Description of European RS-EBV's and abiotic site conditions

This document gives an overview of the abiotic map layers and Remote Sensing based Essential Biodiversity Variables (RS-EBVs) (together denoted as predictors) that can be used in this web application for habitat monitoring using the Maxent model.

The model can be executed using a selection of the 30 predictors, compromising abiotic parameters (climate, soil and topography) and a number of different RS-EBVs. All predictors have the same extent (EU) and a spatial resolution of $1 \times 1 km^2$.

Abiotic predictors

Climate and topography, but also soil are found to be good predictors for modelling the distributions of plant species. In this study the following predictors have been selected.

Climate

These are a collection of climatic and specific bioclimatic (BIO) variables:

- Potential Evapotranspiration ($mm\ yr^{-1}$) (source)
- Solar radiation ($\times$ 365/8 $kWh\ m^{-2}$) (source)
- Temperature Seasonality (standard deviation *100, degrees Celsius) (BIO4) (source)
- Mean Temperature of Wettest Quarter (degrees Celsius) (BIO8) (source)
- Annual Precipitation ($mm\ yr^{-1}$) (BIO12) (source)
- Precipitation Seasonality (%) (Coefficient of Variation) (BIO15) (source)
- Precipitation of Warmest Quarter (mm) (BIO18) (source)

References:

O'Donnel, M. S., & Ignizio, D. A. (2012). Bioclimatic predictors for supporting ecological applications in the conterminous United States (No. 691). US Geological Survey.

Fick, S.E. and R.J. Hijmans, 2017. Worldclim 2: New 1-km spatial resolution climate surfaces for global land areas. International Journal of Climatology.

Link to 1-km climate layers (EU extent):
https://www.synbiosys.alterra.nl/nextgeoss/predictors/eu/climate.zip

Soil

Soil data is taken from SoilGrids (source). SoilGrids is a system for automated soil mapping based on state-of-the-art spatial predictions methods. SoilGrids predictions are based on globally fitted models using soil profile and environmental covariate data. Currently, SoilGrids serves a collection of updatable soil property and class maps of the world at 1km/250m spatial resolutions produced using automated soil mapping based on machine learning algorithms.

SoilGrids provides predictions for the following list of standard soil properties and classes:

- Soil organic carbon content in ‰ ($g\ kg^{-1}$)
- Soil pH in H2O and KCl solution
- Sand, silt and clay (weight %)
- Bulk density ($kg\ m^{-3}$) of the fine earth fraction (< 2mm)
- Cation-exchange capacity (CEC) (cmol + /kg) of the fine earth fraction
- Coarse fragments (volumetric %)
- Depth to bedrock (cm) and occurrence of R horizon
- World Reference Base (WRB) class—at present
- United States Department of Agriculture (USDA) Soil Taxonomy suborders

For the habitat modelling we have selected the following soil maps as predictors:

- Bulk density of the soil (kg m^{-3})
- Cation-exchange capacity (CEC) of the soil
- Weight in % of clay particles (<0.0002 mm)
- Volume % of coarse fragments (> 2 mm)
- Soil organic carbon content (‰)
- Soil pH (water)
- Weight in % of silt particles (0.0002-0.05 mm)
- Weight in % of sand particles (0.05-2 mm)

Link to 1-km abiotic - soil layers (EU extent):
https://www.synbiosys.alterra.nl/nextgeoss/predictors/eu/Soil.zip

References:

Hengl, T., de Jesus, J. M., Heuvelink, G. B., Gonzalez, M. R., Kilibarda, M., Blagotić, A., ... & Guevara, M. A. (2017). SoilGrids250m: Global gridded soil information based on machine learning. PLoS one, 12(2), e0169748.

Hengl, T., de Jesus, J. M., MacMillan, R. A., Batjes, N. H., Heuvelink, G. B., Ribeiro, E., ... & Gonzalez, M. R. (2014). SoilGrids1km—global soil information based on automated mapping. PLoS One, 9(8), e105992.

Shangguan, W., Hengl, T., Mendes de Jesus, J., Yuan, H., & Dai, Y. (2017). Mapping the global depth to bedrock for land surface modeling. *Journal of Advances in Modeling Earth Systems*, *9*(1), 65-88.

Topography

As data source for elevation data (Digital Elevation Map, DEM) we have selected the EU-DEM (v1.1) of the Copernicus Land Monitoring Service (source). Link to 1-km DEM (EU extent):
https://www.synbiosys.alterra.nl/nextgeoss/predictors/eu/Topography.zip

Distance to water is also selected as a predictor for the habitat modelling. Link to 1-km distance-to-water layers (EU extent): https://www.synbiosys.alterra.nl/nextgeoss/predictors/eu/Topography.zip

RS-EBV's

Below an overview (and brief description) is given of the selected (defined) RS-EBV's that are currently available and relevant for habitat modelling.

Land Use Land Cover (LULC) – EBV class *Ecosystem structure*

Patterns in biodiversity are inherently spatial, and as such, can be estimated by analysing maps of land use and land cover (LULC). Here we selected the CORINE Land Cover (CLC) inventory (source). CLC was initiated in 1985 (reference year 1990). Updates have been produced in 2000, 2006, and 2012. It consists of an inventory of land cover in 44 classes.

In this study we selected CLC2012 (Corine Land Cover (CLC) 2012, Version 18.5.1), which is available at 250m. Link to 1-km LULC layer: https://www.synbiosys.alterra.nl/nextgeoss/predictors/eu/LULC.zip

Table 1: Class names CLC2012.

Grid No	Class name
1	Continuous urban fabric
2	Discontinuous urban fabric
3	Industrial or commercial units
4	Road and rail networks and associated land
5	Port areas

6	Airports
7	Mineral extraction sites
8	Dump sites
9	Construction sites
10	Green urban areas
11	Sport and leisure facilities
12	Non-irrigated arable land
13	Permanently irrigated land
14	Rice fields
15	Vineyards
16	Fruit trees and berry plantations
17	Olive groves
18	Pastures
19	Annual crops associated with permanent crops
20	Complex cultivation patterns
21	Land principally occupied by agriculture, with significant areas of natural vegetation
22	Agro-forestry areas
23	Broad-leaved forest
24	Coniferous forest
25	Mixed forest
26	Natural grasslands
27	Moors and heathland
28	Sclerophyllous vegetation
29	Transitional woodland-shrub
30	Beaches, dunes, sands
31	Bare rocks
32	Sparsely vegetated areas
33	Burnt areas
34	Glaciers and perpetual snow
35	Inland marshes
36	Peat bogs
37	Salt marshes
38	Salines
39	Intertidal flats
40	Water courses
41	Water bodies
42	Coastal lagoons
43	Estuaries
44	Sea and ocean
48	NODATA
49	UNCLASSIFIED LAND SURFACE
50	UNCLASSIFIED WATER BODIES
255	UNCLASSIFIED

Vegetation height – EBV class *Ecosystem structure*

Vegetation or canopy height information has been taken from the 3D global vegetation map, which has a spatial resolution of 1km (source) and is representative for the year ~2000.

Link to 1-km vegetation height layer (EU extent):
https://www.synbiosys.alterra.nl/nextgeoss/predictors/eu/VegHeight.zip

Reference:

Simard, M., Pinto, N., Fisher, J. B., & Baccini, A. (2011). Mapping forest canopy height globally with spaceborne lidar. Journal of Geophysical Research: Biogeosciences, 116(G4).

Net Primary Productivity (NPP) – EBV class *Ecosystem function*

Net Primary Productivity (NPP) defines the rate at which all plants in an ecosystem produce net useful chemical energy. In other words, NPP is equal to the difference between the rate at which plants in an ecosystem produce useful chemical energy (or GPP), and the rate at which they expend some of that energy for respiration.

As NPP product we have selected the MODIS-Terra MOD17A3H (MOD17A3.055) NPP-product, which provide annual NNP data at 500m spatial resolution for the years 2000-2014. We have selected the year 2014 (source), which has been resampled to 1km.

Link to 1-km NPP layer (EU extent): https://www.synbiosys.alterra.nl/nextgeoss/predictors/eu/NPP.zip

Reference:

Running, S., Mu, Q., Zhao, M. (2015). MOD17A3H MODIS/Terra Net Primary Production Yearly L4 Global 500m SIN Grid V006 [Data set]. NASA EOSDIS Land Processes DAAC. doi: 10.5067/MODIS/MOD17A3H.006

Inundation – EBV class *Ecosystem function*

The high resolution (30m) global surface water maps developed by the European Commission Joint Research Centre provide detailed information of the location and temporal distribution of surface waters at the global scale over the past 32 years (1984-2015) and provide valuable information for biodiversity studies (source).

The following inundation layers are available:

Table 2: Available inundation layers.

Inundation layer	Description
Change	The Water Occurrence Change Intensity product shows where surface water occurrence increased, decreased or remained invariant between 1984 and 2015. Both the direction of change (i.e. increase, decrease or no change) and its intensity are documented. The occurrence change accommodates for variations in data acquisition over time (i.e. temporal deepness and frequency density of the satellite observations) in order to provide a consistent occurrence change measurement. Decrease (0) < No change (100) < Increase (200) No data: 255
Extent	The Maximum Water Extent map is a simple monochrome layer that shows the maximum extent of detected water over the 1984-2015 period. 0: Land, 1: Water, No data: 255
Occurrence	The Water Occurrence dataset shows where surface water occurred between 1984 and 2015 and provides information concerning overall water dynamics. The occurrence is a measurement of the water presence frequency (expressed as a percentage of the available observations over time actually identified as water). 0% < occurrence < 100% (permanent water over 32 years) No data: 255
Seasonality	The Water Seasonality product provides information concerning the intra-annual behaviour of water surfaces. It separates 'permanent' water bodies (those that are present throughout the period of observation) [nominally a year] from 'seasonal' (those that are present for only part of the year); the degree of seasonality is also represented (i.e. the proportion of the total number of observed months in which water is present). 0 month < seasonality < 12 months (= permanent water) No data: 255
Recurrence	The Water Recurrence map documents the inter-annual variability of water availability. This map shows how frequently water returns from one year to another (expressed as a percentage). As for the occurrence, the recurrence is expressed as a percentage, but unlike the occurrence map the recurrence map is not necessarily computed on the full archive

	(1984 to 2015). The recurrence map's mapping period starts in the year in which water was first observed at any given location (not when the first valid observation was obtained), and ends with the year in which the water was last observed. 0% < recurrence < 100% A 100% water recurrence means that water is present every year from the beginning of the archive or since the first water observation year. Conversely low percentages characterize places where inundation is far from systematic, such that the lower the figure the greater the variability in inundation pattern. No data: 255
Transitions	The Water Transitions map documents changes in water state between the first year and the last year of observation. Classes: 1. New permanent water surfaces (i.e. conversion of a no water place into a permanent water place.) 2. Unchanging permanent water surfaces 3. Lost permanent water surfaces (i.e. conversion of a permanent water place into a no water place) 4. New seasonal water surfaces (i.e. conversion of a no water place into a seasonal water place) 5. Unchanging seasonal water surfaces 6. Lost seasonal water surfaces (i.e. conversion of a seasonal water place into a no water place) 7. Conversion of permanent water into seasonal water 8. Conversion of seasonal water into permanent water 9. Ephemeral permanent water (i.e. no water places replaced by permanent water that subsequently disappeared within the observation period) 10. Ephemeral seasonal water (i.e. no water places replaced by seasonal water that subsequently disappeared within the observation period) No data: 255

In this study the 30m spatial resolution inundation layers have been resampled to 1km. Resampling methods: average resampling and mode resampling (selects the value which appears most often of all the sampled points)).

Link to 1-km inundation layers (EU extent):
https://www.synbiosys.alterra.nl/nextgeoss/predictors/eu/inundation.zip

References:

Pekel, J. F., Cottam, A., Gorelick, N., & Belward, A. S. (2016). High-resolution mapping of global surface water and its long-term changes. Nature, 540(7633), 418.

Phenology – EBV class *Ecosystem function*

Plant phenology is one of the biodiversity indicators that can be derived from time series of satellite images. Here, time series of NDVI images are used. The NDVI is a measure of the green biomass present at the earth surface and has values between 0 (no vegetation, rocks, desert) and 1 (evergreen tropical forest). An annual time series of NDVI images reflects the vegetation dynamics or plant phenology.

In order to extract the characteristics of the vegetation dynamics, a Fourier analysis is performed on the NDVI images. The Harmonic Analysis of NDVI Time Series (HANTS) algorithm is used to process and analyse the time series of satellite images. HANTS is applied on the MODIS-Terra MOD13Q1 NDVI-product, which is a 16-day NDVI-composite available since February 2000.

The processing of the time series of NDVI images into phenology parameters consists of 2 steps. The first step is to remove errors and outliers (e.g. cloud contaminated pixels and snow) in an iterative process, which results into a reconstructed continuous time series of NDVI. The second step is the extraction of the phenological parameters from the HANTS output.

As the cloud/snow presence can be extreme over large areas in Northern Europe, data gaps over large periods (several months) do occur. To overcome this problem, the HANTS method is first applied over an average year of good quality MODIS pixels, extracted from the time span 2010-2016.

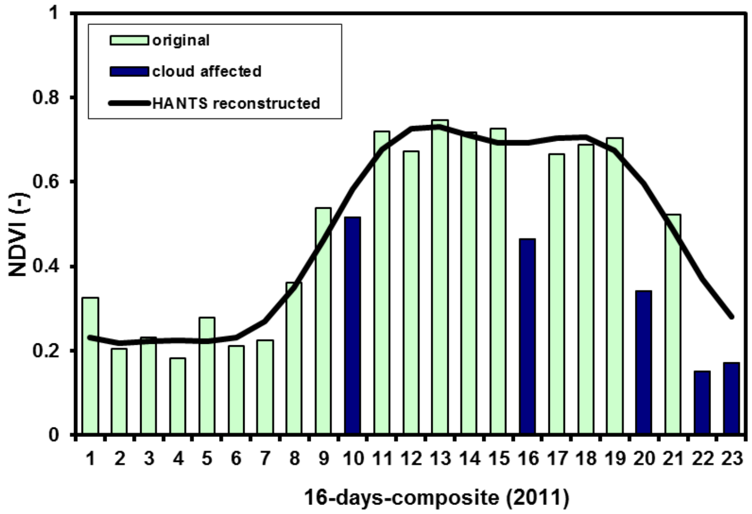

Figure 1: Removal of cloud contaminated data from the NDVI time series.

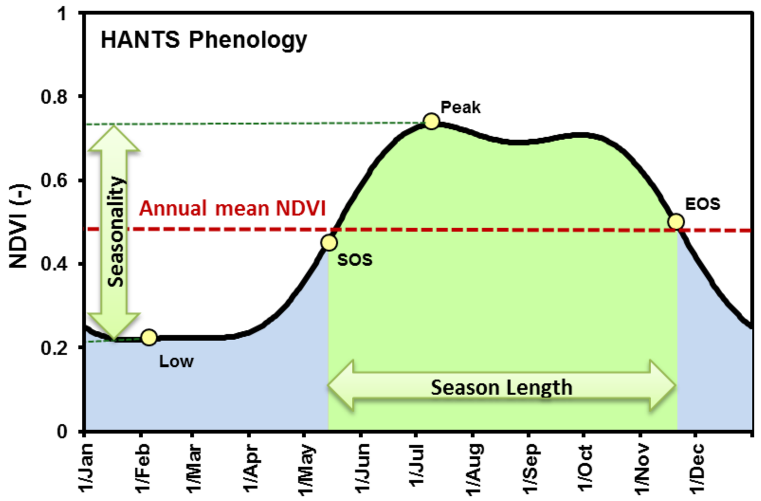

Figure 2: Derivation of phenological parameters from reconstructed NDVI time series.

From the HANTS Fourier components a set of nine phenology indicators are derived:

#	HANTS Phenology Parameter	Unit	Method	Phenological description
1	Mean annual NDVI	NDVI [0..10000] (scale factor 0.0001)	Average NDVI value of the annual NDVI time series	Average greenness of the year
2	Seasonality	NDVI [0..10000] (scale factor 0.0001)	Difference between the maximum and minimum NDVI of the year	Difference in greenness between summer and winter
3	Start of Season (SoS)	Day of the year [1..366]	Day with the highest NDVI increase	Characterisation when the start of the (largest) growing season occurs within a year

4	Length of Season (LoS)	Number of days [1..366]	Absolute difference between end and start of season	Characterisation of the length of the (strongest) growing season within a year
5	End of Season (EoS)	Day of the year [1..366]	Day with the highest NDVI decrease	Characterisation when the end of the (largest) growing season occurs within a year
6	Peak of Season	Day of the year [1..366]	Day with the highest NDVI value within a year	Characterisation when the peak of the (largest) growing season occurs within a year
7	Peak NDVI	NDVI [0..10000] (scale factor 0.0001)	Maximum NDVI within a year	Quantification of the maximum greenness within the year
8	Low of Season	Day of the year [1..366]	Day with the lowest NDVI value within a year	Characterisation when the minimum of the (largest) growing season occurs within a year
9	Low NDVI	NDVI [0..10000] (scale factor 0.0001)	Minimum NDVI within a year	Quantification of the minimum greenness within the year

In this study the 250m phenological parameters have been resampled to 1km. Link to 1-km phenological maps (EU extent): https://www.synbiosys.alterra.nl/nextgeoss/predictors/eu/Phenology.zip

References:

Roerink, G. J., Menenti, M., & Verhoef, W. (2000). Reconstructing cloudfree NDVI composites using Fourier analysis of time series. *International Journal of Remote Sensing*, *21*(9), 1911-1917.

Roerink, G. J., Menenti, M., Soepboer, W., & Su, Z. (2003). Assessment of climate impact on vegetation dynamics by using remote sensing. Physics and Chemistry of the Earth, Parts A/B/C, 28(1-3), 103-109.

Leaf Area Index – EBV class *Ecosystem function*

The Leaf Area Index (LAI) is defined as half the total area of green elements of the canopy per unit horizontal ground area. The satellite-derived value corresponds to the total green LAI of all the canopy layers, including the understory which may represent a very significant contribution, particularly for forests. Practically, the LAI quantifies the thickness of the vegetation cover. LAI is recognized as an Essential Climate Variable (ECV) by the Global Climate Observing System (GCOS) (source).

In this study we have selected the LAI-product provided by the Copernicus Global Land Service (CGLS) (source). The LAI-product is part of the CGLS collection, consisting of LAI, fraction of photo synthetically active radiation (FAPAR), fraction of vegetation cover (FCover), derived from PROBA-V daily data at 300m resolution. The variables are calculated globally on a 10-daily basis.

Link to 1-km LAI maps (EU extent): https://www.synbiosys.alterra.nl/nextgeoss/predictors/eu/LAI.zip

LAI maps are representative for the periods:

- April 2017 (EU201704: LAI April 2017 [0 – 8 m2 / m2]), which is representative for spring season.
- July 2017 (EU201707: LAI July 2017 [0 – 8 m2 / m2]), which is representative for summer season.
- LAI images for winter and autumn are available. However, these images contain gaps do to missing data or 0-values caused by snow.

References:

MANUAL, P. U., LAI, L. A. I., & COVER, F. O. V. Gio Global Land Component-Lot I" Operation of the Global Land Component".