay to 37 classes in Brazil.

Discount rate

All indicators expressed in US dollars utilise a discount rate, which is used to determine the present value of future cash flows. The default rate used in ABC-Map is 0 percent, but users are able specify a different value. Discounting permits a comparison of the value of money in different time periods, considering that a dollar today is worth more than a dollar received tomorrow, i.e. the return that could be earned per unit of time on an investment with similar risk.

Project side calculations

To assess the impact of planned activities, ABC-Map creates a map of the expected land uses resulting from the project's implementation. ABC-Map calculates the value of each indicator after project implementation and compares it to the last year of the baseline to obtain the total impact of the project. ABC-Map offers two options for implementation, linear and sigmoid, which the user selects to define how the equations for project-side indicators are calculated.

In the project assessment outputs, the charts for the MSA, natural capital and total carbon stocks show three separate lines:

- the dynamic baseline which shows the result of a linear regression, representing a continuation of past trends;
- the static baseline which keeps the value constant from the last year of data before project implementation; and
- the project impact.

The values from both the static and dynamic baseline can be used to compare with the predicted project impact.

Annex I – Mapping of land use categories in ABC-Map and GLOBIO v. 3.5

Table A1.1. Mapping of PROBA V 100m land cover classes to ABC-Map, GLOBIO 3.5 and IPCC classes

PROBA V 100M LAND COVER CLASSES	ABC-MAP LAND USE	GLOBIO 3.5 LAND USE	MSA 3.5	NATURAL/ARTIFICIAL	IPCC CLASSES
Shrubs Forest formation	Forest - Shrubland + High integrity	Forest - Natural	1	Natural	Forest
	Forest - Shrubland + Medium integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Shrubland + Low integrity	Forest - Selective logging (Lightly used forest)	0.7		
Herbaceous vegetation / Tree and shrub cover < 10 %.	Grassland - Natural	Natural grassland	1	Natural	Grassland
Cultivated and managed vegetation / agriculture (temporary crops)	Cropland, annual - full tillage + medium input	Intensive cropland	0.1	Artificial	Cropland
Urban / built up	Settlement - Settlement	Urban areas	0.05	Artificial	Settlement
Bare / sparse vegetation	Other Land - Other Land	Bare area	1	Natural	Other Land
Snow and ice	Other Land - Other Land	Bare area	1	Natural	Other Land
Permanent water bodies	Other Land - Water	Bare area	1	Natural	Other Land
Herbaceous wetland	Wetland - Grassland - High Integrity	Natural grassland	1	Natural	Wetland
	Wetland - Grassland - Medium Integrity				
	Wetland - Grassland - Low Integrity				
Moss and lichen	Other Land - Other Land	Bare area	1	Natural	Other Land

PROBA V 100M LAND COVER CLASSES	ABC-MAP LAND USE	GLOBIO 3.5 LAND USE	MSA 3.5	NATURAL/ARTIFICIAL	IPCC CLASSES
Closed forest, evergreen needle leaf	Forest - Forest + High Integrity	Forest - Natural	1	Natural	Forest
	Forest - Forest + Medium Integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Forest + Low Integrity	Forest - Selective logging (Lightly used forest)	0.7		
	Forest - Forest + High Integrity	Forest - Natural	1		
	Forest - Forest + Medium Integrity	Forest - Reduced Impact Logging	0.85		
Closed forest, evergreen broad leaf	Forest - Forest + Low Integrity	Forest - Selective logging (Lightly used forest)	0.7	Natural	Forest
Closed forest, deciduous needle leaf	Forest - Forest + High Integrity	Forest - Natural	1	Natural	Forest
	Forest - Forest + Medium Integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Forest + Low Integrity	Forest - Selective logging (Lightly used forest)	0.7		
Closed forest, deciduous broad leaf	Forest - Forest + High Integrity	Forest - Natural	1	Natural	Forest
	Forest - Forest + Medium Integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Forest + Low Integrity	Forest - Selective logging (Lightly used forest)	0.7		
Closed forest, mixed	Forest - Forest + High Integrity	Forest - Natural	1	Natural	Forest
	Forest - Forest + Medium Integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Forest + Low Integrity	Forest - Selective logging (Lightly used forest)	0.7		
Closed forest, unknown	Forest - Forest + High Integrity	Forest - Natural	1	Natural	Forest
	Forest - Forest + Medium Integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Forest + Low Integrity	Forest - Selective logging (Lightly used forest)	0.7		
Open forest, evergreen needle leaf	Forest - Forest + High Integrity	Forest - Natural	1	Natural	Forest
	Forest - Forest + Medium Integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Forest + Low Integrity	Forest - Selective logging (Lightly used forest)	0.7		

PROBA V 100M LAND COVER CLASSES	ABC-MAP LAND USE	GLOBIO 3.5 LAND USE	MSA 3.5	NATURAL/ARTIFICIAL	IPCC CLASSES
Open forest, evergreen broad leaf	Forest - Forest + High Integrity	Forest - Natural	1	Natural	Forest
	Forest - Forest + Medium Integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Forest + Low Integrity	Forest - Selective logging (Lightly used forest)	0.7		
Open forest, deciduous needle leaf	Forest - Forest + High Integrity	Forest - Natural	1	Natural	Forest
	Forest - Forest + Medium Integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Forest + Low Integrity	Forest - Selective logging (Lightly used forest)	0.7		
Open forest, deciduous broad leaf	Forest - Forest + High Integrity	Forest - Natural	1	Natural	Forest
	Forest - Forest + Medium Integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Forest + Low Integrity	Forest - Selective logging (Lightly used forest)	0.7		
Open forest, mixed	Forest - Forest + High Integrity	Forest - Natural	1	Natural	Forest
	Forest - Forest + Medium Integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Forest + Low Integrity	Forest - Selective logging (Lightly used forest)	0.7		
Open forest, unknown	Forest - Forest + High Integrity	Forest - Natural	1	Natural	Forest
	Forest - Forest + Medium Integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Forest + Low Integrity	Forest - Selective logging (Lightly used forest)	0.7		
Open sea	Other Land - Water	n/a	n/a	n/a	n/a
No data	n/a	n/a	n/a	n/a	n/a

Source: Authors' own elaboration.

Table A1.2. Mapping of ESA CCI 300m land cover classes to ABC-Map, GLOBIO 3.5 and IPCC classes

ESA CCI 300M LAND COVER CLASSES	ABC-MAP LAND USE	GLOBIO 3.5 LAND USE	MSA 3.5	NATURAL/ ARTIFICIAL	IPCC CLASSES
Cropland rainfed	Cropland, annual - full tillage + medium input	Intensive cropland	0.1	Artificial	Cropland
Herbaceous cover	Cropland, annual - full tillage + medium input	Intensive cropland	0.1	Artificial	Cropland
Tree or shrub cover	Cropland, perennial - Monoculture, Orchard + reduced tillage + medium input	Woody biofuels and perennial crops	0.3	Artificial	Cropland
Cropland irrigated or post-flooding	Cropland, flooded rice	Irrigated cropland	0.05	Artificial	Cropland
Mosaic cropland (>50%) / natural vegetation (Tree, shrub, herbaceous cover) (<50%)	Cropland, perennial - Monoculture, Orchard + reduced tillage + medium input	Woody biofuels and perennial crops	0.3	Artificial	Cropland
Mosaic natural vegetation (Tree, shrub, herbaceous cover) (>50%) / cropland (<50%)	Cropland, perennial - Multistrata + full tillage + medium input	Agroforestry	0.5	Artificial	Cropland
Tree cover, broadleaved, evergreen, closed to open (>15%)	Forest - Forest + High integrity	Forest - Natural	1	Natural	Forest
	Forest - Forest + Medium integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Forest + Low integrity	Forest - Selective logging (Lightly used forest)	0.7		
Tree cover, broadleaved, deciduous, closed to open (>15%)	Forest - Forest + High integrity	Forest - Natural	1	Natural	Forest
	Forest - Forest + Medium integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Forest + Low integrity	Forest - Selective logging (Lightly used forest)	0.8		

ESA CCI 300M LAND COVER CLASSES	ABC-MAP LAND USE	GLOBIO 3.5 LAND USE	MSA 3.5	NATURAL/ ARTIFICIAL	IPCC CLASSES
Tree cover, broadleaved, deciduous, closed (>40%)	Forest - Forest + High integrity	Forest - Natural	1	Natural	Forest
	Forest - Forest + Medium integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Forest + Low integrity	Forest - Selective logging (Lightly used forest)	0.9		
Tree cover, broadleaved, deciduous, open (15-40%)	Forest - Forest + High integrity	Forest - Natural	1	Natural	Forest
	Forest - Forest + Medium integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Forest + Low integrity	Forest - Selective logging (Lightly used forest)	0.1		
Tree cover, needleleaved, evergreen, closed to open (>15%)	Forest - Forest + High integrity	Forest - Natural	1	Natural	Forest
	Forest - Forest + Medium integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Forest + Low integrity	Forest - Selective logging (Lightly used forest)	0.11		
Tree cover, needleleaved, evergreen, closed (>40%)	Forest - Forest + High integrity	Forest - Natural	1	Natural	Forest
	Forest - Forest + Medium integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Forest + Low integrity	Forest - Selective logging (Lightly used forest)	0.12		
Tree cover, needleleaved, evergreen, open (15-40%)	Forest - Forest + High integrity	Forest - Natural	1	Natural	Forest
	Forest - Forest + Medium integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Forest + Low integrity	Forest - Selective logging (Lightly used forest)	0.13		

ESA CCI 300M LAND COVER CLASSES	ABC-MAP LAND USE	GLOBIO 3.5 LAND USE	MSA 3.5	NATURAL/ ARTIFICIAL	IPCC CLASSES
Tree cover, needleleaved, deciduous, closed to open (>15%)	Forest - Forest + High integrity	Forest - Natural	1	Natural	Forest
	Forest - Forest + Medium integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Forest + Low integrity	Forest - Selective logging (Lightly used forest)	0.14		
Tree cover, needleleaved, deciduous, closed (>40%)	Forest - Forest + High integrity	Forest - Natural	1	Natural	Forest
	Forest - Forest + Medium integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Forest + Low integrity	Forest - Selective logging (Lightly used forest)	0.15		
Tree cover, needleleaved, deciduous, open (15-40%)	Forest - Forest + High integrity	Forest - Natural	1	Natural	Forest
	Forest - Forest + Medium integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Forest + Low integrity	Forest - Selective logging (Lightly used forest)	0.16		
Tree cover, mixed leaf type (broadleaved and needleleaved)	Forest - Forest + High integrity	Forest - Natural	1	Natural	Forest
	Forest - Forest + Medium integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Forest + Low integrity	Forest - Selective logging (Lightly used forest)	0.17		
Mosaic T and shrub (>50%) / herbaceous cover (<50%)	Forest - Shrubland + High integrity	Forest - Natural	1	Natural	Forest
	Forest - Shrubland + Medium integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Shrubland + Low integrity	Forest - Selective logging (Lightly used forest)	0.7		
Mosaic herbaceous cover (>50%) / T and shrub (<50%)	Grassland - Natural	Natural grassland	1	Natural	Grassland

ESA CCI 300M LAND COVER CLASSES	ABC-MAP LAND USE	GLOBIO 3.5 LAND USE	MSA 3.5	NATURAL/ ARTIFICIAL	IPCC CLASSES
Shrubland	Forest - Shrubland + High integrity	Forest - Natural	1	Natural	Forest
	Forest - Shrubland + Medium integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Shrubland + Low integrity	Forest - Selective logging (Lightly used forest)	0.7		
Shrubland evergreen	Forest - Shrubland + High integrity	Forest - Natural	1	Natural	Forest
	Forest - Shrubland + Medium integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Shrubland + Low integrity	Forest - Selective logging (Lightly used forest)	0.7		
Shrubland deciduous	Forest - Shrubland + High integrity	Forest - Natural	1	Natural	Forest
	Forest - Shrubland + Medium integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Shrubland + Low integrity	Forest - Selective logging (Lightly used forest)	0.7		
Grassland	Grassland - Natural	Natural grassland	1	Natural	Grassland
Lichens and mosses	Other Land - Other Land	Bare area	1	Natural	Other Land
Sparse vegetation (tree, shrub, herbaceous cover) (<15%)	Grassland - Natural	Natural grassland	1	Natural	Grassland
Sparse tree (<15%)	Grassland - Natural	Natural grassland	1	Natural	Grassland
Sparse shrub (<15%)	Grassland - Natural	Natural grassland	1	Natural	Grassland
Sparse herbaceous cover (<15%)	Grassland - Natural	Natural grassland	1	Natural	Grassland

ESA CCI 300M LAND COVER CLASSES	ABC-MAP LAND USE	GLOBIO 3.5 LAND USE	MSA 3.5	NATURAL/ ARTIFICIAL	IPCC CLASSES
Tree cover, flooded, fresh or brakish water	Wetland - Forest - High Integrity	Forest - Natural	1	Natural	Forest
	Wetland - Forest - Medium Integrity	Forest - Reduced Impact Logging	0.85		
	Wetland - Forest - Low Integrity	Forest - Selective logging (Lightly used forest)	0.7		
Tree cover, flooded, saline water	Wetland - Forest - High Integrity	Forest - Natural	1	Natural	Forest
	Wetland - Forest - Medium Integrity	Forest - Reduced Impact Logging	0.85		
	Wetland - Forest - Low Integrity	Forest - Selective logging (Lightly used forest)	0.7		
Shrub or herbaceous cover, flooded, fresh/saline/brakish water	Wetland - Grassland - High Integrity	Natural grassland	1	Natural	Wetland
	Wetland - Grassland - Medium Integrity				
	Wetland - Grassland - Low Integrity				
Urban areas	Settlement - Settlement	Urban areas	0.05	Artificial	Settlement
Bare areas	Other Land - Other Land	Bare area	1	Natural	Other Land
Consolidated bare areas	Other Land - Other Land	Bare area	1	Natural	Other Land
Unconsolidated bare areas	Other Land - Other Land	Bare area	1	Natural	Other Land
Water bodies	Other Land - Water	Bare area	1	Natural	Other Land
Permanent snow and ice	Other Land - Other Land	Bare area	1	Natural	Other Land
No data	n/a	n/a	n/a	n/a	n/a

Source: Authors' own elaboration.

Table A1.3. Mapping of MapBiomas 30m land cover classes to ABC-Map, GLOBIO 3.5 and IPCC classes

MAPBIOMAS 30M LAND COVER CLASSES	ABC-MAP LAND USE	GLOBIO 3.5 LAND USE	MSA 3.5	NATURAL/ARTIFICIAL	IPCC CLASSES
Forest formation	Forest - Forest + High integrity	Forest - Natural	1	Natural	Forest
	Forest - Forest + Medium integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Forest + Low integrity	Forest - Selective logging (Lightly used forest)	0.7		
Forest	Forest - Forest + High integrity	Forest - Natural	1	Natural	Forest
	Forest - Forest + Medium integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Forest + Low integrity	Forest - Selective logging (Lightly used forest)	0.8		
Wooded Savanna (open woodland)	Forest - Forest + High integrity	Forest - Natural	1	Natural	Forest
	Forest - Forest + Medium integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Forest + Low integrity	Forest - Selective logging (Lightly used forest)	0.9		
Mangrove	Wetland - Mangrove + High Integrity	Forest - Natural	1	Natural	Wetland
	Wetland - Mangrove + Medium Integrity	Forest - Reduced Impact Logging	0.85		
	Wetland - Mangrove + Low Integrity	Forest - Selective logging (Lightly used forest)	0.1		

MAPBIOMAS 30M LAND COVER CLASSES	ABC-MAP LAND USE	GLOBIO 3.5 LAND USE	MSA 3.5	NATURAL/ ARTIFICIAL	IPCC CLASSES
Flooded forest	Wetland - Forest + High Integrity	Forest - Natural	1	Natural	Wetland
	Wetland - Forest + Medium Integrity	Forest - Reduced Impact Logging	0.85		
	Wetland Forest + Low Integrity	Forest - Selective logging (Lightly used forest)	0.11		
Wooded sand vegetation	Forest - Forest + High integrity	Forest - Natural	1	Natural	Forest
	Forest - Forest + Medium integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Forest + Low integrity	Forest - Selective logging (Lightly used forest)	0.12		
Sparse woodland	Forest - Forest + High integrity	Forest - Natural	1	Natural	Grassland
	Forest - Forest + Medium integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Forest + Low integrity	Forest - Selective logging (Lightly used forest)	0.12		
Natural non forest formation	Grassland - Natural	Natural grassland	1	Natural	Grassland
Wetland	Wetland - Grassland - High Integrity	Natural grassland	1	Natural	Wetland
	Wetland - Grassland - Medium Integrity				
	Wetland - Grassland - Low Integrity				
Grasslands/ herbaceous	Grassland - Natural	Natural grassland	1	Natural	Grassland
Hypersaline tidal flat	Other Land - Other Land	Bare area	1	Natural	Other Land

MAPBIOMAS 30M LAND COVER CLASSES	ABC-MAP LAND USE	GLOBIO 3.5 LAND USE	MSA 3.5	NATURAL/ARTIFICIAL	IPCC CLASSES
Rocky outcrop	Other Land - Other Land	Bare area	1	Natural	Other Land
Herbaceous sand vegetation	Grassland - Natural	Natural grassland	1	Natural	Grassland
Other non forest formation	Grassland - Natural	Natural grassland	1	Natural	Grassland
Steppe	Grassland - Natural	Natural grassland	1	Natural	Grassland
Shrubland	Forest - Shrubland + High Integrity	Forest - Natural	1	Natural	Forest, shrubland
	Forest - Shrubland + Medium Integrity	Forest - Reduced Impact Logging	0.85		
	Forest - Shrubland + Low Integrity	Forest - Selective logging (Lightly used forest)	0.12		
Agricultural and livestock area	Cropland, annual - full tillage + medium input	Intensive cropland	0.1	Artificial	Cropland, annual
Pasture	Grassland - High intensity grazing	Pasture – moderately to intensively used	0.6	Artificial	Grassland
Cropland	Cropland, annual - full tillage + medium input	Intensive cropland	0.1	Artificial	Cropland, annual
Forest plantation	Forest - Plantation	Forest - Plantation	0.3	Artificial	Forest
Palm oil	Cropland, perennial - Monoculture, Oil palm + full tillage + medium input	Intensive cropland	0.1	Artificial	Cropland, perennial
Mosaic of agriculture and pasture	Cropland, annual - full tillage + medium input	Intensive cropland	0.1	Artificial	Cropland, annual
Shrub plantation	Forest - Plantation	Forest - Plantation	0.3	Artificial	Forest

MAPBIOMAS 30M LAND COVER CLASSES	ABC-MAP LAND USE	GLOBIO 3.5 LAND USE	MSA 3.5	NATURAL/ARTIFICIAL	IPCC CLASSES
Temporary crop	Cropland, annual - full tillage + medium input	Intensive cropland	0.1	Artificial	Cropland, annual
Soybean	Cropland, annual - full tillage + medium input	Intensive cropland	0.1	Artificial	Cropland, annual
Sugar cane	Cropland, annual - full tillage + medium input	Intensive cropland	0.1	Artificial	Cropland, annual
Rice	Cropland, flooded rice	Irrigated cropland	0.05	Artificial	Flooded rice
Cotton (beta)	Cropland, annual - full tillage + medium input	Intensive cropland	0.1	Artificial	Cropland, annual
Other temporary crops	Cropland, annual - full tillage + medium input	Intensive cropland	0.1	Artificial	Cropland, annual
Perennial crop	Cropland, perennial - Monoculture, Orchard + full tillage + medium input	Woody biofuels and perennial crops	0.3	Artificial	Cropland, perennial
Coffee	Cropland, perennial - Monoculture, Orchard + full tillage + medium input	Woody biofuels and perennial crops	0.3	Artificial	Cropland, perennial
Citrus	Cropland, perennial - Monoculture, Orchard + full tillage + medium input	Woody biofuels and perennial crops	0.3	Artificial	Cropland, perennial
Other perennial crops	Cropland, perennial - Monoculture, Orchard + full tillage + medium input	Woody biofuels and perennial crops	0.3	Artificial	Cropland, perennial
Non-vegetated area	Other Land - Other Land	Bare area	1	Natural	Other Land
Beach, dune and sand spot	Other Land - Other Land	Bare area	1	Natural	Other Land
Infrastructure	Settlement - Settlement	Urban areas	0.05	Artificial	Settlement

MAPBIOMAS 30M LAND COVER CLASSES	ABC-MAP LAND USE	GLOBIO 3.5 LAND USE	MSA 3.5	NATURAL/ ARTIFICIAL	IPCC CLASSES
Mining	Other Land - Other Land	Urban areas	0.05	Artificial	Other Land
Other non-vegetated area (anthropic)	Other Land - Other Land	Bare area	1	Artificial	Other Land
Salt flat	Other Land - Other Land	Bare area	1	Natural	Other Land
Other non vegetated natural area	Other Land - Other Land	Bare area	1	Natural	Other Land
Water body	Other Land - Water	Bare area	1	Natural	Other Land
River, lake or ocean	Other Land - Water	Bare area	1	Natural	Other Land
Aquaculture	Other Land - Water	Bare area	1	Artificial	Other Land
Glacier	Other Land - Other Land	Bare area	1	Natural	Other Land
Not observed	n/a	n/a	n/a	n/a	n/a

Source: Authors' own elaboration.

Annex II – Definitions of IPCC land use categories, as used in ABC-Map

Table A2.1. Land use categories

FOREST LAND	A minimum area of land of 0.05 – 1.0 hectares with tree crown cover (or equivalent stocking level) of more than 10 – 30 percent with trees with the potential to reach a minimum height of 2 – 5 metres at maturity in situ. A forest may consist either of closed forest formations where trees of various storeys and undergrowth cover a high portion of the ground or open forest. Young natural stands and all plantations which have yet to reach a crown density of 10 – 30 percent or tree height of 2 – 5 metres are included under forest, as are areas normally forming part of the forest area which are temporarily unstocked as a result of human intervention such as harvesting or natural causes, but which are expected to revert to forest.
CROPLAND	Cropped land, including rice fields, and agro-forestry systems where the vegetation structure falls below the thresholds used for the Forest Land category.
GRASSLAND	Rangelands and pastureland that are not considered Cropland. It also includes systems with woody vegetation and other non-grass vegetation such as herbs and brushes that fall below the threshold values used in the Forest Land category. The category also includes all grassland from wild lands to recreational areas.
WETLAND	Areas of peat extraction and land that is covered or saturated by water for all or part of the year (peatlands and other wetland types) and that does not fall into the Forest Land, Cropland, Grassland or Settlements categories. Unlike the IPCC definition, in ABC-Map reservoirs and natural rivers and lakes are not defined under wetlands, but as “Other Land, Water”.
SETTLEMENT	All developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other categories. It includes soils, herbaceous perennial vegetation such as turf grass and garden plants, trees in rural settlements, homestead gardens and urban areas. This should be consistent with national definitions.
OTHER LAND	Bare soil, rock, ice, and all land areas that do not fall into any of the other five categories including water bodies (including reservoirs, natural rivers and lakes). It allows the total of identified land areas to match the national area, where data are available.

Source: Adapted from IPCC, 2019.

Forest Land

Table A2.2. Forest Land subcategories

FOREST PLANTATION	Forest stands established by planting or/and seeding in the process of afforestation or reforestation. They are either of introduced species (all planted stands), or intensively managed stands of indigenous species, which meet all the following criteria: one or two species at planting, even age class, and regular spacing.
NATURAL FOREST	A forest composed of indigenous trees and not classified as a forest plantation.
SHRUBLAND	Shrublands with high proportions of perennial woody biomass, generally more than 0.5 meters and less than 5 meters in height at maturity and without definite crown.

Source: Adapted from IPCC, 2019.

Table A2.3. Forest Integrity

LOW INTEGRITY	Heavily modified and often internally fragmented ecosystems dominated by trees, including (i) naturally regenerated forests, either in the interior of blocks or at edges, that have experienced multiple strong human pressures, which may include frequent stand-replacing events, sufficient to greatly simplify the structure and species composition and possibly result in significant presence of non-native species, (ii) tree plantations and, (iii) agroforests; in all cases key ecosystem functions such as carbon storage, biodiversity, watershed protection and resilience expected to be well below natural levels (excluding any effects from climate change).
MEDIUM INTEGRITY	Interiors and natural edges of naturally regenerated forest ecosystems in blocks smaller than their natural extent but large enough to have some core areas free from strong anthropogenic edge effects (e.g., set-asides within forestry areas, fragmented protected areas), dominated by native species but substantially modified by humans through a diversity of processes that could include fragmentation, creation of edges and proximity to infrastructure, moderate or high levels of extraction of plant and animal products, significant timber removals, scattered stand-replacement events such as swidden and/or moderate changes to fire and hydrological regimes; key ecosystem functions such as carbon storage, biodiversity, watershed protection and resilience expected to be somewhat below natural levels (excluding any effects from climate change).

HIGH INTEGRITY	Interiors and natural edges of more or less unmodified naturally regenerated (i.e., non-planted) forest ecosystems, comprised entirely or almost entirely of native species, occurring over large areas either as continuous blocks or natural mosaics with non-forest vegetation; typically little human use other than low-intensity recreation or spiritual uses and/or low-intensity extraction of plant and animal products and/or very sparse presence of infrastructure; key ecosystem functions such as carbon storage, biodiversity, and watershed protection and resilience expected to be very close to natural levels (excluding any effects from climate change) although some declines possible in the most sensitive elements (e.g., some high value hunted species).
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Note: Forest integrity is only applied to the forest subcategories Natural Forest and Shrubland.
Source: Adapted from Grantham et al., 2020.

Cropland

Table A2.4. Cropland subcategories

FLOODED RICE	Irrigated or continuously flooded, lowland rice ecosystems. Upland rice is cultivated on fields that are never flooded for a significant period. Upland rice is therefore treated as annual cropland.	
ANNUAL	Cropped land that is sowed or planted at least once within a 12-month period.	
PERENNIAL	Land used for crops that are harvested multiple times over successive years without the need for annual replanting. Includes agro-forestry systems where the vegetation structure falls below the thresholds used for the Forest Land category.	
	Fallow	Land rested from cultivation, but comprises planted and managed trees, often leguminous, shrubs and herbaceous cover crops before it is cultivated again. Includes improved and natural fallows and can be implemented before any of the following systems.
	Perennial Hedgerow	Linear plantation around fields, including shelterbelts, windbreaks, boundary plantings and live fences.
	Alley cropping	Fast-growing, usually leguminous, woody species (mainly shrubs) grown in crop fields, usually at high densities. The woody species are regularly pruned and the prunings are applied as mulch into the alleys as a source of organic matter and nutrients. Also known as intercropping.

PERENNIAL	Multistrata	Multistorey combinations of a large number of various trees and perennial and annual crops. They include home gardens and agroforests.
	Parkland	Intercropping of agricultural crops or grazing land under low density mature scattered trees. Typical of dry areas like Sahel (e.g. <i>Faidherbia albida</i>).
	Shaded perennial	Growing shade-tolerant species such as cacao and coffee under, or in between, overstorey shade trees that can be used for timber or other commercial tree products.
	Silvoarable	Woody species planted in parallel tree rows to allow mechanization and intercropped with an annual crop; usually used for timber (e.p. <i>Juglans</i> spp.), but also for fuel (e.p. <i>Populus</i> spp.). Usually low tree density per hectare.
	Silvopastoral	Woody species planted on permanent grasslands, often grazed.
	Monoculture, oil palm	Monoculture plantation of oil palms.
	Monoculture, olive	Monoculture plantation of olive trees.
	Monoculture, rubber hevea	Monoculture plantation of Rubber Hevea.
	Monoculture, short rotation coppice	Coppice grown as energy crop (e.g. fuelwood).
	Monoculture, tea camelia	Monoculture plantation of tea (<i>Camellia</i>).
	Monoculture, vine system	A plantation of vines, typically producing grapes used for winemaking, but also other crops such as kiwifruit or passionfruit.
	Monoculture, orchard	Land planted with woody vegetation, often fruit trees (e.g. apple, pear, plum, nut trees). Understory vegetation is usually mowed or grazed.

Source: Adapted from Table 5.3 and Table 5.4 IPCC, 2019.

Table A2.5. Management activities in Cropland

MANAGEMENT	DESCRIPTION
Low input	Low residue return occurs when there is removal of residues (via collection or burning), frequent bare-fallowing, production of crops yielding low residues (e.g., vegetables, tobacco, cotton), no mineral fertilization or nitrogen-fixing crops.
Medium input	Annual cropping with cereals where all crop residues are returned to the field. If residues are removed then supplemental organic matter (e.g., manure) is added. Also requires mineral fertilization or nitrogen-fixing crop in rotation.
High input without manure	Significantly greater crop residue inputs over medium carbon input cropping systems due to additional practices, such as production of high residue yielding crops, use of green manures, cover crops, improved vegetated fallows, irrigation, frequent use of perennial grasses in annual crop rotations, but without manure applied (see “high input with manure” below).
High input with manure	Represents significantly higher carbon input over medium carbon input cropping systems due to an additional practice of regular addition of animal manure.
Full tillage	Substantial soil disturbance with full inversion and/or frequent (within year) tillage operations. At planting time, little (less than 30 percent) of the surface is covered by residues.
Reduced tillage	Primary and/or secondary but reduced soil disturbance (usually shallow and without full soil inversion). Normally leaves surface with more than 30 percent coverage by residues at planting.
No tillage	Direct seeding without primary tillage, with only minimal soil disturbance in the seeding zone. Herbicides are typically used for weed control.

Source: Adapted from Table 5.5, IPCC, 2019.

Grassland

Table A2.6. Grassland management

IMPROVED - MEDIUM INPUT	Grassland which is sustainably managed with light to moderate grazing pressure (or cutting and removal of vegetation) and that receives one improvement (e.g., fertilization, species improvement, irrigation).
IMPROVED - HIGH INPUT	Grassland which is sustainably managed with light to moderate grazing pressure (or cutting and removal of vegetation) and that receives more than one improvement (e.g., fertilization, species improvement, irrigation).
NOMINAL / NATIVE	Low or medium intensity grazing regimes, in addition to periodic cutting and removal of above-ground vegetation, without significant management improvements.
HIGH INTENSITY GRAZING	Represents high intensity grazing systems (or cutting and removal of vegetation) with shifts in vegetation composition and possibly productivity but is not severely degraded. High intensity grazing may be moderately degraded, but do not represent excessive grazing intensity that leads to severe grassland degradation
SEVERELY DEGRADED	Major long-term loss of productivity and vegetation cover, due to severe mechanical damage to the vegetation and/or severe soil erosion.

Source: Adapted from Table 6.2, IPCC, 2019.

Wetlands

Table A2.7. Wetlands subcategories

MANGROVE	Coastal wetland with trees.
FOREST	Wetlands containing forests as defined in Table A1.1
CROPLAND, ANNUAL	Wetland containing annual cropland as defined in Table A1.1
PERENNIAL CROPLAND, MONOCULTURE	Wetland containing perennial monoculture as defined in Table A1.1
PERENNIAL CROPLAND, AGROFORESTRY	Wetland containing perennial cropland as defined in Table A1.1
GRASSLAND	Wetland containing grassland as defined in Table A1.1

Source: Authors' own elaboration based on IPCC, 2013.

Table A2.8. Wetlands Integrity

See **Table A1.3** - Forest Integrity

Note: The integrity index is only applied to the wetland subcategories Forest and Mangroves

Settlements

Table A2.9. Settlement subcategories

URBAN GREEN	Woodland, turfgrass (lawns and golf courses), cultivated soils (gardens and horticulture) in an urban setting.
SETTLEMENT	All settlement land uses that do not fall under Urban Green.

Source: Adapted from IPCC, 2019.

Other land

Table A2.10. Other Land subcategories

WATER	Water bodies (including reservoirs, natural rivers and lakes).
OTHER LAND	Bare soil, rock, ice, and all land areas that do not fall into any other land use categories.

Source: Adapted from IPCC, 2019.

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