



PBL Netherlands Environmental
Assessment Agency



**Providing biodiversity information to
a broad audience**

TECHNICAL DOCUMENTATION OF THE
GLOBIOWEB DATASETS

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Colophon

Technical documentation of the GLOBIOWeb datasets

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1 Introduction

The GLOBIO model has a long standing of use in global assessments of human impact on biodiversity and for exploring possible biodiversity futures under various scenarios. GLOBIO is developed and managed by the PBL Netherlands Environmental Assessment Agency in collaboration with research groups at various universities.

To ensure the transparency of the modelling and to support open data policies and FAIR data principles, the GLOBIO project is developing various initiatives to improve sharing of knowledge and data with a broader audience. Dissemination takes place via technical model descriptions, scientific publications, and publicly accessible repositories of model code and outputs (data). The GLOBIO4 modelling code is written in Python, uses open source software and is publicly available in Github and can be found here: <https://github.com/GLOBIO4/GlobioModelPublic>. The documentation of the modelling code and software requirements can be found here: <https://github.com/GLOBIO4/GlobioModelPublic/wiki>

The GLOBIOWeb-tool is developed to provide online and easy access to GLOBIO model output maps and indicators as derived for the period 1992 – 2020 and for three scenarios projected to 2050. The GLOBIOWeb-tool provides a timely answer to the need for scientifically sound information on relevant indicators of biodiversity that is publicly available and can be used by a broad audience, including non-experts. This also relates to the development of a broad indicator framework on biodiversity, supporting the implementation of the new CBD post-2020 global biodiversity framework, as well as to the many global state and non-state actor initiatives that aim to assess and monitor changes in biodiversity in their countries, regions, catchments, landscapes.

This report provides the technical documentation of the data available via the GLOBIOWeb-tool. As the scenario data for 2050 are described elsewhere (Schipper et al. 2020), this report focuses on the 1992-2020 time series. Following this introduction, the second chapter starts with a description of the GLOBIOWeb land use time series and the implementation of the GLOBIO4 land use allocation module. The third chapter describes the inputs used to derive the various GLOBIO4 biodiversity impacts. The fourth chapter outlines the various maps produced for the GLOBIOWeb tool and the indicators on changes in biodiversity presented in the GLOBIOWeb-tool.

2 The GLOBIOWeb land-use time series

This section describes the methodology applied to create the 1992-2020 land-use time series for the GLOBIOWeb application. The section also provides a detailed overview of the various steps in the GLOBIO4 land-use allocation module.

2.1 GLOBIOWeb land use classes

Spatial information on land use and land cover (LULC) is an essential element for assessing potential impacts on biodiversity and therefore a core input of the GLOBIO4 model. The Climate Change Initiative (CCI) of the European Space Agency (ESA) has made available a land-cover time series dataset with a consistent and also broad classification for the period 1992 up to 2020 (ESA-CCI, 2021). This dataset has been used as a starting point for LULC projections towards the year 2050 in various recent scenario studies with the GLOBIO4 model (Schipper et al., 2020; Kok et al., 2022).

To assess the impacts of human land use on biodiversity, the GLOBIO4 model uses its own LULC classification. This classification as used in GLOBIOWeb largely follows the ESA-CCI legend, but adds several classes on land-use intensity, specifically for cropland and grazing activities, and information on forestry plantations. To ensure flexibility for adding new classes in the future (e.g. different types of urban areas and forestry, or mining), human land-use classes are grouped by tens (1, 10, 20, etc.). The land use/cover classification used is shown in Table 2.1, together with the corresponding ESA-CCI codes.

Table 2.1: LULC classification applied in GLOBIOWeb and corresponding ESA-CCI codes

Code	GLOBIO4 LULC description	ESA-CCI LC code
0	No data/Undefined	0
1	Urban-settlement	190
10	Cropland	10, 11, 12, 20
11	Cropland intensive use	(*)
12	Cropland minimal use	(*)
13	Mosaic cropland (>50%) / natural vegetation (tree shrub herbaceous cover) (<50%)	30
14	Mosaic natural vegetation (tree shrub herbaceous cover) (>50%) / cropland (<50%)	40
20	Grazing	(*)
21	Intensive pastures	(*)
22	Extensive rangelands	(*)
30	Forestry	(*)
40	Secondary vegetation	(*)
50	Tree cover broadleaved evergreen closed to open (>15%)	50

Code	GLOBIO4 LULC description	ESA-CCI LC code
60	Tree cover broadleaved deciduous closed to open (>15%)	60
61	Tree cover broadleaved deciduous closed (>40%)	61
62	Tree cover broadleaved deciduous open (15-40%)	62
70	Tree cover needleleaved evergreen closed to open (>15%)	70
71	Tree cover needleleaved evergreen closed (>40%)	71
72	Tree cover needleleaved evergreen open (15-40%)	72
80	Tree cover needleleaved deciduous closed to open (>15%)	80
81	Tree cover needleleaved deciduous closed (>40%)	81
82	Tree cover needleleaved deciduous open (15-40%)	82
90	Tree cover mixed leaf type (broadleaved and needleleaved)	90
100	Mosaic tree and shrub (>50%) / herbaceous cover (<50%)	100
110	Mosaic herbaceous cover (>50%) / tree and shrub (<50%)	110
120	Shrubland	120
121	Shrubland evergreen	121
122	Shrubland deciduous	122
130	Natural grassland	130
140	Lichens and mosses	140
150	Sparse vegetation (tree shrub herbaceous cover) (<15%)	150
151	Sparse tree (<15%)	151
152	Sparse shrub (<15%)	152
153	Sparse herbaceous cover (<15%)	153
160	Tree cover flooded fresh or brackish water	160
170	Tree cover flooded saline water	170
180	Shrub or herbaceous cover flooded fresh/saline/brackish water	180
200	Bare areas	200
201	Consolidated bare areas	201
202	Unconsolidated bare areas	202
210	Water bodies	210
220	Permanent snow and ice	220

(*) The classes are not present in the ESA-CCI LULC maps. These GLOBIO4 land use classes are derived from the GLOBIO4 land use allocation module that adds information on land use intensity for cropland and grazing, adds forestry plantations and classifies abandoned human land use areas as secondary vegetation.

The classification in Table 2.1 reflects the classification used for the GLOBIOWeb time series for the years 1992 – 2020 and aims to stay closely to the ESA-CCI land cover data. For future scenario analyses additional groupings might be made (e.g. relating to the mixed cropland/nature classes as part of the total cropland area) based on specific scenario story lines (e.g. relating land sparing or land sharing, or scenarios focusing on landscape restoration policies).

2.2 The GLOBIO4 land-use module

The GLOBIO4 land-use allocation module was developed to provide a highly flexible method for producing biodiversity-relevant LULC maps. For producing the GLOBIOweb datasets the settings that were used in the overall modelling environment and the steps shown in Figure 2.1 are described below.

Land use allocation modelling code availability and Wiki

The GLOBIO4 modelling code is based on open source software and is publicly available in Github.

The specific code for the land use allocation module can be found here:

- https://github.com/GLOBIO4/GlobioModelPublic/blob/main/Calculations/GLOBIO_CalcDiscreteLanduseAllocationScenSuitIntensity.py

The documentation for the land use allocation module code can be found here:

- <https://github.com/GLOBIO4/GlobioModelPublic/wiki/Land-Use-Allocation-module>

The .glo file used to run the land allocation module for the year 2020 is included as an example for reference in the Annex 1.

Spatial resolution and extent of the GLOBIOweb data

The GLOBIO4 model uses a WGS84 coordinate system. The GLOBIO4 model is flexible in using custom defined spatial resolution, indicated by the raster cell size, and spatial extent as indicated by the 4 coordinates defining the windows of analyses. As the GLOBIOweb data builds on the ESA CCI land cover maps, the spatial resolution is 10 arc-seconds, which resembles raster cells of 300 x 300 meter around the equator and decreasing in area towards the poles. For GLOBIOweb the spatial extent is set to -180, -90, 180, 90, with units in digital degrees indicating a global extent in terms of the WGS84 coordinate system. All spatial raster data layers are in GeoTIFF format.

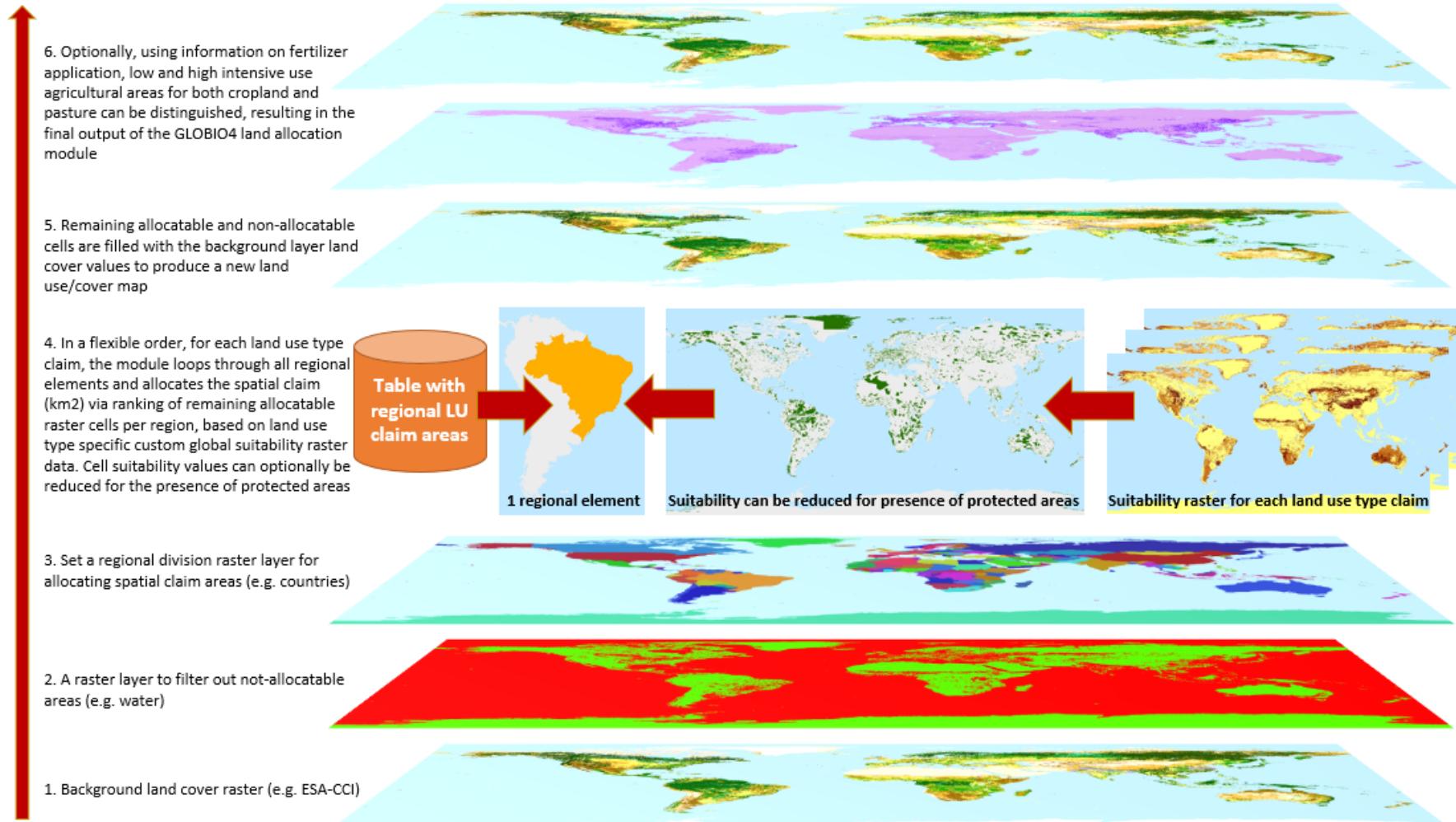
Timesteps during the 1992-2020 period

The ESA-CCI project provides land cover data for every year during the 1992-2020 period. For deriving the impacts on biodiversity, the GLOBIO4 model is also dependent on additional data sources, which do not have an annual temporal resolution. Hence for the GLOBIOweb time series, the years 1992, 1995, 2000, 2005, 2010, 2015 and 2020 were selected. The tool itself is flexible, so additional years can easily be added when data becomes available.

Land-use claims to be allocated for GLOBIOweb: grazing and forestry

The GLOBIO4 land-use allocation module is flexible in allocating any number and type of land-use claims, as this mainly depends on regional claim area statistics, rasterized information on suitability for each land use type and available allocatable land area in the claim region. For example, in future scenario analyses there are often spatial claims for urban, cropland, grazing and forestry areas with corresponding suitability raster layers. For GLOBIOweb the 1992-2020 time period, information on urban and cropland areas is based on the ESA-CCI data, and GLOBIOwebclaims were allocated only for grazing and forestry land. This is further described in the next section 2.3.

Figure 2.1: overview of steps in the GLOBI04 land-use allocation module



2.3 Application of the land-use module

Figure 2.1 illustrates the general allocation procedure. The various steps are described in this section.

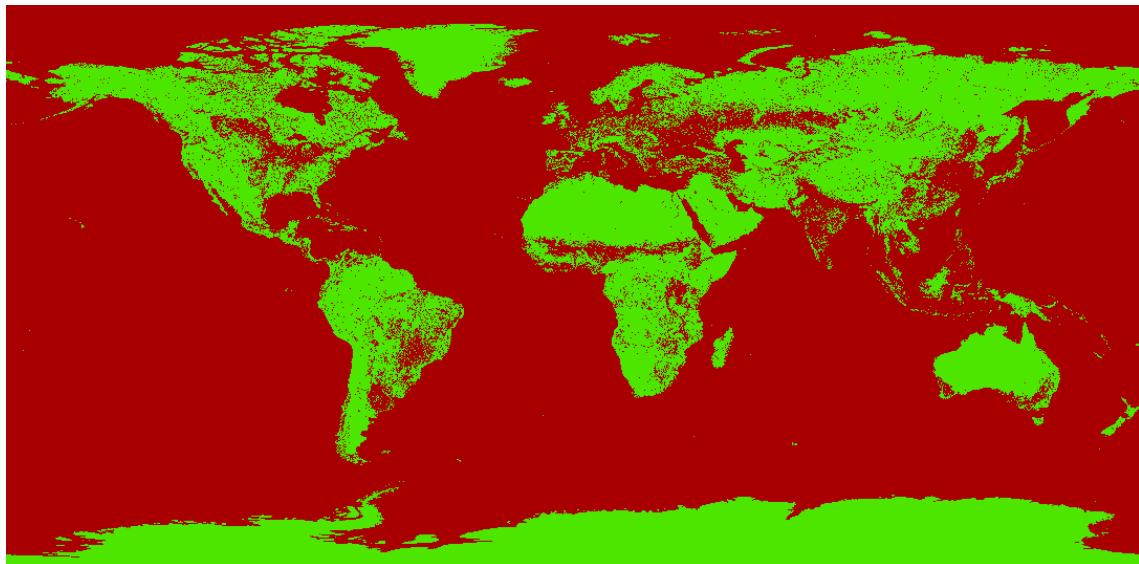
Step 1: the background land-cover rasters

For each time step during the 1992 -2020 period, the GLOBI04 LULC data for that year, based on the reclassified ESA-CCI land cover dataset (described in Table 2.1), was used as a background.

Step 2: defining not-allocatable areas: water plus urban and cropland areas

The not-allocatable areas raster layer distinguishes raster cells that are available for allocating land use claims from those that are not (Figure 2.2). This layer needs to be an integer raster with the values 0 (allocatable) and 1 (not allocatable).

Figure 2.2: example of a global division of allocatable (green) and not-allocatable (red) areas as used in GLOBI0web in 2020, where in this case urban and cropland areas are also considered not-allocatable



At the end of the allocation procedure, the not-allocatable raster cells will receive the value of the background raster defined in step 1. Because for the GLOBI0web 1992-2000 time series the urban and cropland extents follow the spatial patterns from the ESA-CCI data, which represent the situation for the selected recent years, no urban and cropland claims are being allocated.

Therefore, the not-allocable raster layer for each modelled year was derived as follows:

- Not-allocatable: urban (1), cropland (10-14) and water bodies (210)
- Allocatable: all other values from the GLOBI04 LULC data (Table 2.1)

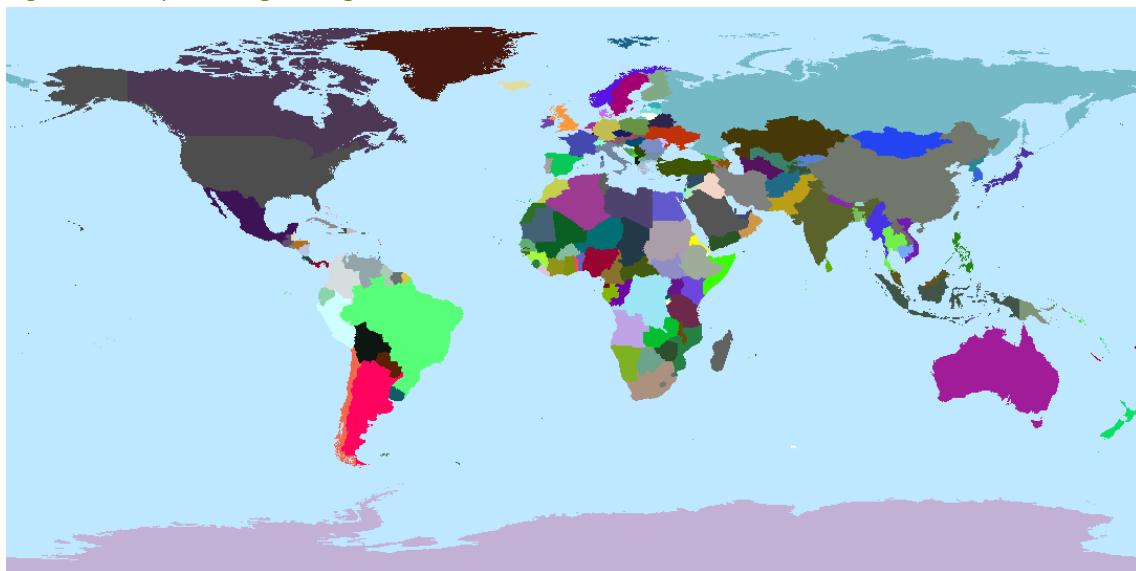
The resulting layers thus define for each selected year in the time series the raster cells available for allocating grazing and forestry claims.

Step 3: regional division raster: countries

The GLOBI04 land-use allocation needs a raster layer that delineates the regions corresponding with the spatial claim statistics. As the GLOBI0web spatial claim information for forestry and

grazing was based on country-level data (see below), a country level regional division layer was obtained from vector data from the GADM database, version 3.6 (GADM, 2021). The vector layer was converted to a 10 arc-seconds raster layer with the extent matched to the spatial extent of the land area in the GLOBO4 LULC map (Figure 2.3). For consistency within the time series, the same region layer was used for the whole 1992-2020 period.

Figure 2.3: map showing the regional division in countries used in GLOBIOWeb



Step 4: spatial allocation of country-level land-use claims

This step is the core of the GLOBO4 land allocation module as it brings all the elements together. For each land-use type that needs to be allocated, the module loops through all the user-defined regions (in this case, countries; Figure 2.3) and uses so-called suitability raster layers to allocate available raster cells in order of decreasing suitability until the spatial claim area for the specific land-use type is fulfilled. The suitability rasters need to be a floating type raster with values between 0-1, with larger values indicating higher suitability. The order of the land-use types needs to be defined upfront such that cells allocated to a certain type are no longer available for the next type. In general, the following order is used in GLOBO: urban, cropland, forestry, grazing (Schipper et al. 2020). For the GLOBIOWeb 1992-2020 time series, only forestry and grazing were allocated. As spatial land use type claims are in km² and the model works in a WGS84 coordinate system that uses digital degrees for cell sizes, the GLOBO4 land-use allocation module applies a global raster layer that provides the area in km² of each 10 arc second raster cell, to make sure the correct areas are allocated.

Below, first the spatial claims are described, followed by the suitability layers used in this step.

Forestry claim per region and year

Forestry area claims were retrieved from the FAO Global Forest Resource Assessment (FRA) database (FAO, 2021a) based on data on plantation forest for the 1990 – 2020 period. The FRA database describes plantation forest as “planted forest that is intensively managed and meet all the following criteria at planting and stand maturity: one or two species, even age class, and regular spacing. Additionally, it specifically includes: short rotation plantation for wood, fibre and energy. It specifically excludes: forest planted for protection or ecosystem restoration and forest

established through planting or seeding which at stand maturity resembles or will resemble naturally regenerating forest". The original FRA data were converted from hectares to km². As the years 1995 and 2005 were missing in the FRA time series, these were derived as the average of the preceding and following years (+/- 5 years). For 1992, FRA data from 1990 were used. All country level forestry plantation claim areas are provided in Annex 3.

Grazing claim per region and year

The grazing area claims per country were derived from the FAO FAOSTAT database (FAO, 2021b) in July 2021. Claims were based on the annual country-level information on "land under permanent and temporary meadows and pastures" in units of 1000 ha for the time period of 1990-2020. The data were matched with the country raster layer and converted to values in km². To deal with large fluctuations in grazing area in the FAOSTAT time series, the annual data availability allowed us to calculate 3-year averages centred on each GLOBIOWeb timestep. For 2020, the average of the 2018-2020 data was used. All country-level grazing claims are provided in Annex 3.

Where needed, the claims for both forestry and grazing were splitted or merged in order to align with the country map (Figure 2.3), for example claims reported for the former Yugoslavian Republic or claims relating to Sudan and South Sudan. Where possible and depending on the information in the source data, older aggregated claims were splitted and attributed to 'new' countries based on the more recent individual country values. The list of countries and their spatial claims for grazing and forestry are included in Annex 3.

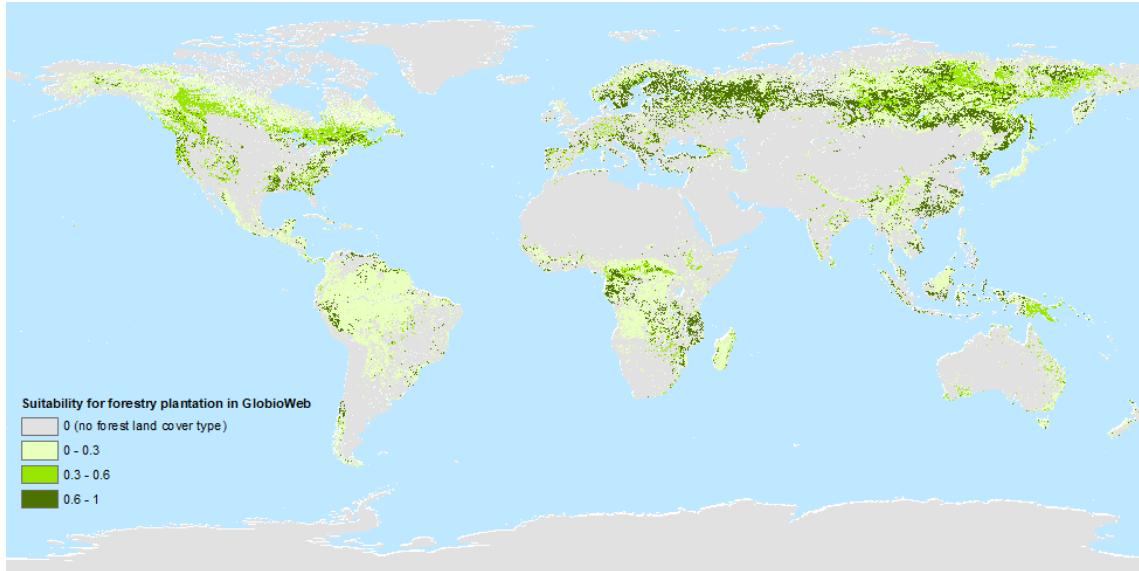
Forestry suitability layer

The suitability layer for forestry was established according to Schipper et al. (2020), where it is assumed that accessibility to wood is primarily determined by elevation, proximity to infrastructure, and area protection measures (FAO, 2000). In Schipper et al. (2020) the proximity to infrastructure was calculated as the Euclidian distance to roads or, in South-America, to either roads or rivers (FAO, 2000). A roads map was retrieved from PBL's GRIP database (Meijer et al., 2018) and the rivers were delineated using the Digital Chart of the World (DCW, 1996) and the Global Lakes and Wetland Database (GLWD, 2004). Distances were inverted and normalized, and multiplied with inverted and normalized elevation values to arrive at suitability values between 0 and 1. For each year in the GLOBIOWeb time series, the suitability layer was clipped to land cover with trees according to the respective LULC map (classes 50-110; Table 2.1). As an additional step compared to the suitability raster as described in Schipper et al. (2020), the GLOBIOWeb forestry suitability layer was updated with a forest use map from Schulze et al. (2018), which distinguishes forest areas used for production, multiple uses and other/no use. Each forest use class was given a forestry plantation preference value (see Table 2.2), the resulting forestry plantation preference scores were summed to the initial forestry suitability raster layers, and the resulting raster layers, with values ranging from 0 to 3, were then again normalized to arrive at suitability values between 0 and 1 (Figure 2.3; Figure 2.4).

Table 2.2: forest use classes (Schulze et al. (2018) and forestry plantation preference values

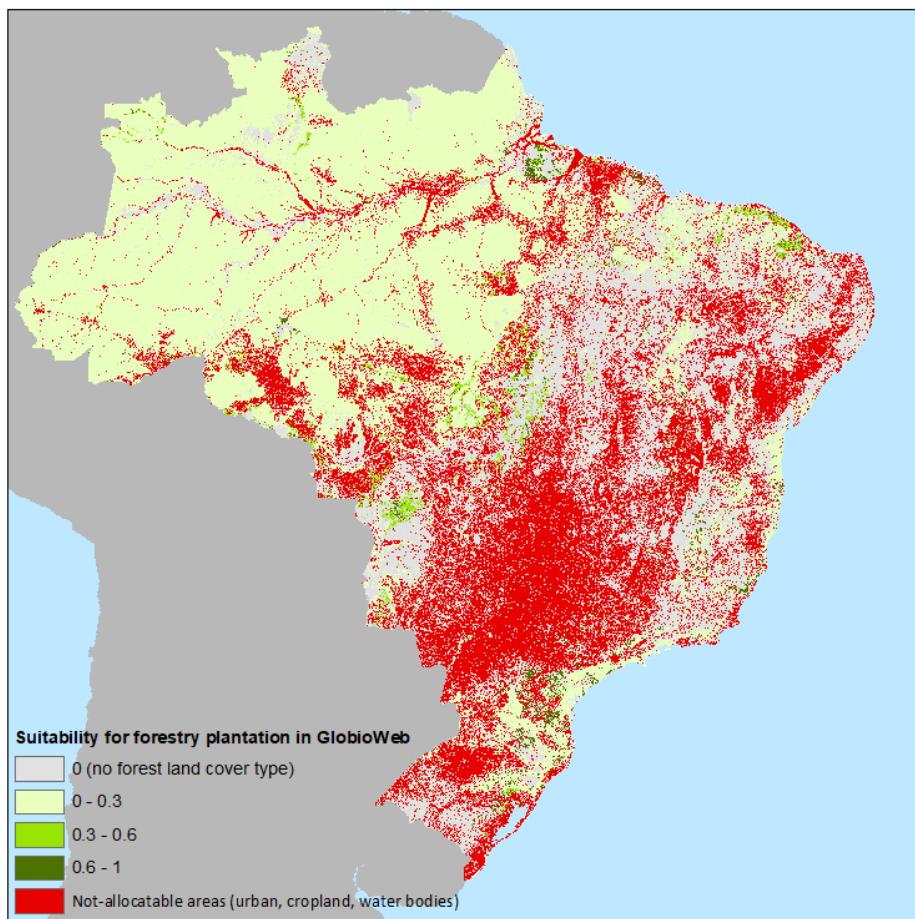
Forest use classes	Forestry plantation preference value
Primarily used for production	2
Multiple uses	1
Other/no use	0
Unclassified use	0

Figure 2.3: forestry plantation suitability layer for the year 2020



The availability of raster cells is based on the not-allocatable raster layer (defined in step 2, Figure 2.1) and the raster cells already allocated to other land use types in the allocation sequence. Figure 2.4 shows this in more detail as an example for Brazil.

Figure 2.4: forestry plantation suitability for allocatable areas in Brazil in 2020



Grazing suitability layer

The global grazing area suitability raster layer was created building on Schipper et al. (2020), where suitability was inferred from the density of grazing livestock species (Robinson et al., 2014), which was retrieved from FAO's gridded livestock of the world (GLW) dataset (resolution of 30 arc-seconds; <https://livestock.geo-wiki.org/download/>). From this dataset densities of three ruminant livestock species (cattle, goat, sheep) were selected, heads were converted to so-called tropical livestock units (TLU) by assuming that goat/sheep = 0.1 TLU and cattle = 0.6 TLU per individual (Petz et al., 2014). The TLUs per grid were summed and the resulting values were normalized to achieve suitability values ranging from 0 to 1. However, as the FAO GLW data has a coarser resolution than the 10 arc-second GLOBIO4 LULC raster, the same suitability value is assigned to all 10 arc-seconds LULC cells within a given 30 arc-seconds GLW cell, irrespective of the land cover. To adapt grazing allocation to the spatial detail of the LULC map, the suitability layer was adjusted to reflect that livestock grazing is more likely in certain land cover types (like grasslands, sparse vegetation and shrublands) compared to other types (like urban, bare and snow/ice covered areas), in line with Robinson et al. (2014). To that end, grazing preferences were assigned to the land cover categories in the background map of each time step (Table 2.3) and the resulting grazing preference raster layers were summed with the initial suitability raster. The resulting raster layers, containing values between 0-4, were again normalized between 0-1. These layers (see Figure 2.5, Figure 2.6) were used as the suitability raster layers for allocating the grazing area claims per country.

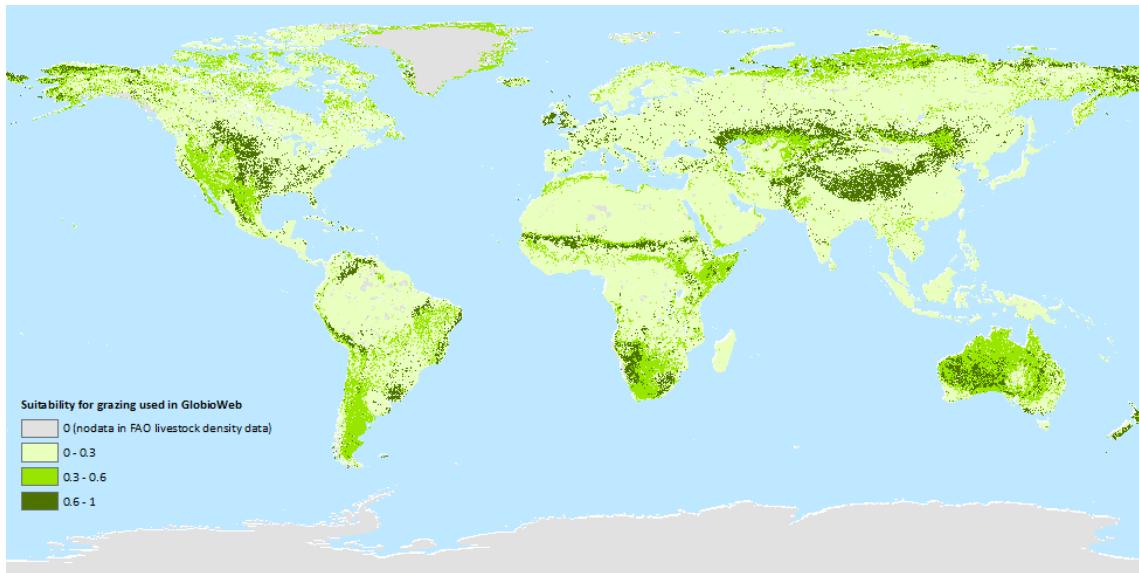
Table 2.3: GLOBIO4 LULC and grazing allocation preference values

Code	Description	Grazing preference value
0	No data/Undefined	0
1	Urban-settlement	0
10	Cropland	0
11	Cropland intensive use	(*)
12	Cropland minimal use	(*)
13	Mosaic cropland (>50%) / natural vegetation (tree shrub herbaceous cover) (<50%)	0
14	Mosaic natural vegetation (tree shrub herbaceous cover) (>50%) / cropland (<50%)	0
20	Grazing	(*)
21	Intensive pastures	(*)
22	Extensive rangelands	(*)
30	Forestry	(*)
40	Secondary vegetation	(*)
50	Tree cover broadleaved evergreen closed to open (>15%)	0
60	Tree cover broadleaved deciduous closed to open (>15%)	0
61	Tree cover broadleaved deciduous closed (>40%)	0
62	Tree cover broadleaved deciduous open (15-40%)	0
70	Tree cover needleleaved evergreen closed to open (>15%)	0
71	Tree cover needleleaved evergreen closed (>40%)	0
72	Tree cover needleleaved evergreen open (15-40%)	0
80	Tree cover needleleaved deciduous closed to open (>15%)	0
81	Tree cover needleleaved deciduous closed (>40%)	0
82	Tree cover needleleaved deciduous open (15-40%)	0

Code	Description	Grazing preference value
90	Tree cover mixed leaf type (broadleaved and needleleaved)	0
100	Mosaic tree and shrub (>50%) / herbaceous cover (<50%)	0
110	Mosaic herbaceous cover (>50%) / tree and shrub (<50%)	1
120	Shrubland	2
121	Shrubland evergreen	2
122	Shrubland deciduous	2
130	Natural grassland	3
140	Lichens and mosses	1
150	Sparse vegetation (tree shrub herbaceous cover) (<15%)	2
151	Sparse tree (<15%)	2
152	Sparse shrub (<15%)	2
153	Sparse herbaceous cover (<15%)	2
160	Tree cover flooded fresh or brackish water	0
170	Tree cover flooded saline water	0
180	Shrub or herbaceous cover flooded fresh/saline/brackish water	0
200	Bare areas	0
201	Consolidated bare areas	0
202	Unconsolidated bare areas	0
210	Water bodies	0
220	Permanent snow and ice	0

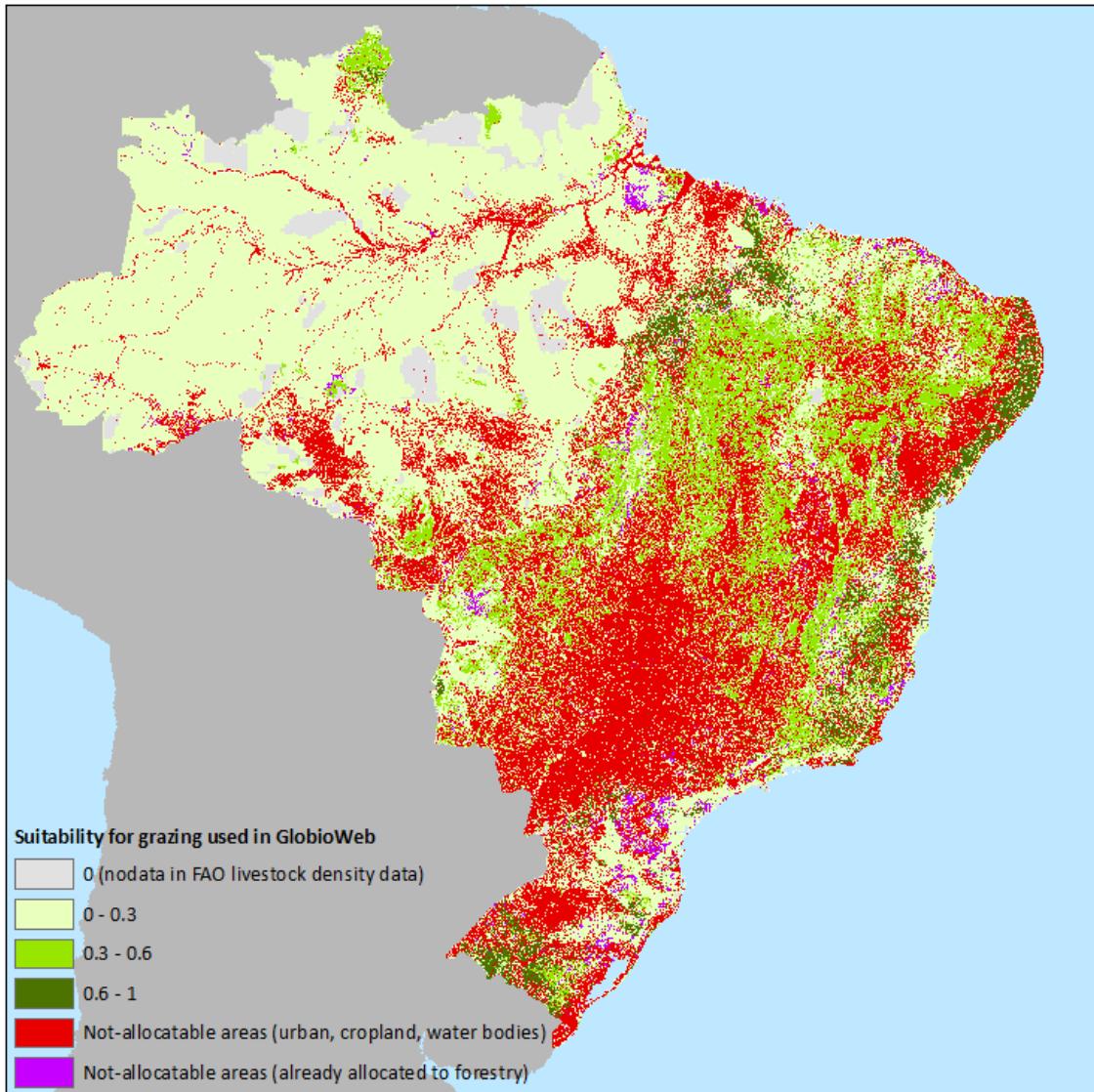
(*) These categories are not present in the background raster layers.

Figure 2.5: livestock grazing suitability layer for the year 2020 used in GLOBIOWeb



Again, the availability of raster cells for allocation is based on the not-allocatable raster layer (defined in step 2) and the raster cells already allocated to other land use types in the allocation sequence. In this case forestry area claims are allocated before the grazing area claims. Figure 2.6 shows this in more detail as an example for Brazil.

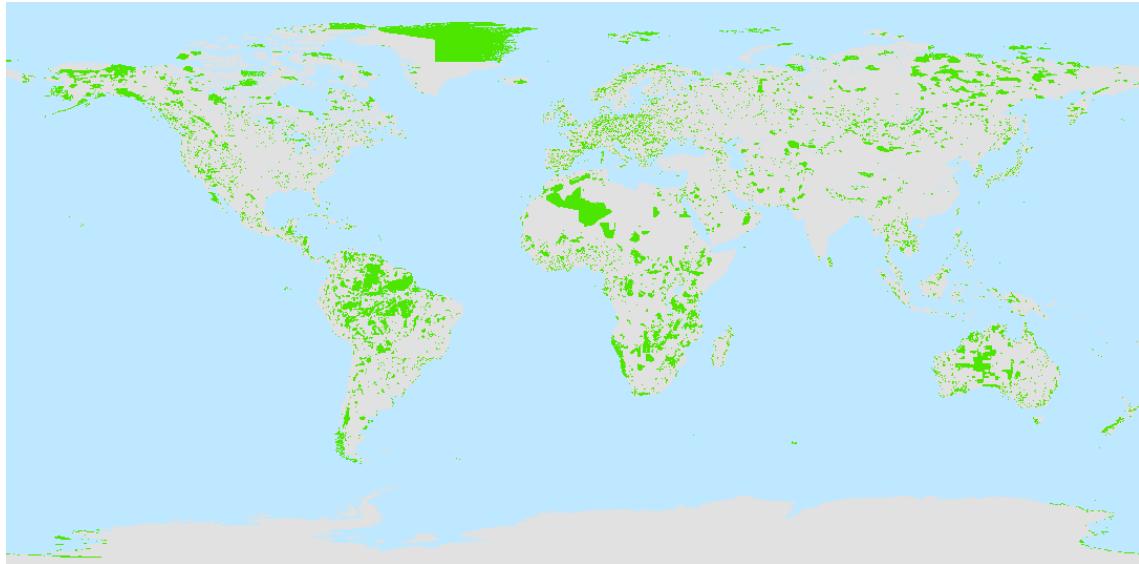
Figure 2.6: example for Brazil of country level grazing suitability for allocatable areas in 2020



As illustrated in Figure 2.1, before the actual spatial claim allocation starts, the suitability value per raster cell can be reduced by the multiplication with another floating type raster where 1.0 means no reduction/protection and 0.0 means full reduction/protection. As such this can reflect for example policy measures on protected areas in future scenarios. In the GLOBIOWeb time series the suitability for both forestry and grazing is reduced by using spatial data from the World Database on Protected Areas, version July 2021 (UNEP-WCMC and IUCN, 2021), shown in Figure 2.7.

The polygon layer from WDPA was converted to a raster with a spatial resolution of 10 arc-seconds and the extent was snapped to match the GLOBIO4 LULC data. All raster cells with presence of WDPA protected areas were assigned a value of 0 (=full protection, reduce suitability value to zero), and all other raster cells were assigned a value of 1 (no reduction of the suitability value). To maintain consistency in allocation over 1992-2020, one single raster layer with recent information on WPDA protected areas was used to reduce land use type suitability in all allocation time steps.

Figure 2.7: terrestrial protected areas (green) from the WDPA (July 2021)



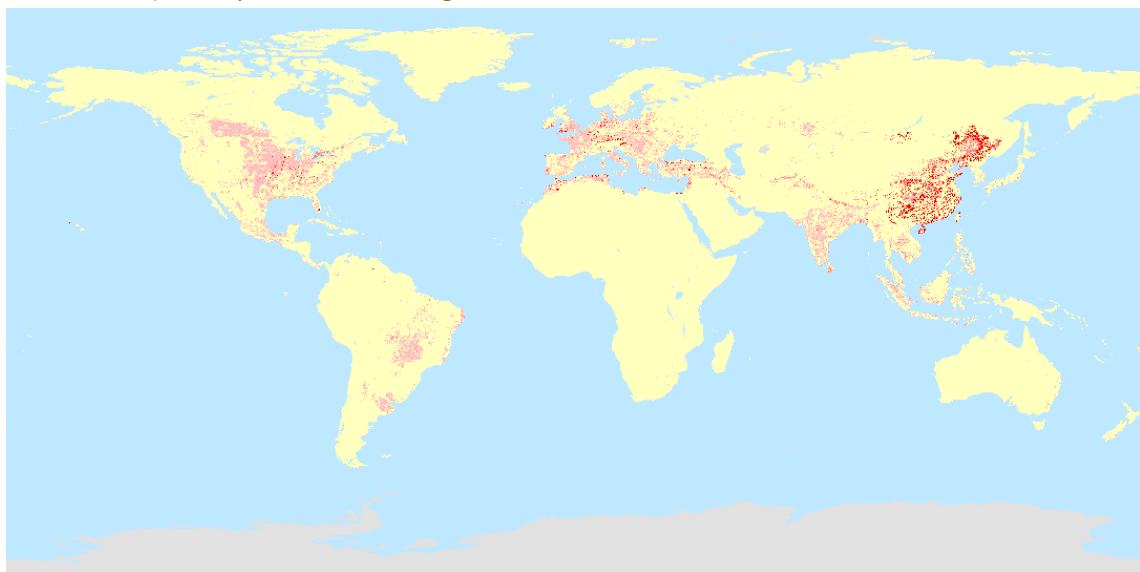
Step 5: create the new GLOBIO4 land use/cover map

When for the GLOBIOWeb 1992-2020 time series all land-use claims are allocated (step 4), the remaining allocatable and the not-allocatable raster cells are filled with LULC information from the background raster layer defined in step 1. All combined this results in the basic GLOBIOWeb LULC raster layer that contains human land use information for urban, cropland, forestry and grazing areas and natural land cover. The module supports the introduction of secondary vegetation in case human land use claims are decreasing compared to previous timesteps (i.e. due land abandonment and/or restoration of nature, often applied in future scenarios). In GLOBIOWeb however the ESA-CCI patterns for urban and cropland areas are used and potentially abandoned forestry and grazing areas receive the background raster LULC class.

Step 6: assign land-use intensity to cropland and grazing areas

As an optional final step, the GLOBIO4 land-use allocation module provides the opportunity to assign land-use intensity to cropland and grazing areas based on the amount of inorganic nitrogen fertilizer application. For the GLOBIOWeb time series, nitrogen fertilizer application data were obtained from the IMAGE model of PBL Netherlands Environmental Assessment Agency (Doelman et al., 2018; Stehfest et al., 2014). The spatial resolution of these fertilizer application data is 5 arc-minutes, corresponding to about 8x8 km around the equator (figure 2.8). The GLOBIO4 land-use allocation module uses a threshold of 100 kg/ha (10 Mg/km²) nitrogen application to reclassify cropland and grazing land (Temme and Verburg 2011). For GLOBIOWeb, cropland (LU code 10) and grazing land (LU code 20) were classified into intensive cropland (GLOBIO4 LU code 11) and intensively used pasture (GLOBIO4 LU code 21) if the nitrogen application rate was above the threshold. The remaining cropland and grazing areas were reclassified to low intensive croplands (LU code 12) and low intensive rangelands (LU code 22), respectively. The few other remaining cropland and grazing area raster cells that lack fertilizer application information retain their original cropland and grazing land-use codes.

Figure 2.8: agricultural areas with inorganic nitrogen fertilizer application rates above 10 Mg/km² (in shades of red) in the year 2020 according to the IMAGE model



3 Biodiversity impacts in GLOBIOWeb

This section describes the input data used for calculating the biodiversity impacts of land use, climate change, nitrogen deposition, roads that fragment and disturb, and hunting in tropical biomes, expressed in terms of the Mean Species Abundance (MSA) indicator, as included in GLOBIOWeb. For a complete technical reference on each module, the .glo file that is used to run all the GLOBIO4 modules for the year 2020 is provided in Annex 2. For more details on the pressure-impact relationships, see Schipper et al. (2020).

3.1 Land use

Land use is one of the main drivers of change in and loss of biodiversity. The pressure of land use on MSA is split up between the effect on plants and birds & mammals. The GLOBIO4 module that calculates the impact of land use on MSA requires three main inputs: a LULC raster layer, obtained with the GLOBIO land-use allocation module (Chapter 2), and two files (.csv) that contain the remaining MSA values for each LULC class for plants and birds & mammals, respectively (Table 3.1). The code for the module can be found online at GitHub:

https://github.com/GLOBIO4/GlobioModelPublic/blob/main/Calculations/GLOBIO_CalcLanduseMS_A.py

Table 3.1: MSA values for birds & mammals and plants per GLOBIO4 LULC type*

Code	GLOBIO4 land use/cover description	Birds and mammals	Plants	Additional information
0	No data/Undefined	1.000	1.000	
1	Urban-settlement	0.264	0.361	Based on Schipper et al. 2020
10	Cropland	0.452	0.156	Based on Kok et al. 2022, MSA for overall agricultural land use
11	Cropland intensive use	0.401	0.149	Based on Kok et al. 2022, MSA for intense agricultural land use
12	Cropland minimal use	0.502	0.162	Based on Kok et al. 2022, MSA for minimal agricultural land use
13	Mosaic cropland (>50%) / natural vegetation (tree shrub herbaceous cover) (<50%)	0.671	0.493	MSA based on 60% cropland value and 40% natural land over value (1.000)
14	Mosaic natural vegetation (tree shrub herbaceous cover) (>50%) / cropland (<50%)	0.781	0.662	MSA based on 40% cropland value and 60% natural land over value (1.000)
20	Grazing	0.452	0.156	Based on Kok et al. 2022, MSA for overall agricultural land use
21	Intensive pastures	0.401	0.149	Based on Kok et al. 2022, MSA for intense agricultural land use
22	Extensive rangelands	0.502	0.162	Based on Kok et al. 2022, MSA for minimal agricultural land use
30	Forestry	0.589	0.259	Based on Schipper et al. 2020
40	Secondary vegetation	0.621	0.568	Based on Schipper et al. 2020

(*) all other classes (natural land cover 50 -220) were assigned an MSA value of 1

The output of the module consists of two global 10 arc-seconds raster layers with remaining MSA based on the impact of land use on plants and birds & mammals, respectively.

3.2 Climate change

The impact from climate change on biodiversity follows the pressure-impact relationships as established by Schipper et al. (2020). The code for the climate change MSA module can be found online at Github:

https://github.com/GLOBIO4/GlobioModelPublic/blob/main/Calculations/GLOBIO_CalcClimateChangeMSA.py

The module requires for each timestep a single input value reflecting the global mean temperature increase (GMTI) since pre-industrial times. For the 1992-2020 time period the GMTI values were retrieved from recent runs for the Shared Socioeconomic Pathways with the IMAGE model (Doelman et al., 2018), as provided in Table 3.2.

Table 3.2: global mean temperature increase values per GLOBIOWeb timestep

GLOBIOWeb year	GMTI ($^{\circ}$ C) since pre-industrial times as retrieved from the IMAGE model
1992	0.637
1995	0.693
2000	0.796
2005	0.899
2010	0.999
2015	1.116
2020	1.259

The impact of climate change is quantified for plants and birds & mammals separately, with the output of the module consisting of two global 10 arc-seconds raster layers.

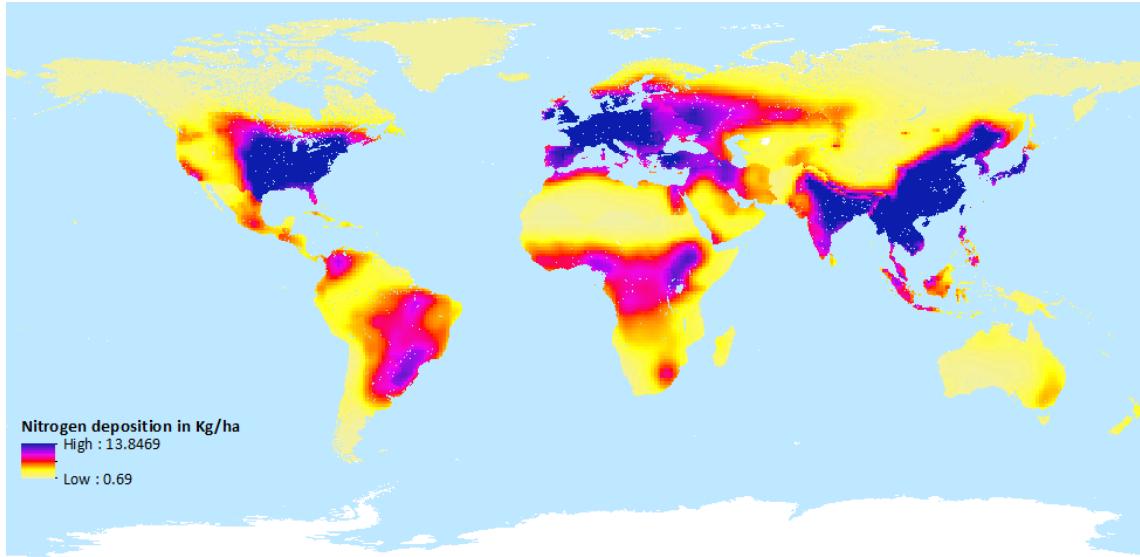
3.3 Nitrogen deposition

The impact of nitrogen deposition are quantified for plants in natural land cover types is based on the pressure-impact relationship that was established by Schipper et al. (2020). The modelling code for the nitrogen deposition MSA module can be found online at Github:

https://github.com/GLOBIO4/GlobioModelPublic/blob/main/Calculations/GLOBIO_CalcNDepositionMSA.py

The module requires a global raster layer with nitrogen deposition (kg/ha/year), which were obtained at a 5 arc-minutes resolution from the IMAGE model (Doelman et al., 2018). The GLOBIO4 module resamples the input raster layer to a 10 arc-seconds resolution. Figure 3.1 shows the global nitrogen deposition map for the year 2020 from the IMAGE model. A second input to this module is a list of land use types that are excluded from the pressure-impact relationship. In this case the following land use types were excluded: urban (1), cropland (10-13) and grazing (20-22).

Figure 3.1: nitrogen deposition for the year 2020 from the IMAGE model



The output of the module is a 10 arc-seconds global raster layer with the remaining MSA for plants based on the impact of nitrogen deposition.

3.4 Impacts of roads

Spatial information on road infrastructure is used in two GLOBIO4 pressure modules: the combined impact of roads and human land use that cause fragmentation of natural habitats and the proximity to roads that causes disturbance of animals. Spatial data on road infrastructure were obtained from the GRIP database, which was developed within the GLOBIO project (Meijer et al., 2018).

Road data used for the impact of fragmentation

The impact of habitat fragmentation by roads and human land use is calculated for birds & mammals in natural land cover types based on the pressure-impact relationship that was established by Schipper et al. (2020). The modelling code for the fragmentation MSA impact module can be found online at Github:

https://github.com/GLOBIO4/GlobioModelPublic/blob/main/Calculations/GLOBIO_CalcInfraFragmentationMSA.py

As input for the module, a 10 arc-seconds rasterized version of the global GRIP road type vector dataset was created, covering the five road types included in GRIP and spatially aligned with the GLOBIOweb LULC raster layers. From this roads raster layer the module selects the road types 1-3 (main and secondary roads) and combines this with natural land cover raster layer, as obtained from the LULC map for each GLOBIOweb time step (Annex 4), to determine patches of natural land cover for which the impact of fragmentation is assessed. Due to limited availability of information on the time of road construction, the same GRIP raster layer was applied in all GLOBIOweb timesteps over the 1992-2020 period. This implies that roads are causing fragmentation, but that changes in MSA due to fragmentation are the result of changes in land use. The output of the module is a 10 arc-seconds global raster layer with the remaining MSA for birds & mammals based on the impact of fragmentation by roads and human land use.

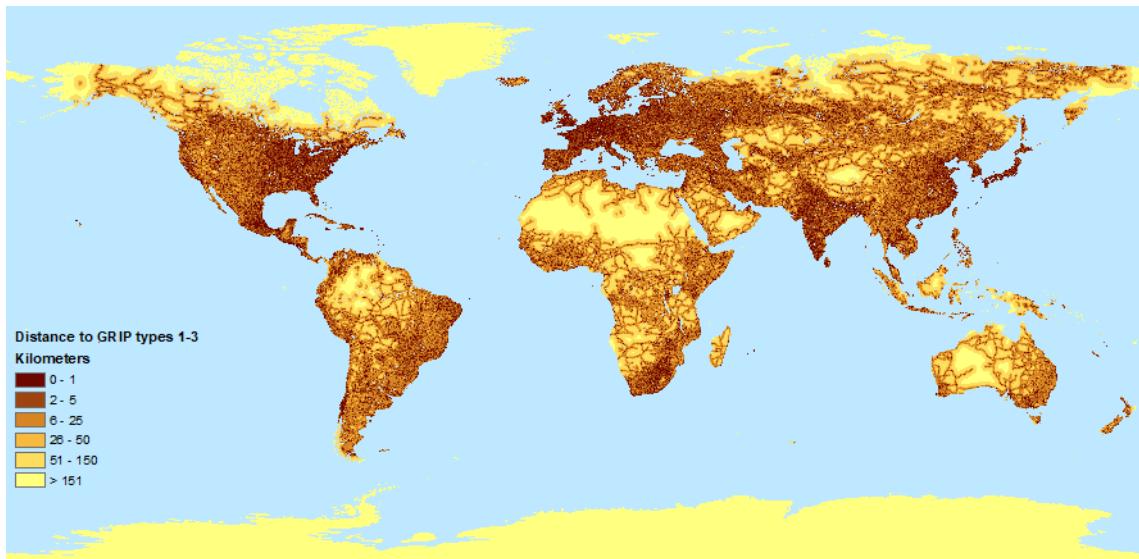
Road data used for the impact of disturbance

Impacts due to the proximity to roads are assessed for birds & mammals in both agricultural and natural land cover types based on the pressure-impact relationship that was established by Schipper et al. (2020). The modelling code for the road disturbance MSA impact module can found online at Github:

https://github.com/GLOBIO4/GlobioModelPublic/blob/main/Calculations/GLOBIO_CalcInfraDisturbanceMSA.py

The module requires a global raster layer indicating the distance to roads (in km) as input. Here again the global raster layer based on the GRIP database was used, where only the main and secondary roads were considered (GRIP types 1-3) in the Euclidean distance calculation (figure 3.2).

Figure 3.2: distance to road types 1-3 from the GRIP database used in the road disturbance module



The same GRIP-based road distance raster layer was applied in all GLOBIOWeb timesteps over the 1992-2020 period. This indicates that changes over time in MSA due to road disturbance reflect changes in land use patterns, as no road disturbance impacts are assumed in urban areas. The output of the module is also a 10 arc-seconds global raster layer with the remaining MSA for birds & mammals based on the impacts of disturbance in the proximity of roads.

3.5 Hunting in tropical biomes

Impacts of hunting are quantified for birds & mammals in natural land cover types in tropical biomes, based on the pressure-impact relationship that was established by Schipper et al. (2020).

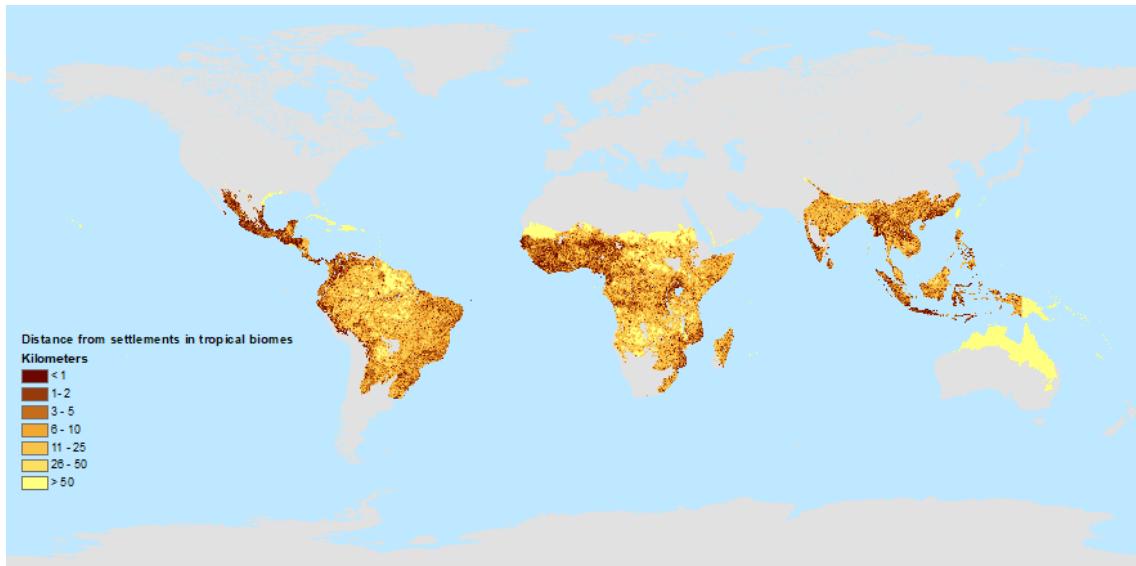
The modelling code for the hunting impact MSA module can found online at Github:

https://github.com/GLOBIO4/GlobioModelPublic/blob/main/Calculations/GLOBIO_CalcHumanEncroachmentMSA_V2b.py

The module uses the time step specific GLOBIO4 LULC data as input to derive the natural land cover area to which the pressure is applied (Annex 4). The LULC classes excluded from this pressure are urban (1), cropland, (10-14), grazing (20-22) and forestry (30).

The dataset used for the global delineation of the tropical biomes, to which hunting impacts are restricted, and the layer with tropical settlements as an indication of hunter access points (see Figure 3.3), are both the same as those used in Schipper et al. (2020) and are used consistently over all time steps. Both raster layers have a 10 arc-seconds resolution and are aligned with the GLOBI04 LULC raster layers.

Figure 3.3: distance from hunter access point (settlements) in tropical biomes as used in the hunting module



The output of the module is also a 10 arc-seconds global raster layer with the remaining MSA for birds & mammals based on the impact of hunting in the tropical biomes.

4 Description of output maps and indicators

4.1 Output: natural land cover

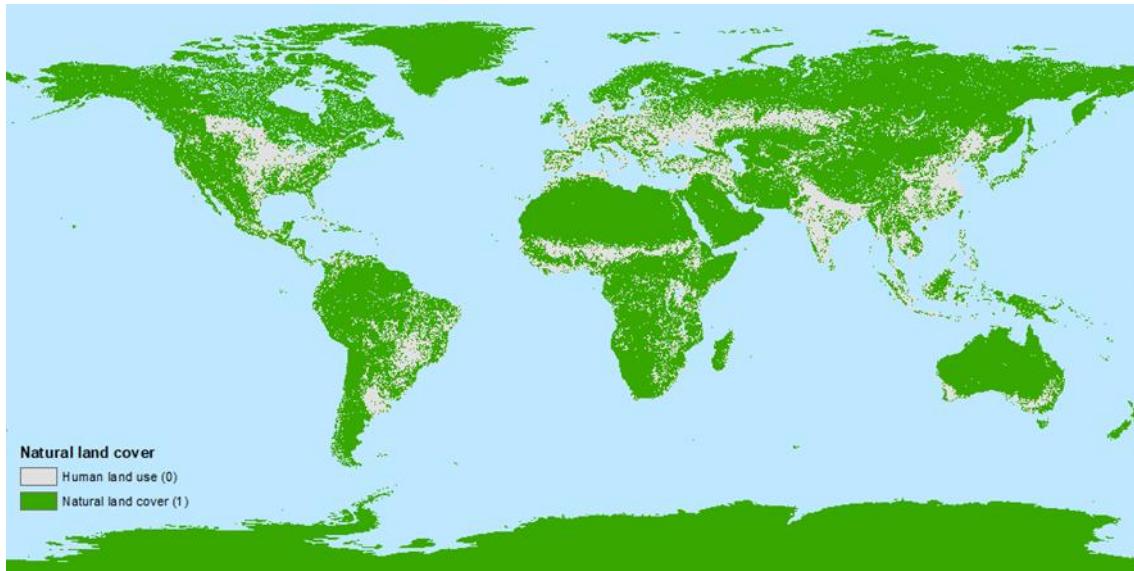
For each GLOBIOWeb timestep, the final GLOBIO4 LULC raster layer is converted into a global raster layer that distinguishes natural land cover from human land use (Table 4.1, Figure 4.1, Annex 4). This raster is then used to calculate the “Natural land cover (%)” indicator in the GLOBIOWeb-tool regional summary statistics.

Table 4.1: identification of natural land cover and human land use

Code	Description	GLOBIO4 LULC class
1	Natural land cover	22, 30, 40, 50, 60, 61, 62, 70, 71, 72, 80, 81, 82, 90, 100, 110, 120, 121, 122, 130, 140, 150, 151, 152, 153, 160, 170, 180, 200, 201, 202, 220
0	Human land use	0, 1, 10, 11, 12, 13, 14, 20, 21

Given the focus on land cover, both rangelands and forestry are considered natural land cover for this specific output.

Figure 4.1: natural land cover areas in 2020



The natural land cover dataset is created using the GLOBIO4 CalcNaturalLanduse module. The code for this module can be found on GitHub:

https://github.com/GLOBIO4/GlobioModelPublic/blob/main/Calculations/GLOBIO_CalcNaturalLanduse.py.

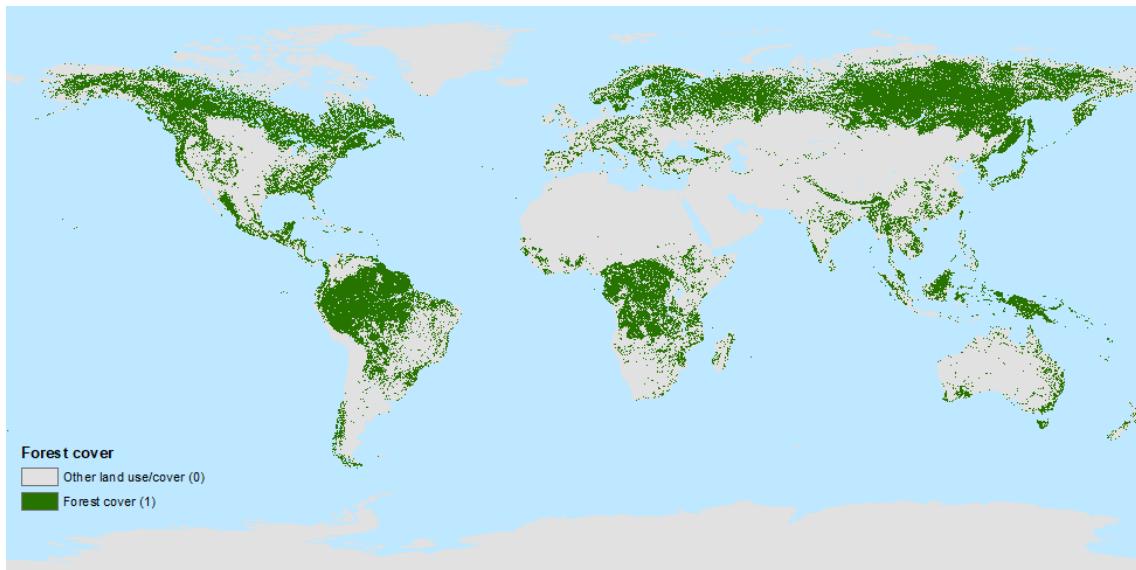
4.2 Output: forest land cover

Another output that is derived for each GLOBIOWeb timestep is a global raster layer that distinguishes forest classes from other LULC classes (Table 4.2, Figure 4.2, Annex 4). This global raster is used to calculate the “forest cover (%)” indicator in the GLOBIOWeb-tool regional summary statistics.

Table 4.2: identification of forest cover

Code	Description	GLOBIOWEB LULC class
1	Forest cover	30, 40, 50, 60, 61, 62, 70, 71, 72, 80, 81, 82, 90, 100, 110, 120, 121, 122, 130, 140, 150, 151, 152, 153, 160, 170
0	Other LULC	0, 1, 10, 11, 12, 13, 14, 20, 21, 22, 40, 110, 120, 121, 122, 130, 140, 150, 151, 152, 153, 180, 200, 201, 202, 220

Figure 4.2: forest cover areas in 2020



The forest cover dataset is created using the GLOBIOWEB CalcNaturalLanduse module. The code for this module can be found on GitHub:

https://github.com/GLOBIOWEB/GlobioModelPublic/blob/main/Calculations/GLOBIOWEB_CalcNaturalLanduse.py

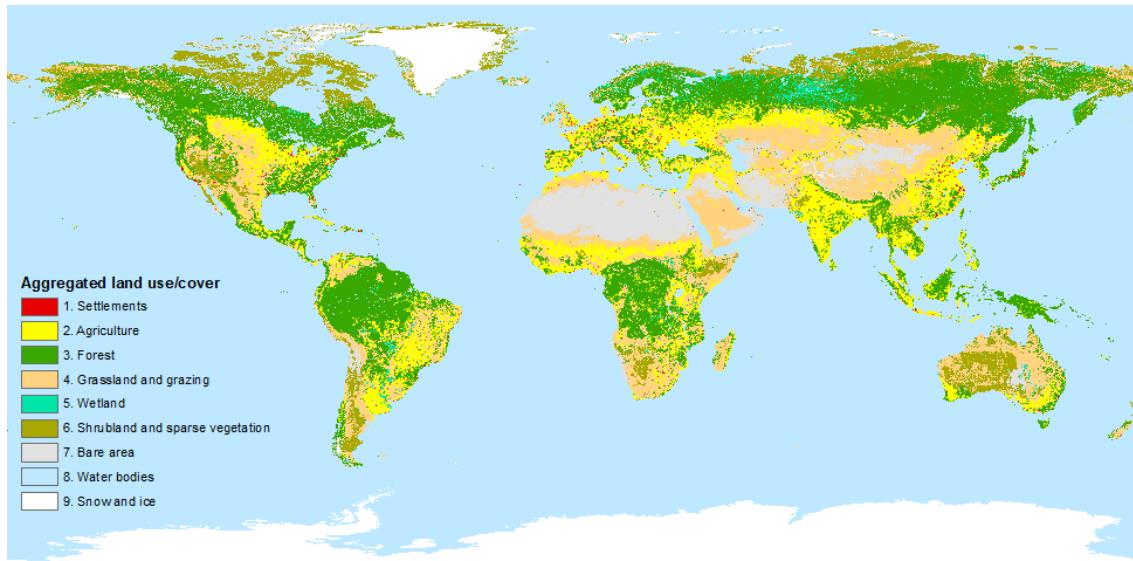
4.3 Output: aggregated land cover

For the regional summary statistics in the GLOBIOWeb-tool, an aggregated LULC dataset is created for each time step. The aggregated classes (Table 4.3, Figure 4.3, Annex 4) are based on the IPCC classes considered for change detection and are in line with the aggregation as used by the ESA-CCI initiative (ESA-CCI, 2021, see Table 3.3 in the ESA-CCI documentation guide).

Table 4.3: aggregation of GLOBIO4 LULC classes

Aggregated code	Aggregated name	GLOBIO4 LULC class
1	Settlement	1
2	Agriculture	10, 11, 12, 13, 14
3	Forest	30, 50-100, 160, 170
4	Grassland and grazing	20, 21, 22, 110, 130
5	Wetland	180
6	Shrubland and sparse vegetation	120, 121, 122, 140, 150, 151, 152, 153
7	Bare area	200, 201, 202
8	Water	210
9	Permanent snow and ice	220
0	No data/Undefined	0

Figure 4.3: aggregated LULC for 2020



The aggregated LULC dataset is created using the GLOBIO4 CalcNaturalLanduse module. The code for this module can be found on GitHub:

https://github.com/GLOBIO4/GlobioModelPublic/blob/main/Calculations/GLOBIO_CalcNaturalLanduse.py.

4.4 Output: MSA maps

The GLOBIO4 model produces maps with the overall terrestrial MSA for plants and birds & mammals, respectively, which is obtained by combining outputs of remaining MSA from the individual pressure-impact modules. The code for this module can be found online at Github:

https://github.com/GLOBIO4/GlobioModelPublic/blob/main/Calculations/GLOBIO_CalcTerrestrialMSA.py

The following additional global 10 arc-seconds raster layers are also generated:

- Combined overall terrestrial MSA: the average of the MSA for plants and birds & mammals
- Combined overall terrestrial MSA reclassified in intervals of 0.1 (10 classes)
- High MSA areas: raster cells with an MSA value ≥ 0.8 , as a proxy of wilderness areas.

The code for the module creating these outputs can be found online at Github:

https://github.com/GLOBIO4/GlobioModelPublic/blob/main/Calculations/GLOBIO_CalcOverallTerrestrialMSA.py

The .glo file used for creating the above outputs for the year 2020 is included in Annex 5 for detailed technical reference.

4.5 Indicators provided in GLOBIOWeb

Global MSA maps are available for display for the recent past, starting from 1992 up to 2020, and for the three future scenarios for the year 2050 described by Schipper et.al. (2020). For user-selected administrative regions, watersheds or custom defined extents, GLOBIOWeb generates a selection of aggregated indicators (Table 4.4). The national and provincial boundaries shown in the online GLOBIOWeb map and used for the regional summary generation are derived from the [GADM database](#), and the watershed boundaries are based on [HydroBasins](#) Pfafstetter level 4 data combined with [GRDC WMO sub-basin](#) names.

Table 4.4: regional summary indicators generated in GLOBIOWeb per timestep

Regional summary indicator/graph	Description of calculation per selected region
Mean MSA	(Sum of (MSA per cell * cell area)) / total land area
Mean MSA loss	1 – Mean MSA
Natural land cover %	Total area with natural land cover / total land area
Forest cover %	Total area with forest cover / total land area
Protected area cover %	Total area covered by WDPA / total land area
Area with MSA values of ≥ 0.8 in %, as a proxy of wilderness areas	Total area with MSA value ≥ 0.8 / total land area
Land cover and use graph, % per category	Total area per LULC class / total area
Land area per MSA class graph, % per class	Total area per MSA interval class / total land area
Pressures contributing to MSA loss graph, for birds & mammals and plants respectively	Per pressure: (Sum of (MSA loss per cell * cell area)) / total land area

Figures 4.4 and 4.5 show an example of the regional summary statistics in the GLOBIOWeb interface, where all the indicators and graphs are presented for the selected region, in this case the Central Province of Cameroon, for the selected year, in this case 2020. All input and output datasets used for generating the regional summary statistics are included in the zipfile that can be downloaded.

Figure 4.4: example presentation of the regional summary indicators for the Central Province, Cameroon

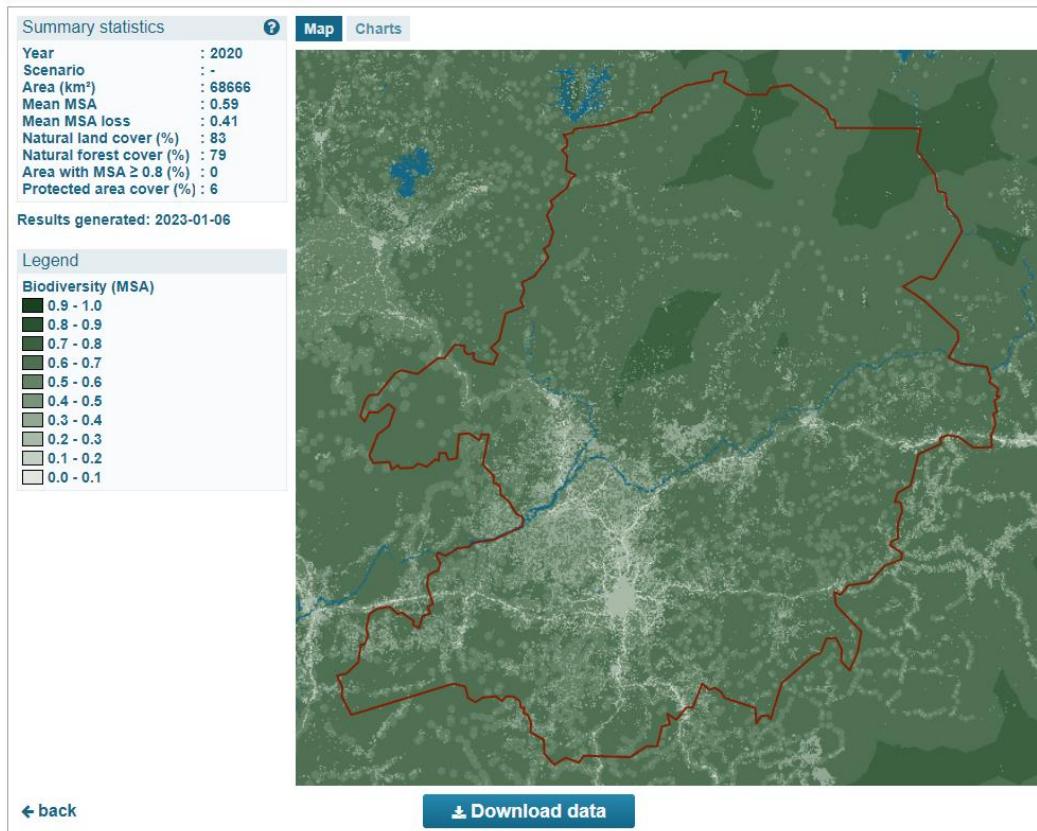
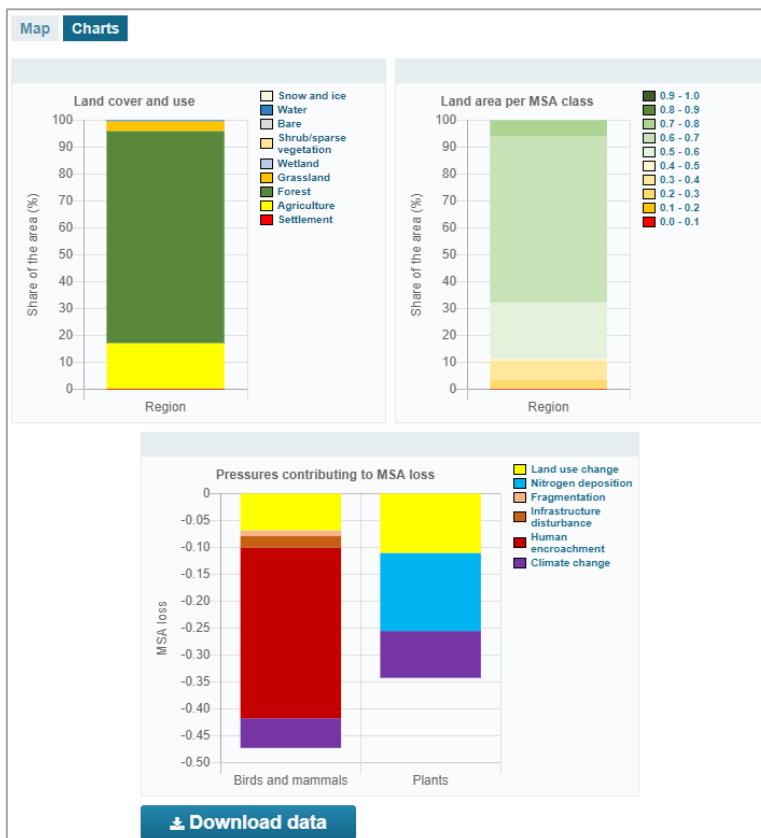


Figure 4.5: example regional summary graphs for the Central Province, Cameroon



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Annex 1: GLOBIO4 land allocation module .glo file

```
#-----
# RUN_LANDUSEALLOCATION.GLO
#
# Runs the land-use allocation module with the extent set to Europe.
# Uses a regional filter (region 11) and some excluded regions to prevent
# border effects.
#
#-----
#
# Include landuse allocation module.
INCLUDE LanduseAllocation.glo

#-----
BEGIN_RUN Calculations()

    # Save temporary data?
    #SaveTmpData = True
    SaveTmpData = False

    ### SAME SETUP AS GLOBIO4 GLO scripts
    #PBL GLOBIO4 scenario folder setting (path from the BaseInDir: Y:/data/Globio/GLOBIO4/Models/Terra/Projects).
    #ProjectName should reflect the folder name under the Terra/Projects folder.
    STRING ProjectName = GBW_GIS
    #ScenarioName should reflect the name of the scenario folder name under the ScenarioRuns folder.
    STRING ScenarioName = GBW

    DIR BaseInDir = W:\Globio4Runs

    #This will be scenario folder:
    DIR ProjectScenario = $BaseInDir;\$ProjectName;\ScenarioRuns\$ScenarioName;

    #Set the scenario run year to refer to correct input and output data
    STRING ScenarioYear = 2020

    #If you are using custom lookup files and not the global ones
    # (Y:/data/GLOBIO/GLOBIO4/Models/Terra/Shared/LookupGlobal), specify the LookupDir here.
    LookupDir = $BaseInDir;\$ProjectName;\SharedLookup

    # Set input directory.
    InDir = $ProjectScenario;\input

    # Set output directory.
    OutDir = $ProjectScenario;\output

    # Set tmp directory.
    TmpDir = $ProjectScenario;\tmp

    #Shared data folder.
    DIR SharedData = $BaseInDir;\$ProjectName;\SharedData
    ###

    # Set region and resolution.
    Extent = wrld
    #Extent = -180,-57,-26,84
    STRING ExtentStr = World
    CellSize = 10sec
    STRING CellSizeStr = 10

    # Set output raster.
    RASTER OutAllocatedLanduse = $OutDir;\Globio4_\$ScenarioName;_LU_\$ScenarioYear;_\$CellSizeStr;sec.tif

    # Set input directories.
    DIR ClaimDir = $InDir;
    DIR Lcdir = $SharedData;
    DIR RegionDir = $SharedData;
    DIR PaDirDir = $SharedData;
    DIR SuitDir = $SharedData;
    DIR LuDirDir = $SharedData;
    DIR NotAllocDir = $SharedData;

    # Set other input parameters.
    STRING LanduseCodes = 1|10|30|20|21|22|40|0|11|12
    STRING LanduseNames = Urban|Cropland|Forestry|Grazing|Pasture intensive|Rangeland extensive|secondary
    vegetation|undefined|Cropland high intensive|Cropland low intensive
    STRING LandusePriorityCodes = 30|20

    RASTER Landcover = $OutDir;\ESACCI_GLOBIO_\$ScenarioYear;.tif
```

```

RASTER Regions = $RegionDir;\Countries2020_10sec.tif
STRING RegionFilter = NONE
STRING RegionExcudeFilter = NONE

RASTER Landuse = $OutDir;\ESACCI_GLOBIO_$ScenarioYear;.tif

STRING LanduseReplaceCodes = 30|20
STRING LanduseReplaceWithCode = 40
STRING LanduseUndefinedCode = 0

RASTER NotAllocatableAreas = $NotAllocDir;\non_allocatable_LU_$ScenarioYear;.tif
#RASTER PAReduceFactor = $PaDirDir;\pa_reduce_gbw_$ScenarioYear;.tif
RASTER PAReduceFactor = NONE

STRING SuitRasterCodes = 20|30
RASTERLIST SuitRasterNames =
$SuitDir;\Norm_Suit_Grazing_ESACCI_GLOBIO_$ScenarioYear;_32bit.tif|$SuitDir;\Norm_Suit_FSA_suit_forestry_$ScenarioYear
;_32bit.tif

FILE ClaimFileName = $ClaimDir;\Claim$ScenarioYear;.csv
STRING ClaimRegionFieldName = Region
STRING ClaimLanduseFieldName = Attribute
STRING ClaimAreaFieldName = Value
#FILE ClaimLookup = $SharedData;\LookupGlobalLanduseAllocation\LanduseClassToLanduseType.csv
FILE ClaimLookup = NONE

STRING ClaimAreaMultiplierLanduseCodes = NONE
STRING ClaimAreaMultipliers = NONE

# Scenario specific layers to adjust the suitability to follow a scenario spatial pattern. The value is averaged
with the general suitability input
# If no scenario input, then provide the general suitability input, so the suitability remains the same
# The sequence should resemble to the above SuitRasterCodes and SuitRasterNames sequence
# now testing for crops and intensive pastures
#RASTERLIST ScenarioSuitRasterNames =
NONE|$InDir;\IMAGE\suit__$ScenarioName;_CropSuit_2050.tif|$InDir;\IMAGE\suit__$ScenarioName;_PastureSuit_2050.tif|$InDir
;\IMAGE\suit__$ScenarioName;_RangelandSuit_2050.tif|NONE
RASTERLIST ScenarioSuitRasterNames = NONE|NONE
# The FLOATING ratio for the weights of the ScenSuitRaster input. 0.5 means the ScenSuit raster accounts for half,
1.0 means the ScenSuit raster will count for 100% and the default suitability raster is ignored.
#STRING ScenSuitRasterWeights = 0.0|0.0|0.0|0.0|0.0
STRING ScenSuitRasterWeights = 0.0|0.0

# Cropland and grazing intensity adjustment, based on Nitrogen application.
# Use path to a raster tif or NONE if not needed
RASTER Gfertilizer = $InDir;\IMAGE\GFERTILIZER__$ScenarioName;__$ScenarioYear;.tif
# The cropland part
# The GLOBO default land use code used for cropland
STRING LandUseCodeCrops = 10
# The land use codes to use for low and high intensity cropland
STRING LandUseCodeCropsHighIntensive = 11
STRING LandUseCodeCropsLowIntensive = 12
# The grazing part
# The GLOBO default land use code used for grazing
STRING LandUseCodeGrazing = 20
# The land use codes to use for low and high intensity grazing
STRING LandUseCodeGrazingHighIntensive = 21
STRING LandUseCodeGrazingLowIntensive = 22
# The fertilizer criterium
# The threshold value, if other than the default value for IMAGE GFERTILIZER (=10)
# GNM is in kg/ha
#FLOAT GfertilizerThreshold = 100
# Set Land use intensity output raster, same name as above, with _LU_INT extention.
RASTER OutAllocatedLanduseLUInt = $OutDir;\Globio4__$ScenarioName;_LU__$ScenarioYear;_CellSizeStr;sec_LU_INT.tif

RASTER CellAreas = $SharedData;\areakm2__$CellSizeStr;sec.tif
#RASTER CellAreas = NONE
BOOLEAN AddNoiseFlag = True
#BOOLEAN AddNoiseFlag = False

# Set output files/raster.
#FILE OutRegionAreasFileName = $OutDir;\regio_areas__$CellSizeStr;sec__$ScenarioYear;_ExtentStr;.csv
FILE OutRegionAreasFileName = NONE
#FILE OutRegionLandcoverAreasFileName =
$OutDir;\regio_landcover_areas__$CellSizeStr;sec__$ScenarioYear;_ExtentStr;.csv
FILE OutRegionLandcoverAreasFileName = NONE
FILE OutRegionLanduseAreasFileName = $OutDir;\regio_landuse_areas__$CellSizeStr;sec__$ScenarioYear;_ExtentStr;.csv

# Create the 3 reclassified land use/cover rasters based on adapted IPCC classification
# (using the natural landuse calculation)
# 1. LAND USE/COVER
#RASTER LandUse = $OutAllocatedLanduseLUInt;
FILE ReclassLanduseLookupLU = $LookupDir;\LC_LU_reclass.csv
RASTER ReclassLCLU = $OutDir;\Globio4__$ScenarioName;_LU__$ScenarioYear;_CellSizeStr;sec_LU_aggregated.tif

# 2. NATURAL LAND COVER
FILE ReclassLanduseLookupNAT = $LookupDir;\LC_NAT_reclass.csv

```

```

RASTER ReclassLCNAT = $OutDir;\Globio4_$ScenarioName;_LU_$ScenarioYear;_$CellSizeStr;sec_LC_natural.tif

# 3. FOREST COVER
FILE ReclassLanduseLookupFOR = $LookupDir\LC_FOR_reclass.csv
RASTER ReclassLCFOR = $OutDir;\Globio4_$ScenarioName;_LU_$ScenarioYear;_$CellSizeStr;sec_LC_forest.tif

#-----
# Start running.
#-----

RUN_MODULE CalcDiscreteLanduseAllocationScenSuitIntensity(
    $Extent,$CellSize,
    $LanduseCodes,$LanduseNames,
    $LandusePriorityCodes,
    $Landcover,
    $Regions,
    $RegionFilter,$RegionExcludeFilter,
    $Landuse,
    $LanduseReplaceCodes,
    $LanduseReplaceWithCode,$LanduseUndefinedCode,
    $NotAllocatableAreas,
    $PAReduceFactor,
    $SuitRasterCodes,$SuitRasterNames,
    $ScenarioSuitRasterNames,$ScenSuitRasterWeights,
    $Gfertilizer,$GfertilizerThreshold,
    $LandUseCodeCrops,$LandUseCodeCropsLowIntensive,$LandUseCodeCropsHighIntensive,
    $LandUseCodeGrazing,$LandUseCodeGrazingLowIntensive,$LandUseCodeGrazingHighIntensive,
    $ClaimFileName,$ClaimLanduseFieldName,
    $ClaimRegionFieldName,$ClaimAreaFieldName,
    $ClaimLookup,
    $ClaimAreaMultiplierLanduseCodes,
    $ClaimAreaMultipliers,
    $CellAreas,
    $AddNoiseFlag,
    $OutRegionAreasFileName,
    $OutRegionLandcoverAreasFileName,
    $OutRegionLanduseAreasFileName,
    $OutAllocatedLanduse,
    $OutAllocatedLanduseLUInt)

RUN_MODULE CalcNaturalLanduse($Extent,$OutAllocatedLanduseLUInt,$ReclassLanduseLookupLU,$ReclassLCLU)

RUN_MODULE CalcNaturalLanduse($Extent,$OutAllocatedLanduseLUInt,$ReclassLanduseLookupNAT,$ReclassLCNAT)

RUN_MODULE CalcNaturalLanduse($Extent,$OutAllocatedLanduseLUInt,$ReclassLanduseLookupFOR,$ReclassLCFOR)

END_RUN

#-----
#-----
RUN Calculations()

```

Annex 2: GLOBIO4 MSA impact modules .glo file

```
#-----
# RUN_ALL.GLO
#-----
BEGIN_RUN Calculations()

#PBL GLOBIO4 scenario folder setting (path from the BaseInDir: Y:\data\Globio\GLOBIO4\Models\Terra\Projects).
#ProjectName should reflect the folder name under the Terra\Projects folder.
STRING ProjectName = GBW_GIS
#ScenarioName should reflect the name of the scenario folder name under the ScenarioRuns folder.
STRING ScenarioName = GBW
DIR BaseInDir = W:\Globio4Runs

#This will be scenario folder:
DIR ProjectScenario = $BaseInDir;\\$ProjectName;\\ScenarioRuns\\$ScenarioName;

#Set the scenario run year to refer to correct input and output data
STRING ScenarioYear = 2020

#If you are using custom lookup files and not the global ones
#LookupDir = $BaseInDir;\\$ProjectName;\\<lookupfolder>
LookupDir = $BaseInDir;\\$ProjectName;\\SharedLookup

# Set input directory.
InDir = $ProjectScenario;\\input

# Set output directory.
DIR OutDir = $ProjectScenario;\\output
DIR OutDirOri = $ProjectScenario;\\output

# Set tmp directory.
TmpDir = $ProjectScenario;\\tmp

#Shared data folder.
DIR SharedData = $BaseInDir;\\$ProjectName;\\SharedData

# Set region.
#Extent = europe
Extent = wrld
#Extent = 30,30,50,40
STRING ExtentStr = World

# Set resolution.
CellSize = 10sec
STRING CellSizeStr = 10

# Save temporary data?
#SaveTmpData = True
SaveTmpData = False

# Set input\output rasters.

# Natural land use module
RASTER LandUse = $OutDir;\\Globio4\\$ScenarioName;\\_LU\\$ScenarioYear;\\$CellSizeStr;sec_LU_INT.tif
FILE NaturalLanduseLookup = $LookupDir;\\NaturalLanduse.csv
RASTER NaturalLanduse = $OutDir;\\NaturalLanduse\\$ScenarioYear;\\$ExtentStr;.tif

# Climate change module
FLOAT TemperatureChange = 1.25926351547241
FILE WaterLookupFile = $LookupDir;\\WaterAreasFilter.csv
RASTER ClimateChangeMSA = $OutDir;\\ClimateChangeMSA\\$ScenarioYear;\\$ExtentStr;.tif
RASTER ClimateChangeMSA_wbvert = $OutDir;\\ClimateChangeMSA\\$ScenarioYear;\\$ExtentStr;\\wbvert.tif
RASTER ClimateChangeMSA_plants = $OutDir;\\ClimateChangeMSA\\$ScenarioYear;\\$ExtentStr;\\plants.tif

# Land use module
FILE LanduseMSALookup_WBvert = $LookupDir;\\LanduseMSA_WBvert.csv
FILE LanduseMSALookup_Plants = $LookupDir;\\LanduseMSA_Plants.csv
RASTER LanduseMSA = $OutDir;\\LanduseMsa\\$ScenarioYear;\\$ExtentStr;.tif
# These will be created anyway, based on the one above
#RASTER LanduseMSA_wbvert = $OutDir;\\LanduseMsa\\$ScenarioYear;\\$ExtentStr;\\wbvert.tif
#RASTER LanduseMSA_plants = $OutDir;\\LanduseMsa\\$ScenarioYear;\\$ExtentStr;\\plants.tif

# Nitrogen deposition module
STRING NDEP_LandcoverExlCodes = 1|10|11|12|13|20|21|22
#STRING NDEP_LandcoverExlCodes = 1|2|3|4|230|231|232|233|234|235
RASTER Ndep = $InDir;\\IMAGE\\GNDEP\\$ScenarioName;\\$ScenarioYear;\\_KG.tif
RASTER NDepositionMSA = $OutDir;\\NDepositionMSA\\$ScenarioYear;\\$ExtentStr;.tif
RASTER NDepositionMSA_plants = $OutDir;\\NDepositionMSA\\$ScenarioYear;\\$ExtentStr;\\plants.tif
```

```

# Human encroachment module
# Land use codes for which the pressure is NOT included in the final output
STRING HUMANENC_LandcoverExlCodes = 1|10|11|12|13|14|20|21|22|30
#STRING HUMANENC_LandcoverExlCodes = 1|2|3|4|5|230|231|232|233|234|235
# If you have a prepared settlement distance raster (in km), provide the path. If None, check inputs below.
RASTER SettlementDistance = $SharedData;\HumanEnc_globalsettlements_distance_km_v20170907.tif
#RASTER SettlementDistance = NONE
# if SettlementDistance is not specified the input data below will be used to create it
# If you already have a settlement raster, provide the path. If None, provide a folder with point shapefiles below
RASTER SettlementRaster = $SharedData;\HumanEnc_globalsettlements_v20170907.tif
# Shapes only used if SettlementRaster is None
DIR InSettlementsDir = $SharedData;\GlobalSettlements
# Tropical biome raster to use a mask for the output (value 1 for tropical biomes, rest nodata)
RASTER TropBiome = $SharedData;\Biome_trop.tif
# The water LU code for global runs, to prevent calculating distances for the whole globe. Here ESA 210 value is default
STRING MASK_Global_LU_ExlCode = 210
# The urban land cover code used to buffer and filter out settlements
STRING LandcoverCodes = 1
# The MSA output rasters
RASTER HumanEncroachmentMSA = $OutDir;\HumanEncroachmentMSA__$ScenarioYear;__$ExtentStr;.tif
RASTER HumanEncroachmentMSA_wbvert = $OutDir;\HumanEncroachmentMSA__$ScenarioYear;__$ExtentStr;_wbvert.tif

# Infrastructure fragmentation module
RASTER RoadsRaster = $SharedData;\GRIP4_5types_10sec.tif
BOOLEAN CloseRoadConnections = False
RASTER InfraFragmentationMSA = $OutDir;\InfraFragmentationMSA__$ScenarioYear;__$ExtentStr;.tif
RASTER InfraFragmentationMSA_wbvert = $OutDir;\InfraFragmentationMSA__$ScenarioYear;__$ExtentStr;_wbvert.tif

# Infrastructure disturbance module
STRING INFRADIST_LandcoverExlCodes = 1
RASTER RoadDistance = $SharedData;\GRIP4_distance_km_tp123_10sec.tif
# if RoadDistance is not specified the input data below will be used to create it
RASTER Roads = $SharedData;\GRIP4_5types_10sec.tif
FLOAT MaximumDistanceKM = 150
RASTER InfraDisturbanceMSA = $OutDir;\InfraDisturbanceMSA__$ScenarioYear;__$ExtentStr;.tif
RASTER InfraDisturbanceMSA_wbvert = $OutDir;\InfraDisturbanceMSA__$ScenarioYear;__$ExtentStr;_wbvert.tif

#-----
# Start running.
#-----

RUN_MODULE CalcNaturalLanduse($Extent,$LandUse,$NaturalLanduseLookup,$NaturalLanduse)

RUN_MODULE CalcClimateChangeMSA($Extent,$LandUse,$WaterLookupFile,
                               $TemperatureChange,$CLIMCH_WbVertRegressionCoefficients,
                               $CLIMCH_PlantRegressionCoefficients,$ClimateChangeMSA)

RUN_MODULE CalcLanduseMSA($Extent,
                         $LandUse,$LanduseMSALookup_WBvert,
                         $LanduseMSALookup_Plants,
                         $LanduseMSA)

RUN_MODULE CalcNDepositionMSA($Extent,$LandUse,$NDEP_LandcoverExlCodes,$WaterLookupFile,$Ndep,
                             $NDEP_PlantRegressionCoefficients,
                             $NDEP_WeightFactor,$NDepositionMSA)

RUN_MODULE CalcHumanEncroachmentMSA_V2b($Extent,$LandUse,$HUMANENC_LandcoverExlCodes,$WaterLookupFile,
                                         $SettlementDistance,
                                         $InSettlementsDir,$TropBiome,
                                         $LandcoverCodes,
                                         $HUMANENC_LandcoverBufferDistanceKM,
                                         $HUMANENC_WbVertRegressionCoefficients,
                                         $HUMANENC_WeightFactor,
                                         $MASK_Global_LU_ExlCode,
                                         $SettlementRaster,
                                         $HumanEncroachmentMSA)

RUN_MODULE CalcInfraFragmentationMSA($Extent,
                                     $LandUse,
                                     $WaterLookupFile,
                                     $RoadsRaster,
                                     $NaturalLanduse,
                                     $INFRAG_WbVertRegressionCoefficients,
                                     $INFRAG_WeightFactor,
                                     $CloseRoadConnections,
                                     $InfraFragmentationMSA)

RUN_MODULE
CalcInfraDisturbanceMSA($Extent,$LandUse,$INFRADIST_LandcoverExlCodes,$WaterLookupFile,$RoadDistance,$Roads,$INFRADIST_MaximumDistanceKM,
                        $INFRADIST_WbVertRegressionCoefficients,
                        $INFRADIST_WeightFactor,$InfraDisturbanceMSA)

END_RUN
#-----
# RUN Calculations()

```

Annex 3: GLOBIOWeb Countries and land use claims

Country	Name	Forestry plantation in km ² , source FAO							Grazing (permanent + temporary meadows) in km ² , source FAO						
		1992*	1995*	2000	2005*	2010	2015	2020	1992	1995	2000	2005	2010	2015	2020
4	Afghanistan	0	0	0	0	0	0	0	300000	300000	300000	300000	300000	300000	300000
8	Albania	704	704	704	704	704	704	704	4240	4240	4460	4230	7053	6825	6805
10	Antarctica	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	Algeria	0	0	0	0	0	0	0	308160	316340	315390	328490	329810	329918	328418
16	American Samoa	0	0	0	0	0	0	0	2	2	2	0	0	0	1
20	Andorra	0	0	0	0	0	0	0	220	220	220	226	205	185	185
24	Angola	9606	9511	9417	9081	8745	8408	8072	421126	425289	434060	455916	476669	495422	517375
28	Antigua and Barbuda	0	0	0	0	0	0	0	40	40	40	40	40	40	40
31	Azerbaijan	95	97	99	101	103	216	226	24314	24537	26306	26914	26562	26097	24266
32	Argentina	7660	9210	10760	11315	11870	12850	14360	999600	999300	998800	1009582	930435	849225	784250
36	Australia	10229	12538	14847	17468	20089	19734	19427	4454000	4511000	4304290	3688260	3567460	3421160	3275890
40	Austria	0	0	0	0	0	0	0	15129	14951	14822	15799	15215	14594	14073
44	Bahamas	0	0	0	0	0	0	0	20	20	20	20	20	20	20
48	Bahrain	2	3	4	4	5	6	7	40	40	40	40	40	40	40
50	Bangladesh	752	752	752	736	719	1581	1581	6000	6000	6000	6000	6000	6000	6000
51	Armenia	0	0	0	0	0	0	0	6870	7000	8350	10000	12439	11759	11726
52	Barbados	0	0	0	0	0	0	0	20	20	20	20	20	20	20
56	Belgium	4463	4271	4079	4071	4064	4382	4382	5735	4733	5566	6070	5820	5600	5730
60	Bermuda	0	0	0	0	0	0	0	0	0	0	0	0	0	0
64	Bhutan	193	194	195	196	198	203	208	3500	3500	4000	4070	4070	4130	4130
68	Bolivia	200	235	271	306	341	369	388	335000	338350	338310	328410	330000	330000	330000
70	Bosnia and Herzegovina	0	0	0	0	0	0	0	12000	12000	10500	10440	10290	10450	10820
72	Botswana	0	0	0	0	0	0	0	256000	256000	256000	256000	256000	256000	256000
74	Bouvet Island	0	0	0	0	0	0	0	0	0	0	0	0	0	0
76	Brazil	35581	36052	36522	54903	73283	99379	112236	1782952	1778488	1743028	1700563	1697224	1719964	1733608

Country	Name	Forestry plantation in km ² , source FAO							Grazing (permanent + temporary meadows) in km ² , source FAO						
		1992*	1995*	2000	2005*	2010	2015	2020	1992	1995	2000	2005	2010	2015	2020
84	Belize	21	21	22	22	23	23	24	490	490	500	500	500	500	500
86	British Indian Ocean Territory	0	0	0	0	0	0	0	0	0	0	0	0	0	0
90	Solomon Islands	399	359	318	289	259	246	232	50	60	70	80	80	80	80
92	British Virgin Islands	0	0	0	0	0	0	0	50	50	50	50	50	50	50
96	Brunei Darussalam	0	0	0	0	0	0	0	50	50	40	40	34	34	34
100	Bulgaria	0	0	0	0	0	0	0	19990	19420	18200	19040	18140	14520	15180
104	Myanmar	307	307	307	1680	3052	4060	4271	3590	3450	3240	3110	3060	3060	2987
108	Burundi	1614	1372	1130	1130	1130	1130	1130	8200	7730	5670	4830	4830	4830	4830
112	Belarus	8	8	8	13	17	60	61	31300	29740	29750	32900	32630	28440	26300
116	Cambodia	673	836	999	1272	1545	5443	6040	7000	7500	8000	13800	15000	15000	15000
120	Cameroon	181	196	211	311	411	511	611	20000	20000	20000	20000	20000	20000	20000
124	Canada	0	0	0	0	0	0	0	201050	200200	201020	293940	278990	258750	250640
132	Cape Verde	17	139	260	275	290	305	320	250	250	250	250	250	250	250
136	Cayman Islands	0	0	0	0	0	0	0	20	20	20	20	20	20	20
140	Central African Republic	20	20	20	20	20	20	20	30000	30000	31250	32000	32000	32000	32000
144	Sri Lanka	2568	2453	2338	2198	2058	2483	2498	4390	4400	4400	4400	4400	4400	4400
148	Chad	0	0	0	0	0	0	0	450000	450000	450000	450000	450000	450000	450000
152	Chile	16463	19622	22781	25543	28304	30458	31847	128500	129000	129300	140000	140150	140150	140150
156	China	353216	371011	388805	405338	421870	429618	457360	3790040	3928330	3928330	3928330	3928330	3928330	3928330
158	Taiwan, Province of China	0	0	0	0	0	0	0	0	0	0	0	0	0	0
162	Christmas Island	0	0	0	0	0	0	0	0	0	0	0	0	0	0
166	Cocos (Keeling) Islands	0	0	0	0	0	0	0	0	0	0	0	0	0	0
170	Colombia	970	1314	1657	2735	3813	4240	4274	400830	400830	413040	386830	391860	412440	396000
174	Comoros	35	30	24	19	13	8	2	150	150	150	150	150	150	150
175	Mayotte	0	0	0	0	0	0	0	0	0	0	0	0	0	0
178	Congo	595	595	595	595	595	595	595	100000	100000	100000	100000	100000	100000	100000
180	Democratic Republic of the Congo	555	561	567	572	577	577	577	181000	181000	181000	181000	182000	182000	182000
184	Cook Islands	5	8	11	11	11	11	11	0	0	0	0	0	0	0

Country	Name	Forestry plantation in km ² , source FAO							Grazing (permanent + temporary meadows) in km ² , source FAO						
		1992*	1995*	2000	2005*	2010	2015	2020	1992	1995	2000	2005	2010	2015	2020
188	Costa Rica	266	366	466	566	666	766	866	16886	15750	13880	13220	12860	12340	12000
191	Croatia	923	870	816	782	748	748	686	10790	10910	8350	2890	3823	6940	6720
192	Cuba	3470	3445	3420	4190	4960	5280	5327	28700	25000	25000	23940	26478	28761	28623
196	Cyprus	0	0	0	0	0	0	0	40	20	11	10	43	22	18
203	Czech Republic	0	0	0	0	0	0	0	8551	8900	9500	8581	9252	10150	10230
204	Benin	130	145	160	180	200	220	230	5500	5500	5500	5500	5500	5500	5500
208	Denmark	2730	2730	2730	2730	2730	2728	2378	2120	3170	3420	8020	7330	7540	7071
212	Dominica	8	8	8	8	8	8	8	20	20	20	20	20	20	20
214	Dominican Republic	53	104	155	298	441	530	759	12000	12000	11970	11970	11970	11970	11970
218	Ecuador	444	573	702	775	848	1269	1110	49190	50930	50950	50040	49860	30874	30940
222	El Salvador	99	112	125	138	151	163	176	5296	5171	6000	4573	6300	6035	5823
226	Equatorial Guinea	1250	1250	1250	1250	1250	1250	1250	1040	1040	1040	28	746	1040	1040
231	Ethiopia	2717	2717	2717	4321	5926	7776	9627	200000	200000	200000	208440	213960	220310	217640
232	Eritrea	0	30	60	73	85	146	164	69000	69670	69670	69000	69000	69000	69000
233	Estonia	61	62	62	64	65	67	68	2470	1400	1300	3899	4669	4790	4920
234	Faroe Islands	1	1	1	1	1	1	1	0	0	0	0	0	0	0
238	Falkland Islands (Malvinas)	0	0	0	0	0	0	0	11900	12100	11309	11324	11240	11145	11416
239	South Georgia and the South Sandwich Islands	0	0	0	0	0	0	0	0	0	0	0	0	0	0
242	Fiji	848	1051	1255	1458	1662	1865	2069	1730	1730	1750	1750	1750	1750	1750
246	Finland	219	233	247	290	334	336	336	1230	1100	210	6480	6740	6850	7870
250	France	0	0	0	0	0	0	0	114476	109206	104321	131322	130507	127522	126135
254	French Guiana	7	7	7	7	7	7	8	90	100	110	70	93	125	142
258	French Polynesia	28	44	61	61	62	62	62	200	200	200	200	200	200	200
260	French Southern Territories	0	0	0	0	0	0	0	0	0	0	0	0	0	0
262	Djibouti	0	0	0	0	0	0	2	13350	14000	15500	17000	17000	17000	17000
266	Gabon	300	300	300	300	300	300	300	21000	19700	19390	19400	19400	19480	19400
268	Georgia	540	569	599	659	720	720	720	3910	3720	3070	2000	1700	1600	1600
270	Gambia	18	18	18	18	18	18	18	3910	3720	3070	2000	1700	1600	1600

Country	Name	Forestry plantation in km ² , source FAO							Grazing (permanent + temporary meadows) in km ² , source FAO						
		1992*	1995*	2000	2005*	2010	2015	2020	1992	1995	2000	2005	2010	2015	2020
275	Occupied Palestinian Territory	0	0	0	0	0	0	0	2770	2770	2770	2770	2770	2770	2770
276	Germany	0	0	0	0	0	0	0	53290	52710	51140	66320	70880	75080	75840
288	Ghana	500	500	500	1350	2200	2605	2971	84000	84000	79478	74677	74205	74611	73827
292	Gibraltar	0	0	0	0	0	0	0	0	0	0	0	0	0	0
296	Kiribati	0	0	0	0	0	0	0	0	0	0	0	0	0	0
300	Greece	1178	1231	1285	1337	1389	1389	1389	52200	52500	48000	43190	38740	28730	28820
304	Greenland	2	2	2	2	2	2	2	2371	2380	2395	2410	2425	2431	2431
308	Grenada	2	2	2	2	2	2	2	10	10	10	10	10	10	10
312	Guadeloupe	5	5	5	5	5	5	5	230	240	250	210	350	275	259
316	Guam	0	0	0	0	0	0	0	80	80	80	80	80	80	80
320	Guatemala	180	225	270	507	745	958	1172	25000	26020	25000	25000	18330	17990	18110
324	Guinea	100	125	150	175	200	210	250	107000	107000	107000	107000	107000	107000	107000
328	Guyana	0	0	0	0	0	0	0	5826	5940	6120	6605	7127	7620	7813
332	Haiti	120	160	200	240	280	320	320	4960	4950	4900	4900	4900	4900	4900
334	Heard Island and McDonald Islands	0	0	0	0	0	0	0	0	0	0	0	0	0	0
340	Honduras	0	0	0	0	0	0	0	15000	15300	15100	17000	17620	18170	19150
348	Hungary	1506	1506	1506	1506	1506	1410	1300	11730	11480	11470	10810	10140	7760	8610
352	Iceland	0	0	0	0	0	0	0	17650	17650	17600	18760	18670	18660	18660
356	India	35140	53405	71670	84175	96681	98540	100390	114040	109660	108960	104840	103440	102650	102610
360	Indonesia	1455	19967	38480	40173	41865	46684	45257	117270	118000	111770	110000	110000	110000	110000
364	Iran (Islamic Republic of)	5157	5157	5157	7283	9410	9410	10009	450000	455000	460000	466000	294770	294770	294770
368	Iraq	608	623	638	654	670	704	898	40000	40000	40000	40000	40000	40000	40000
372	Ireland	3804	4647	5489	5943	6396	6578	6742	34100	33730	33390	38810	41919	40990	41590
376	Israel	0	0	0	0	0	0	0	1450	1450	1410	1330	1400	1400	1580
380	Italy	1311	1283	1255	1250	1245	1264	1283	42040	45590	43770	43540	64310	60370	54560
384	Cote d'Ivoire	67	103	140	140	140	140	140	130000	130000	130000	132000	132000	132000	132000
388	Jamaica	88	85	82	83	83	83	84	2500	2290	2290	2290	2290	2290	2290
392	Japan	0	0	0	0	0	0	0	4500	4500	4050	6350	6190	10190	9700
398	Kazakhstan	0	0	0	0	0	0	0	1862620	1868230	1828800	1840720	1820477	1871972	1861561

Country	Name	Forestry plantation in km ² , source FAO							Grazing (permanent + temporary meadows) in km ² , source FAO						
		1992*	1995*	2000	2005*	2010	2015	2020	1992	1995	2000	2005	2010	2015	2020
400	Jordan	469	469	469	469	469	469	469	7910	7910	7910	7430	7420	7420	7420
404	Kenya	1528	1528	1528	1528	1528	1528	1528	213000	213000	213000	213000	213000	213000	213000
408	Democratic People's Republic of Korea	11300	10926	10552	10379	10205	10037	9873	500	500	500	500	500	500	500
410	Republic of Korea	19092	19908	20723	21539	22355	22813	22633	700	630	550	570	580	573	560
414	Kuwait	35	42	49	56	63	63	63	1360	1360	1360	1360	1360	1360	1360
417	Kyrgyzstan	0	0	0	0	0	0	0	87000	90000	92910	93640	92663	92013	90058
418	Lao People's Democratic Republic	60	120	180	650	1120	1400	1680	8000	8000	8150	7600	7000	6750	6750
422	Lebanon	0	0	0	0	0	0	0	3000	3000	3175	3600	4000	4000	4000
426	Lesotho	53	53	53	53	53	53	53	20000	20000	20000	20000	20000	20000	20000
428	Latvia	0	0	0	33	66	125	184	8200	8000	6180	6210	6590	6570	6350
430	Liberia	12	55	98	141	184	227	270	6370	7278	7891	9154	10317	11230	12540
434	Libyan Arab Jamahiriya	2170	2170	2170	2170	2170	2170	2170	133000	133000	133000	133000	133000	133000	133000
438	Liechtenstein	0	0	0	0	0	0	0	30	30	30	34	34	34	38
440	Lithuania	0	0	0	0	0	0	0	4600	4960	5000	11927	10889	11117	10010
442	Luxembourg	0	0	0	0	0	0	0	735	607	714	650	674	796	807
450	Madagascar	2310	2515	2720	3435	4150	3120	3120	330000	330000	360000	372930	372950	372950	372950
454	Malawi	1391	1286	1180	1074	968	862	757	18400	18400	18500	18500	18500	18500	18500
458	Malaysia	19347	17811	16275	14682	13089	17080	16971	2780	2810	2850	2850	2850	3805	3770
462	Maldives	0	0	0	0	0	0	0	10	10	10	10	10	10	10
466	Mali	0	0	0	0	0	0	0	300000	320000	330000	350000	350010	350010	350010
470	Malta	0	0	0	0	0	0	0	0	0	0	0	0	0	0
474	Martinique	24	25	26	26	27	27	27	190	140	110	110	195	148	157
478	Mauritania	0	0	0	0	0	0	0	392500	392500	392500	392500	392500	392500	392500
480	Mauritius	0	0	0	0	0	0	0	70	70	70	70	70	70	70
484	Mexico	388	367	345	482	619	755	755	814580	813030	810130	807320	769110	759150	757910
496	Mongolia	44	67	90	96	101	77	77	1247610	1171470	1290910	1129758	1130520	1123643	1121006
498	Moldova, Republic of	0	0	0	0	0	0	0	3580	3670	3740	3840	3540	3490	3411
499	Montenegro	80	80	80	80	80	80	80	7963	7982	7039	7073	4520	2180	2421
500	Montserrat	0	0	0	0	0	0	0	10	10	10	10	10	10	10

Country	Name	Forestry plantation in km ² , source FAO							Grazing (permanent + temporary meadows) in km ² , source FAO						
		1992*	1995*	2000	2005*	2010	2015	2020	1992	1995	2000	2005	2010	2015	2020
504	Morocco	3184	3314	3443	4337	5231	5768	6346	209000	210000	210000	210000	210000	210000	214660
508	Mozambique	380	380	380	463	546	660	743	317490	323360	330410	334863	336743	345416	354638
512	Oman	0	0	0	0	0	0	0	10000	10000	10000	14160	13974	13706	14009
516	Namibia	0	0	0	0	0	0	0	380000	380000	380000	380000	380000	380000	380000
520	Nauru	0	0	0	0	0	0	0	0	0	0	0	0	0	0
524	Nepal	879	1128	1377	1791	2206	2206	2206	17940	17910	17860	17880	17930	17953	17953
528	Netherlands	310	175	40	40	40	30	30	10800	10510	10180	10121	10171	9935	9870
530	Netherlands Antilles	0	0	0	0	0	0	0	0	0	0	0	0	0	0
533	Aruba	0	0	0	0	0	0	0	0	0	0	0	0	0	0
540	New Caledonia	90	94	98	101	104	104	104	2140	2180	2310	2260	1950	1748	1743
548	Vanuatu	0	0	0	0	0	0	0	350	370	420	420	420	420	420
554	New Zealand	15311	17781	20251	20247	20243	20251	20845	137150	133630	133000	114070	109480	104590	99090
558	Nicaragua	3	13	23	91	160	411	663	25600	26550	29360	30160	31600	32750	32750
562	Niger	480	605	730	855	980	1100	1225	220000	220000	230000	243120	287820	287820	287820
566	Nigeria	2653	2571	2489	2408	2326	2244	2163	297290	293041	254207	253372	289537	279702	286235
570	Niue	0	0	0	0	0	0	0	10	10	10	10	10	10	10
574	Norfolk Island	1	1	1	1	1	1	1	10	10	10	10	10	10	10
578	Norway	1150	1150	1150	1150	1150	1080	1080	1180	1290	1510	6550	6576	6542	6587
580	Northern Mariana Islands	0	0	0	0	0	0	0	20	20	10	10	12	12	4
583	Micronesia (Federated States of)	203	187	172	157	142	142	142	30	30	30	30	30	30	30
584	Marshall Islands	0	0	0	0	0	0	0	30	30	30	30	30	1	1
585	Palau	0	0	0	0	0	0	0	20	20	20	20	20	20	20
586	Pakistan	2539	2539	2539	2539	2539	2539	2539	50000	50000	50000	50000	50000	50000	50000
591	Panama	111	219	328	443	559	614	657	14800	14700	14770	15246	15116	15380	15380
598	Papua New Guinea	608	608	608	608	608	608	608	1400	1550	1800	1900	1900	1900	1900
600	Paraguay	102	204	305	407	508	985	1557	122046	134970	170460	146369	158796	170000	170000
604	Peru	2630	4890	7151	8425	9699	10572	10885	179160	173040	177190	181340	185480	188000	188000
608	Philippines	2906	3056	3206	3356	3506	3655	3805	12700	12800	14500	15000	15000	15000	15000
612	Pitcairn Island	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Country	Name	Forestry plantation in km ² , source FAO							Grazing (permanent + temporary meadows) in km ² , source FAO						
		1992*	1995*	2000	2005*	2010	2015	2020	1992	1995	2000	2005	2010	2015	2020
616	Poland	0	0	0	0	0	40	0	40380	40550	40340	33650	31800	31200	31500
620	Portugal	5740	5985	6230	6515	6800	6950	6950	8380	10000	14370	16320	17846	18458	19325
624	Guinea-Bissau	2	3	4	5	7	9	11	10800	2155	1467	1669	2091	2313	2651
626	Timor-Leste	0	0	0	0	0	0	0	1500	1500	1500	1500	1500	1500	1500
630	Puerto Rico	0	0	0	0	0	0	0	3150	2320	1613	1146	1142	1093	1027
634	Qatar	0	0	0	0	0	0	0	500	500	500	500	500	500	500
638	Reunion	97	97	97	97	97	97	97	120	120	90	90	119	122	122
642	Romania	0	0	0	0	0	0	0	47780	48720	49360	53440	51980	54850	51950
643	Russian Federation	0	0	0	0	0	0	0	879230	873070	899700	920240	920520	920520	920520
646	Rwanda	1130	1198	1265	1323	1380	1440	1500	6900	5450	5450	4550	4400	4100	4100
654	Saint Helena, Ascension and Tristan da Cunha	0	0	0	0	0	0	0	80	80	80	80	80	80	80
652	Saint Barthélemy	0	0	0	0	0	0	0	0	0	0	0	0	0	0
659	Saint Kitts and Nevis	0	0	0	0	0	0	0	20	20	20	10	13	9	9
660	Anguilla	0	0	0	0	0	0	0	0	0	0	0	0	0	0
662	Saint Lucia	32	32	32	32	32	32	32	20	20	14	11	6	6	6
663	Saint Martin	0	0	0	0	0	0	0	0	0	0	0	0	0	0
666	Saint Pierre and Miquelon	0	0	0	0	0	0	0	0	0	0	0	0	0	0
670	Saint Vincent and the Grenadines	0	0	1	1	1	2	2	20	20	20	20	20	20	20
674	San Marino	0	0	0	0	0	0	0	0	0	0	0	0	0	0
678	Sao Tome and Principe	0	0	0	0	0	0	0	10	10	10	10	10	10	10
682	Saudi Arabia	0	0	0	0	0	0	0	1200000	1340000	1700000	1700000	1700000	1704180	1700000
686	Senegal	320	320	320	320	320	320	320	57000	57000	56500	56500	56000	56000	56000
688	Serbia	0	0	0	106	212	237	344	13157	13188	11631	11687	7150	7132	6760
690	Seychelles	49	49	49	49	49	49	49	0	0	0	0	0	0	0
694	Sierra Leone	67	73	79	112	146	180	213	22040	22000	22000	22000	22000	22000	22000
702	Singapore	0	0	0	0	0	0	0	0	0	0	0	0	0	0
703	Slovakia	0	4	9	48	88	87	85	8179	8350	8560	5140	5850	5842	5800
704	Viet Nam	7450	13323	19196	25014	30833	38863	43494	3260	3280	6420	6420	7010	6833	6420

Country	Name	Forestry plantation in km ² , source FAO							Grazing (permanent + temporary meadows) in km ² , source FAO						
		1992*	1995*	2000	2005*	2010	2015	2020	1992	1995	2000	2005	2010	2015	2020
705	Slovenia	0	0	0	0	0	0	0	3280	3190	2980	3080	3900	3777	3763
706	Somalia	30	30	30	30	30	30	30	430000	430000	430000	430000	430000	430000	430000
710	South Africa	12700	12700	12700	12700	12700	12700	12700	828000	835000	839280	839280	839280	839280	839280
716	Zimbabwe	1540	1370	1200	1140	1080	1080	1080	101300	105200	111900	121000	121000	121000	121000
724	Spain	7585	8455	9325	9738	10150	10167	10043	102820	106870	114500	121630	117530	105380	105030
728	South Sudan	1879	1879	1879	1879	1879	1879	1879	383280	393733	400196	405371	408461	257732	257732
729	Sudan	1200	1225	1250	1260	1270	1300	1300	716720	736267	748354	758029	763809	481950	481950
732	Western Sahara	0	0	0	0	0	0	0	50000	50000	50000	50000	50000	50000	50000
740	Suriname	130	130	130	130	130	130	130	210	210	210	185	174	172	160
744	Svalbard and Jan Mayen Islands	0	0	0	0	0	0	0	0	0	0	0	0	0	0
748	Swaziland	1638	1535	1432	1328	1225	1122	1019	10320	10320	10320	10320	10320	10320	10320
752	Sweden	5900	5900	5900	6365	6830	3820	3820	5680	5760	4470	14256	15033	15456	15035
756	Switzerland	8	8	8	8	8	8	8	11703	11442	11353	12479	12373	12249	12094
760	Syrian Arab Republic	1488	1608	1728	1846	1964	1964	2114	79360	82990	82650	82790	82440	81880	81880
762	Tajikistan	776	778	780	780	780	802	807	35040	35000	36820	37730	38750	38750	38750
764	Thailand	17200	18535	19870	26145	32420	37020	35370	7900	8000	8000	8000	8000	8000	8000
768	Togo	165	219	272	325	379	432	486	10000	10000	10000	10000	10000	10000	10000
776	Tonga	10	10	10	10	10	10	10	40	40	40	40	40	40	40
780	Trinidad and Tobago	600	600	600	600	600	600	600	60	60	70	70	70	70	70
784	United Arab Emirates	0	0	0	0	0	0	0	2500	2900	3000	3000	3000	3000	3000
788	Tunisia	505	546	586	622	657	686	716	43350	44700	45120	48850	48530	48410	47500
792	Turkey	5460	5508	5557	5889	6220	6981	7173	123780	123780	135000	146170	146170	146170	146170
795	Turkmenistan	0	0	0	0	0	0	0	338000	337000	336500	329500	321550	318380	318380
796	Turks and Caicos Islands	0	0	0	0	0	0	0	0	0	0	0	0	0	0
798	Tuvalu	0	0	0	0	0	0	0	0	0	0	0	0	0	0
800	Uganda	1700	2192	2684	3176	3668	4160	4652	51120	51120	51120	51120	53150	53150	53150
804	Ukraine	3030	3170	3310	3370	3430	3680	3700	74730	75040	78380	91473	91550	89170	84970
807	The former Yugoslav Republic of Macedonia	0	0	0	0	0	0	0	6450	6350	6490	7530	5580	8110	8050
818	Egypt	0	0	0	0	0	0	0	0	0	0	6533	5873	4651	5549

Country	Name	Forestry plantation in km ² , source FAO							Grazing (permanent + temporary meadows) in km ² , source FAO						
		1992*	1995*	2000	2005*	2010	2015	2020	1992	1995	2000	2005	2010	2015	2020
826	United Kingdom of Great Britain and Northern Ireland	0	0	0	0	0	0	0	115100	114370	112510	124290	124740	123496	124188
831	British channel islands	1	1	1	2	2	2	0	0	0	0	0	0	0	0
833	Isle of Man	0	0	0	0	0	0	201	220	251	409	384	353	368	
834	United Republic of Tanzania	5530	5530	5530	5530	5530	5530	215590	227780	239000	240000	240000	240000	240000	
840	United States of America	60900	74060	87220	106615	126010	131440	140290	2391720	2370000	2358190	2622900	2579347	2507206	2509690
850	United States Virgin Islands	0	0	0	0	0	0	50	50	40	30	20	20	22	
854	Burkina Faso	7	21	34	48	61	75	89	60000	60000	60000	60000	60000	60000	60000
858	Uruguay	2010	4150	6290	8041	9791	10710	11820	136220	135960	135520	136640	130620	125206	125400
860	Uzbekistan	6168	7962	9756	11417	13078	15986	14584	228700	228000	225000	219310	212110	211260	211025
862	Venezuela	4210	5423	6637	7670	8704	12348	12378	182450	182400	182400	182400	182000	182000	182000
876	Wallis and Futuna	2	3	4	5	5	6	6	0	0	0	0	0	0	0
882	Samoa	29	32	34	37	39	41	44	20	20	25	30	50	100	121
887	Yemen	0	0	0	0	0	0	0	220000	220000	220000	220180	220180	220180	220180
894	Zambia	570	560	550	542	534	494	454	180500	186000	194800	200000	200000	200000	200000

(*) Forestry data: 1990 FRA data was used for the 1992 claims. FRA does not provide data for 1995 and 2005. For 1995 the average of 1990 and 2000 data was used. For the 2005 the average of 2000 and 2010 data was used.

Annex 4: GLOBIO4 LULC and aggregated output categories

Code	GLOBIO LULC Description	Non-Allocatable	Grazing preference	Forestry preference	Aggregated LULC	LC_Forest	LC_Natural
0	No data/Undefined	0	0	0	0		
1	Urban-settlement	1	0	1	1		
10	Cropland	1	0	1	2		
11	Cropland intensive use	1	0	1	2		
12	Cropland minimal use	1	0	1	2		
13	Mosaic cropland (>50%) / natural vegetation (tree shrub herbaceous cover) (<50%)	1	0	1	2		
14	Mosaic natural vegetation (tree shrub herbaceous cover) (>50%) / cropland (<50%)	1	0	1	2		
20	Grazing	0	3	1	4		
21	Intensive pastures	0	3	1	4		
22	Extensive rangelands	0	3	1	4		1
30	Forestry	0	0	0	3	1	1
40	Secondary vegetation	0	1	0	3		1
50	Tree cover broadleaved evergreen closed to open (>15%)	0	0	0	3	1	1
60	Tree cover broadleaved deciduous closed to open (>15%)	0	0	0	3	1	1
61	Tree cover broadleaved deciduous closed (>40%)	0	0	0	3	1	1
62	Tree cover broadleaved deciduous open (15-40%)	0	0	0	3	1	1
70	Tree cover needleleaved evergreen closed to open (>15%)	0	0	0	3	1	1
71	Tree cover needleleaved evergreen closed (>40%)	0	0	0	3	1	1
72	Tree cover needleleaved evergreen open (15-40%)	0	0	0	3	1	1
80	Tree cover needleleaved deciduous closed to open (>15%)	0	0	0	3	1	1
81	Tree cover needleleaved deciduous closed (>40%)	0	0	0	3	1	1

Code	GLOBIO LULC Description	Non-Allocatable	Grazing preference	Forestry preference	Aggregated LULC	LC_Forest	LC_Natural
82	Tree cover needleleaved deciduous open (15-40%)	0	0	0	3	1	1
90	Tree cover mixed leaf type (broadleaved and needleleaved)	0	0	0	3	1	1
100	Mosaic tree and shrub (>50%) / herbaceous cover (<50%)	0	0	0	3	1	1
110	Mosaic herbaceous cover (>50%) / tree and shrub (<50%)	0	1	0	4		1
120	Shrubland	0	2	1	6		1
121	Shrubland evergreen	0	2	1	6		1
122	Shrubland deciduous	0	2	1	6		1
130	Natural grassland	0	3	1	4		1
140	Lichens and mosses	0	1	1	6		1
150	Sparse vegetation (tree shrub herbaceous cover) (<15%)	0	2	1	6		1
151	Sparse tree (<15%)	0	2	1	6		1
152	Sparse shrub (<15%)	0	2	1	6		1
153	Sparse herbaceous cover (<15%)	0	2	1	6		1
160	Tree cover flooded fresh or brakish water	0	0	1	3	1	1
170	Tree cover flooded saline water	0	0	1	3	1	1
180	Shrub or herbaceous cover flooded fresh/saline/brakish water	0	0	1	5		1
200	Bare areas	0	0	1	7		1
201	Consolidated bare areas	0	0	1	7		1
202	Unconsolidated bare areas	0	0	1	7		1
210	Water bodies	1	0	1	8		
220	Permanent snow and ice	0	0	1	9		1

Annex 5: GLOBI04 combined overall terrestrial MSA modules .glo file

```
#-----
# RUN_ALL.GLO
#-----

#-----
BEGIN_RUN Calculations()

#PBL GLOBI04 scenario folder setting (path from the BaseInDir: Y:\data\Globio\GLOBI04\Models\Terra\Projects).
#ProjectName should reflect the folder name under the Terra\Projects folder.
STRING ProjectName = GBW_GIS
#ScenarioName should reflect the name of the scenario folder name under the ScenarioRuns folder.
STRING ScenarioName = GBW

DIR BaseInDir = W:\Globio4Runs

#This will be scenario folder:
DIR ProjectScenario = $BaseInDir;\\$ProjectName;\\ScenarioRuns\\$ScenarioName;

#Set the scenario run year to refer to correct input and output data
STRING ScenarioYear = 2020

#If you are using custom lookup files and not the global ones
(Y:\data\GLOBI04\GLOBI04\Models\Terra\Shared\LookupGlobal), specify the LookupDir here.
#LookupDir = $BaseInDir;\\$ProjectName;\\<lookupfolder>
LookupDir = $BaseInDir;\\$ProjectName;\\SharedLookup

# Set input directory.
InDir = $ProjectScenario;\\input

# Set output directory.
DIR OutDir = $ProjectScenario;\\output
DIR OutDirOri = $ProjectScenario;\\output

# Set tmp directory.
TmpDir = $ProjectScenario;\\tmp

#Shared data folder.
DIR SharedData = $BaseInDir;\\$ProjectName;\\SharedData

# Set region.
#Extent = europe
Extent = wrld
#Extent = 30,30,50,40
STRING ExtentStr = World

# Set resolution.
CellSize = 10sec
STRING CellSizeStr = 10

# Save temporary data?
#SaveTmpData = True
SaveTmpData = False

# Set input\output rasters.

# Climate change module
RASTER ClimateChangeMSA_wbvert = $OutDir;\\ClimateChangeMSA_\\$ScenarioYear;\\$ExtentStr;\\wbvert.tif
RASTER ClimateChangeMSA_plants = $OutDir;\\ClimateChangeMSA_\\$ScenarioYear;\\$ExtentStr;\\plants.tif

# Land use module
RASTER LanduseMSA_wbvert = $OutDir;\\LanduseMsa_\\$ScenarioYear;\\$ExtentStr;\\wbvert.tif
RASTER LanduseMSA_plants = $OutDir;\\LanduseMsa_\\$ScenarioYear;\\$ExtentStr;\\plants.tif

# Nitrogen deposition module
RASTER NDepositionMSA = $OutDir;\\NDepositionMSA_\\$ScenarioYear;\\$ExtentStr;.tif
RASTER NDepositionMSA_plants = $OutDir;\\NDepositionMSA_\\$ScenarioYear;\\$ExtentStr;\\plants.tif

#Human encroachment module
RASTER HumanEncroachmentMSA = $OutDir;\\HumanEncroachmentMSA_\\$ScenarioYear;\\$ExtentStr;.tif
RASTER HumanEncroachmentMSA_wbvert = $OutDir;\\HumanEncroachmentMSA_\\$ScenarioYear;\\$ExtentStr;\\wbvert.tif

# Infrastructure fragmentation module
RASTER InfraFragmentationMSA = $OutDir;\\InfraFragmentationMSA_\\$ScenarioYear;\\$ExtentStr;.tif
RASTER InfraFragmentationMSA_wbvert = $OutDir;\\InfraFragmentationMSA_\\$ScenarioYear;\\$ExtentStr;\\wbvert.tif
```

```

# Infrastructure disturbance module
RASTER InfraDisturbanceMSA = $OutDir;\InfraDisturbanceMSA_$ScenarioYear;_ExtentStr;.tif
RASTER InfraDisturbanceMSA_wbvert = $OutDir;\InfraDisturbanceMSA_$ScenarioYear;_ExtentStr,_wbvert.tif

# Terrestrial MSA module
RASTER TerrestrialMSA = $OutDir;\TerrestrialMSA_$ScenarioYear;_ExtentStr;.tif
RASTER TerrestrialMSA_wbvert = $OutDir;\TerrestrialMSA_ScenarioYear;_ExtentStr,_wbvert.tif
RASTER TerrestrialMSA_plants = $OutDir;\TerrestrialMSA_ScenarioYear;_ExtentStr,_plants.tif
RASTER AreaRaster = $SharedData;\areakm2_$CellSizeStr;sec.tif
RASTER TerrestrialMSA_area = $OutDir;\TerrestrialMSA_area_ScenarioYear;_ExtentStr;.tif

#-----
# Start running.
#-----

# Modules below part of 2nd run
RUN_MODULE CalcTerrestrialMSA($Extent,$CellSize,$LanduseMSA_wbvert,
                               $HumanEncroachmentMSA_wbvert,NONE,
                               $ClimateChangeMSA_wbvert,$InfraDisturbanceMSA_wbvert,
                               $InfraFragmentationMSA_wbvert,$TerrestrialMSA_wbvert)

RUN_MODULE CalcTerrestrialMSA($Extent,$CellSize,$LanduseMSA_plants,NONE,
                               $NDepositionMSA_plants,$ClimateChangeMSA_plants,
                               NONE,NONE,$TerrestrialMSA_plants)

RUN_MODULE CalcOverallTerrestrialMSA($Extent,
                                     $CellSize,
                                     $TerrestrialMSA_wbvert,
                                     $TerrestrialMSA_plants,
                                     $AreaRaster,
                                     $TerrestrialMSA,
                                     $TerrestrialMSA_area)

END_RUN

#-----
#-----

RUN Calculations()

```