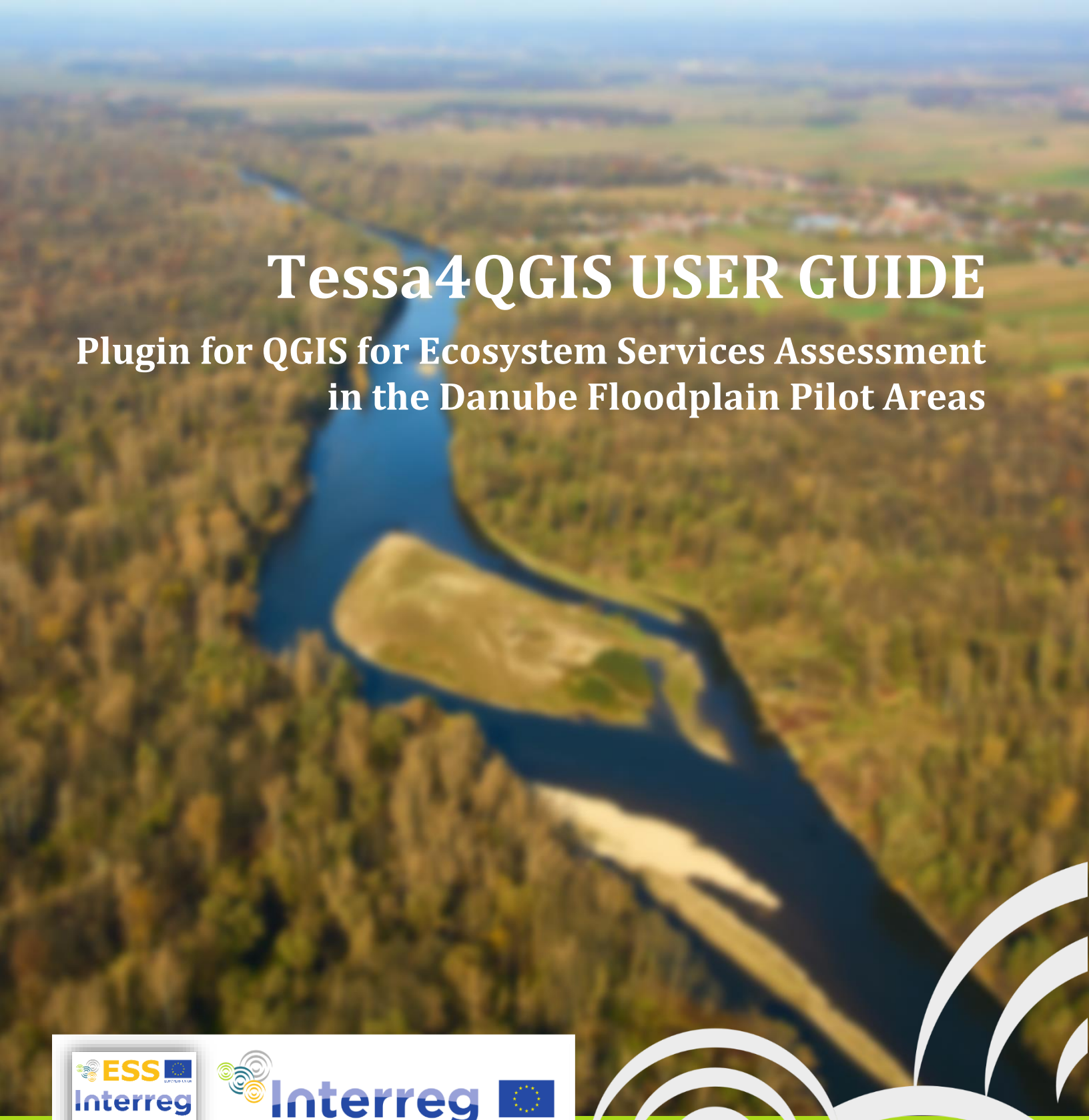

Tessa4QGIS USER GUIDE

Plugin for QGIS for Ecosystem Services Assessment in the Danube Floodplain Pilot Areas

ESS Interreg Danube Floodplain

Interreg Danube Transnational Programme Danube Floodplain

Project co-funded by European Union funds (ERDF, IPA)

Impressum

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Note of the authors:
This deliverable is adapted from the D 4.3.2: Deliverable 4.3.2. Method documentation describing the implementation of ESS and biodiversity to traditional CBA as input for D 4.3.4 and therefore of output 5.1 (Danube Floodplain 2021b).

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1. Introduction

1.1. Ecosystem Services

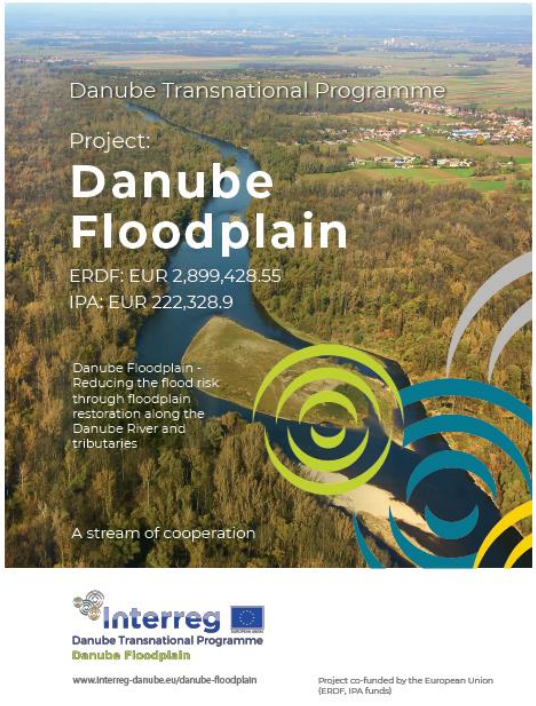
Ecosystem services (ESS) are the benefits that humans get from nature. Although the concept appears easy and their estimation could seem straightforward, many variables can affect ESS provision, which makes their estimation and their valuation a complex process.

This tool was created for facilitating a first estimation of ESS in the framework of the Danube Floodplain project, without forgetting the stakeholders of the pilot area. Their contribution is included in the tool as input data, in the form of ESS maps, produced from the collaboration among stakeholders, local project partners (PPs), and the Catholic University of Eichstätt-Ingolstadt (CUEI).

1.2. Background

The TESSA Toolkit (Peh et al. 2017) was used as theoretical background for the ESS estimation and in some cases for the ESS valuation. The Tool is the result of Deliverable 6.1.3 (Graphical User Interface for TESSA) of the Danube Floodplain Project.

Goal of the Danube Floodplain project is to improve the transnational water management and the flood risk prevention while maximizing benefits for biodiversity conservation.



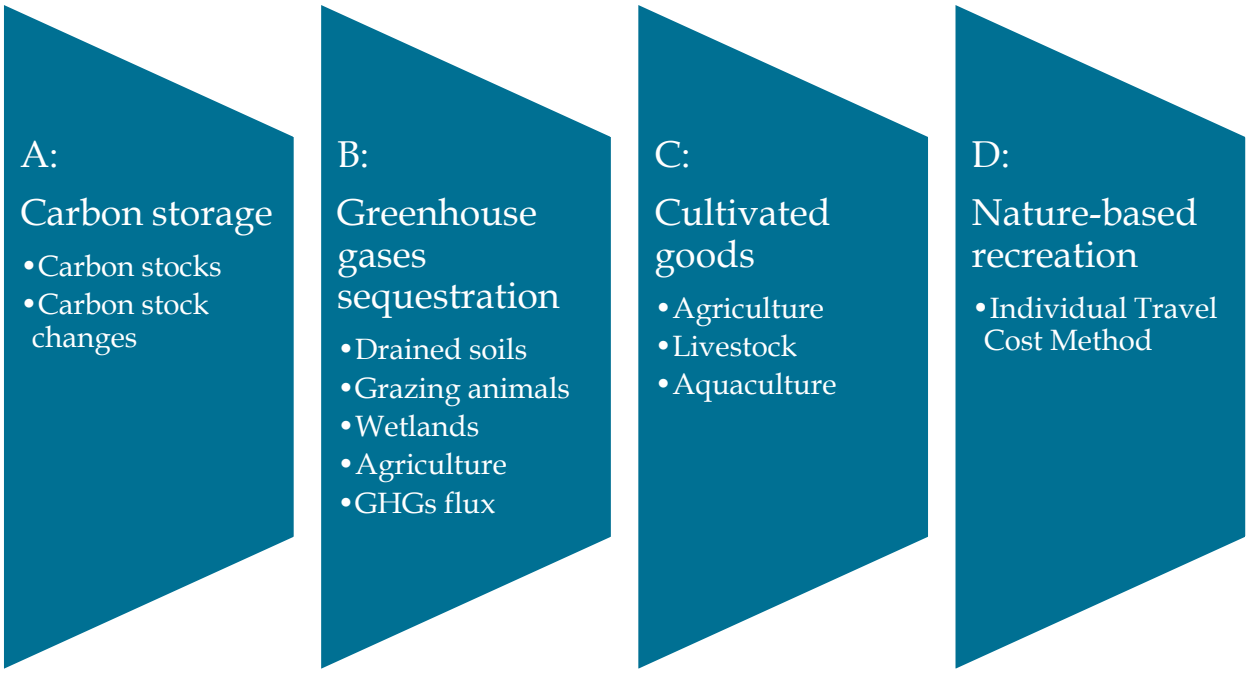
THE PLUGIN

- It can be run from QGIS3
- It is divided into 4 blocks of ESS
- Each block (besides GHGs flux) can be run independently from the others
- Each block should be run for the same times of scenarios

2. Structure

The code behind the tool is written in python and can be run from QGIS3.

The tool consists of four packages (until now), divided according the division of the methodologies implemented in the TESSA Toolkit and to ESS types.

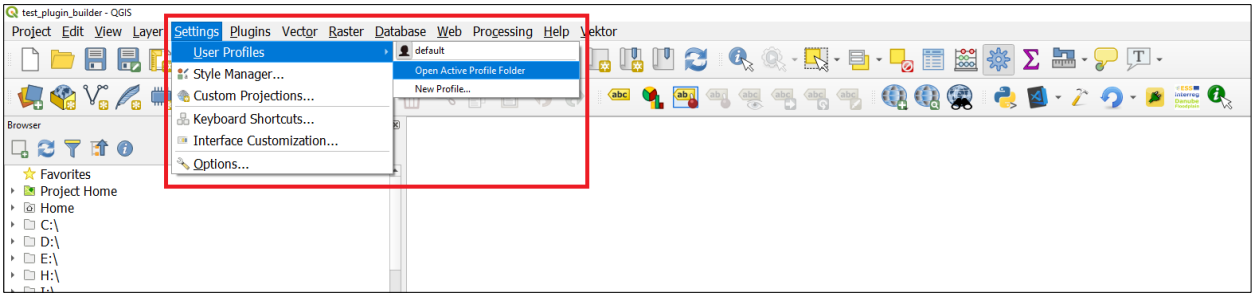


Each section is described in the next chapters of this user guide. The sections can be run independently and to each of them correspond a different tab.

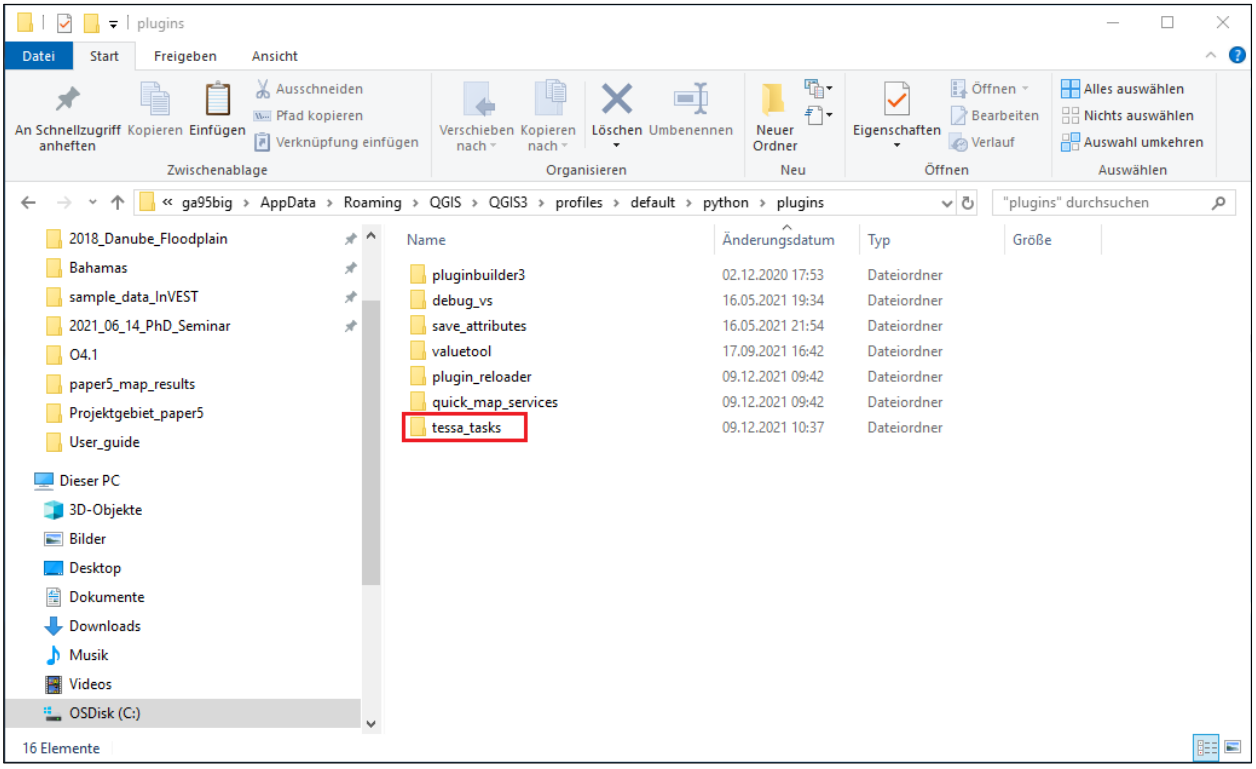
Note: The sections are presented in this User Guide as they appear in the python code

3. Initial steps: set up the plugin

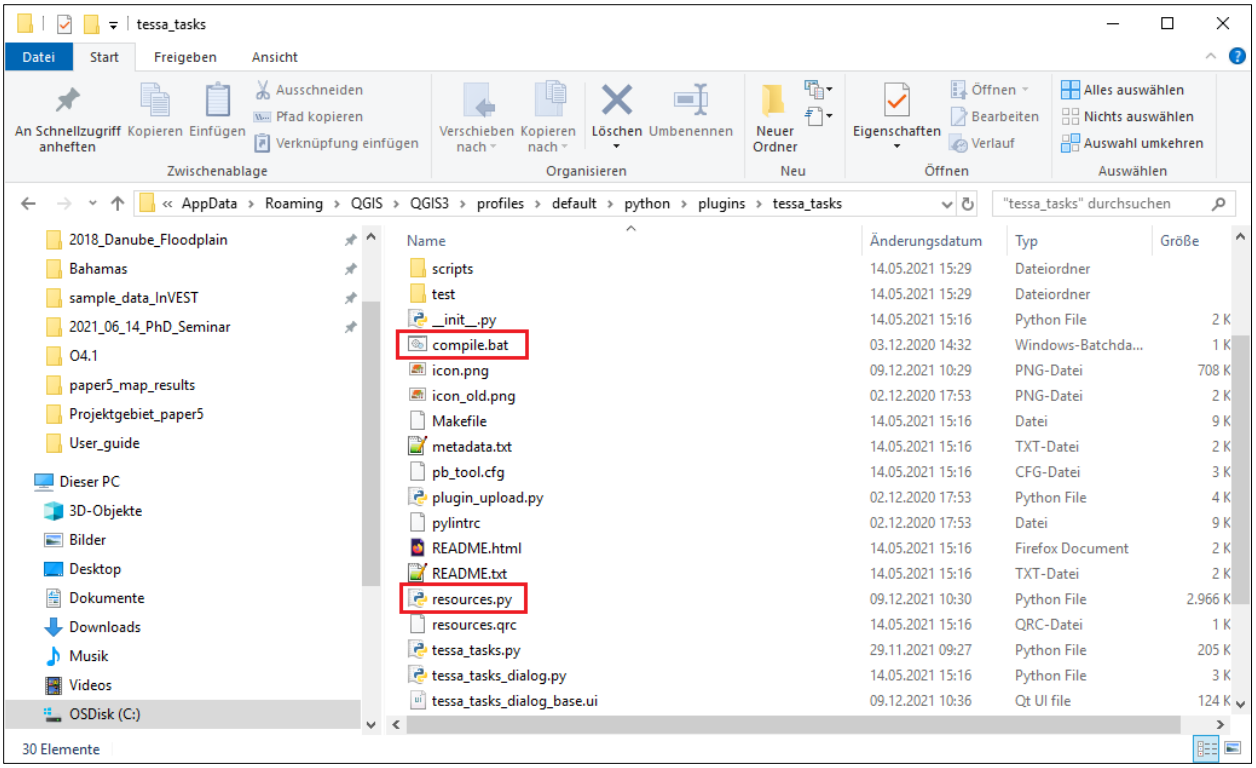
1. Download QGIS3 (https://qgis.org/en/site/forusers/download.html), open it, and create a new project.
2. Look for `plugins` folder in the computer which is inside of QGIS3's folder. How? On QGIS3 main window, go to menu `Settings` → `User profiles` → `Open active profile folder`. From there, you can go to `python` → `plugins`. That's the folder.



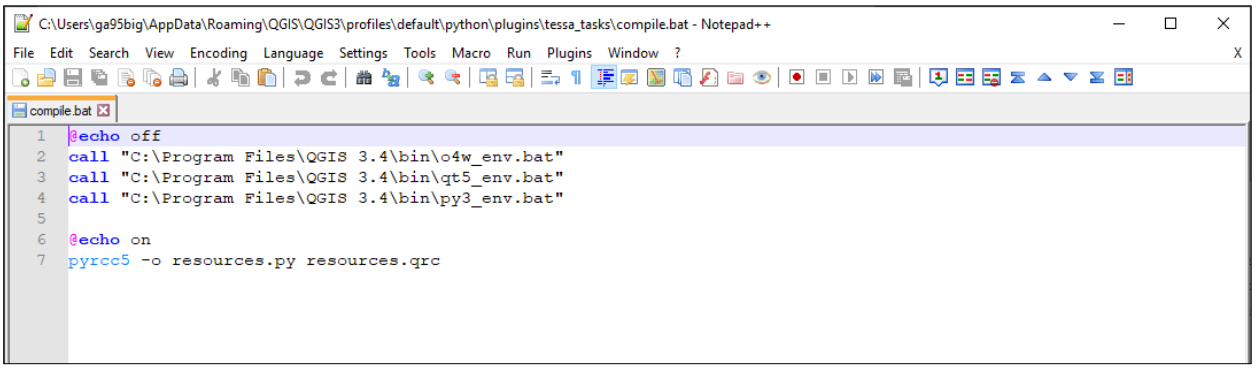
3. Paste the zip file that you downloaded into the `plugins` folder
4. Unzip it (make sure that the folder is called `tessa_tasks`)



5. Open the `tessa_tasks` folder and look for the `compile.bat` file



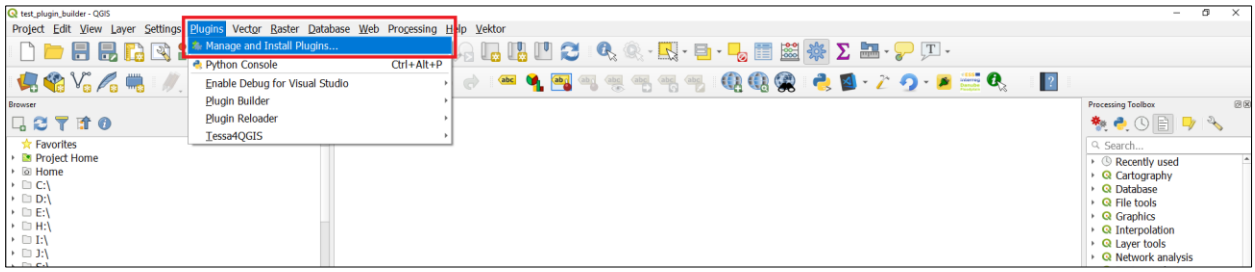
6. Open the `compile.bat` file with a text editor, e.g. Notepad++ (https://notepad-plus-plus.org/) and replace the `C:\Program Files\QGIS 3.4 \bin\` with your path, if you installed QGIS at a different path



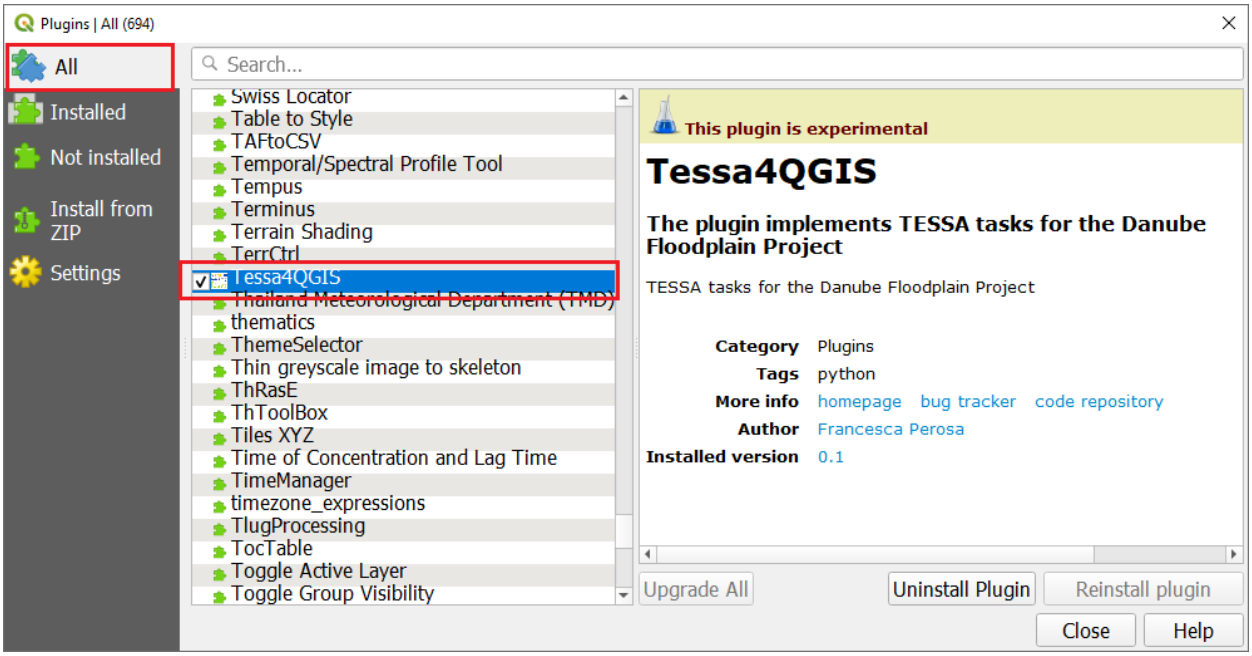
7. Run the `compile.bat` file by double clicking on it. Afterwards, the `resources.py` file should have been updated.

Note: If this step fails, you can launch `cmd.exe` and browse to the plugin folder using `cd` command. Run the Batch file by running `compile.bat` to see the error.

8. Now, the plugin should be ready to be installed on QGIS3.
9. In QGIS3, go to menu `Plugins` → `Manage and install plugins` → `All`.

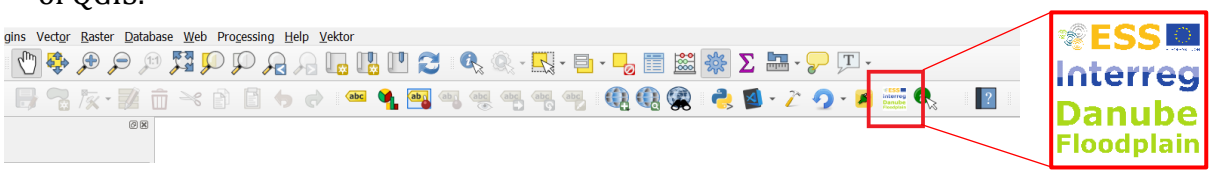


10. Install the plugin by enabling it in the QGIS plugin manager

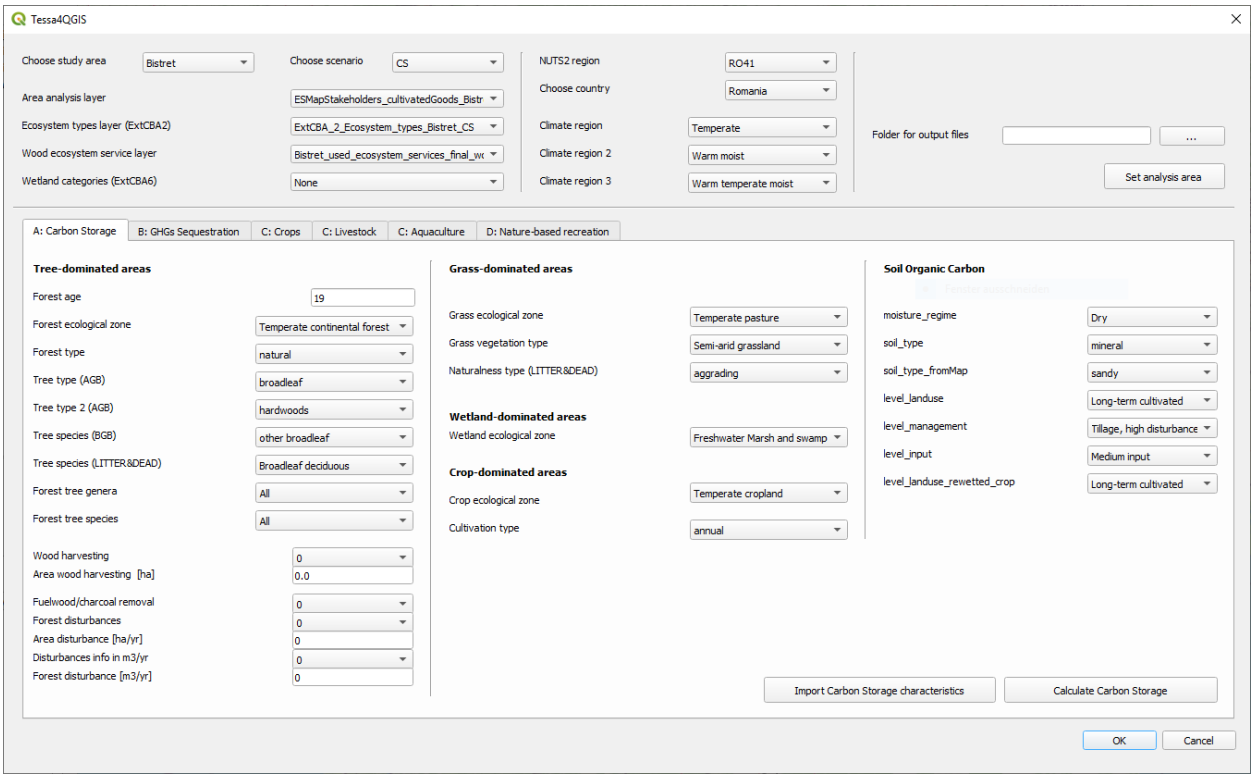


Note: Plugin Reloader is an experimental plugin. Make sure you have checked Show also experimental plugins in Plugin Manager settings if you cannot find it.

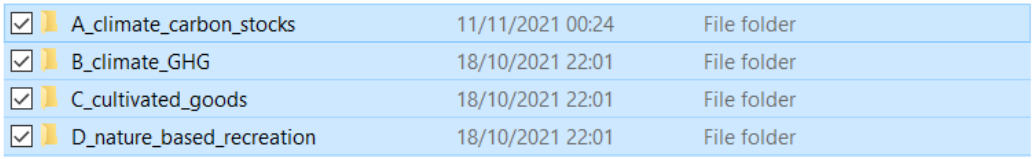
11. After installing the plugin in QGIS, you should see the corresponding button in the toolbar of QGIS.



12. Click on the plugin button and you will see the staring tab of the Tessa4QGIS plugin.



13. The installation of the plugin is finalized.
14. Now, the folder for output data should be prepared.
    a. Select a folder for output files that includes the same folders as following:

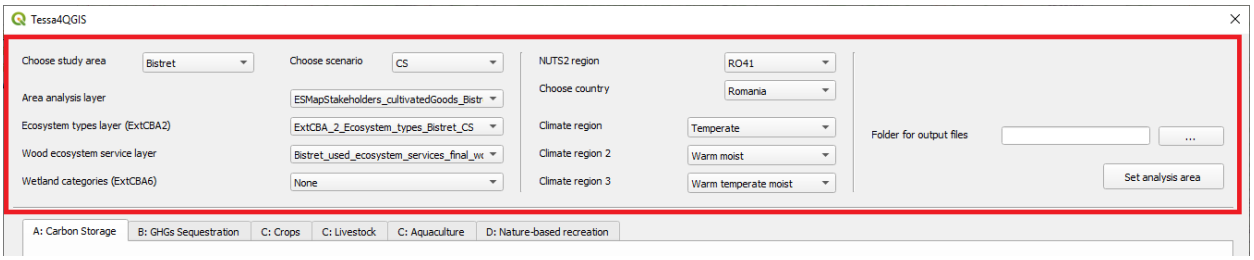


    b. Otherwise, select the output folder in the following directory: `…\plugins\tessa_tasks\Outputs`
15. The plugin is ready to be run.
16. Sample input data for all required data mentioned in the following chapters can be found in the following folder of the plugin: `…\plugins\tessa_tasks\Inputs_sample_data`.

4. Setting up the study area

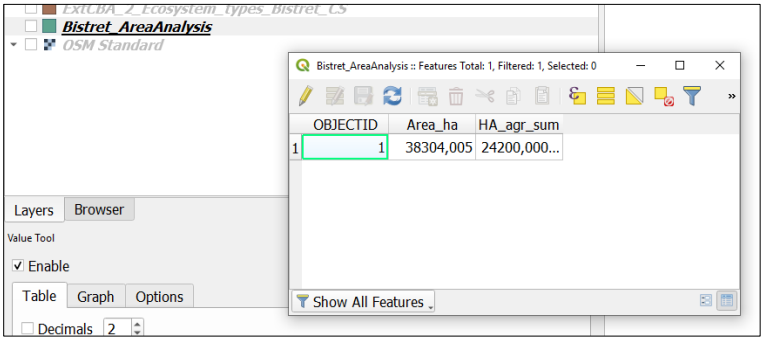
4.1. Prepare input data

Before running any of the packages (A, B, C, D), the study area has to be set. For this, various input data have to be prepared.



4.1.1. Area analysis layer

`Area analysis layer`: the shapefile of the area that the user wants to analyze; in its attribute table; this shapefile should include one field for the size of the study area in hectares (`Area_ha`)

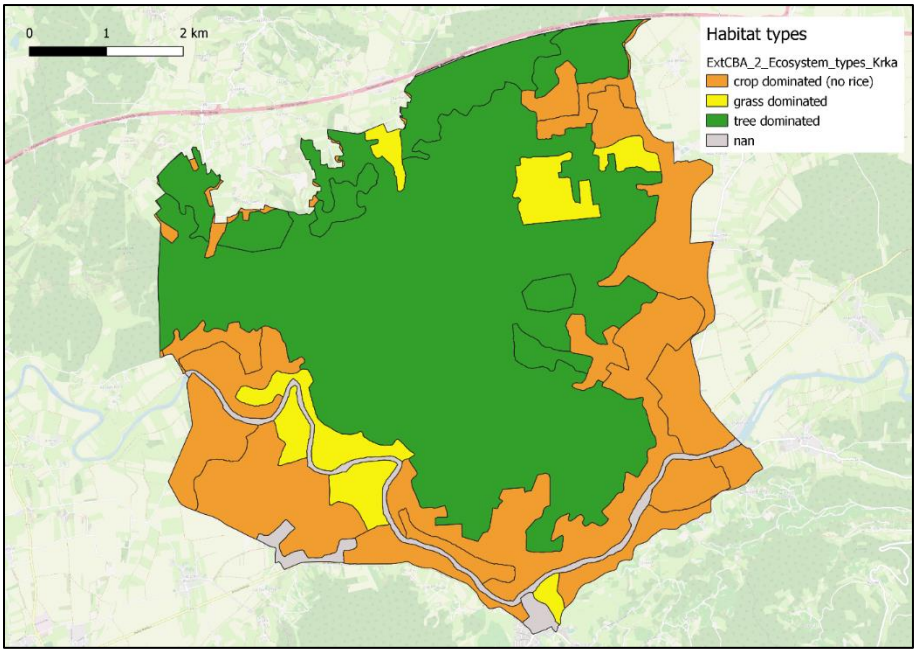


4.1.2. Ecosystem types layer (ExtCBA2)

`Ecosystem types layer (ExtCBA2)`: shapefile (see example in figure below) in which the habitats are divided into:

1. Grass-dominated (field `Habit_Code=1`)
2. Tree-dominated (field `Habit_Code=2`)
3. Crop-dominated (no rice) (field `Habit_Code=3`)
4. Crop-dominated (rice) (field `Habit_Code=4`)
5. Wetland-dominated (field `Habit_Code=5`)

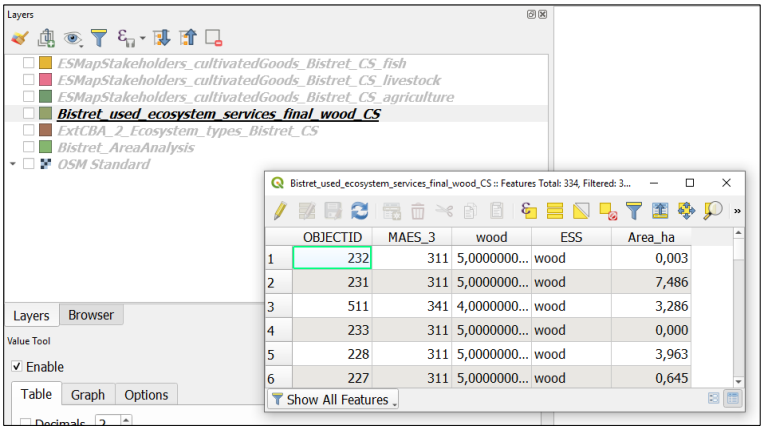
Moreover, the shapefile should include one field for the size of the study area in hectares (`Area_ha`).



4.1.3. Wood ESS layer

`Wood ESS layer`: the shapefile of the ecosystem services (ESS) maps with the information on the area size on which wood harvesting is taking place (Gelhaus 2020). It should include the following layers:

- `ESS`: field (char) with the word "wood";
- `Area_ha`: field for the size of the wood areas in hectares.



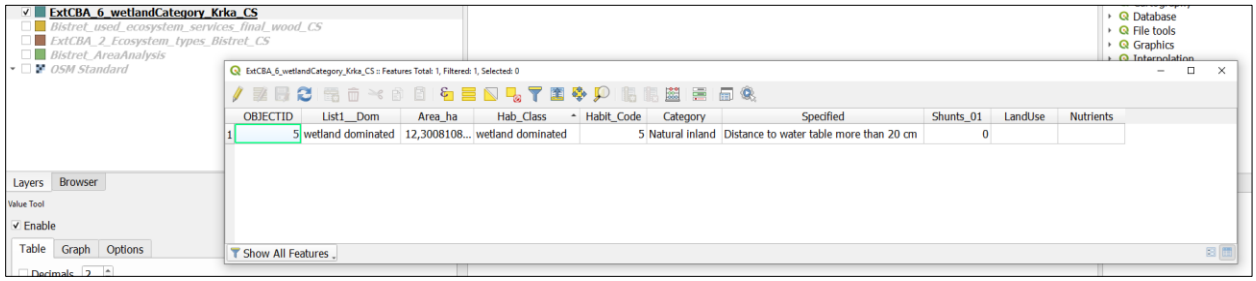
	OBJECTID	MAES_3	wood	ESS	Area_ha
1	232	311	5,0000000...	wood	0,003
2	231	311	5,0000000...	wood	7,486
3	511	341	4,0000000...	wood	3,286
4	233	311	5,0000000...	wood	0,000
5	228	311	5,0000000...	wood	3,963
6	227	311	5,0000000...	wood	0,645

4.1.4. Wetland categories shapefile layer (ExtCBA6)

`Wetland categories shapefile (ExtCBA6)`: the shapefile of wetlands' categories, as suggested in TESSA (Peh et al. 2017). It should include the following layers:

- `Hab_Class`: field (char) with the expression "wetland dominated";
- `Habit_Code`: field (int) with the number `5`
- `Area_ha`: field for the size of the wood areas in hectares
- `Category`: field (char) with the expressions:
  - "`Natural inland`";
  - "`Managed drained`";
  - "`Managed not drained`";
- `Specified`: field (char) with the specified characteristics of the category; They can be:
  - Position of the water table for the natural inland wetlands:
    - "`Distance to water table more than 20 cm`"
    - "`Distance to water table less than 20 cm`"
  - For the managed drained wetlands, whether they have been:
    - "`Drained not rewetted`"
    - "`Drained and rewetted`"
  - For the managed not drained wetlands, whether the wetland is:
    - "`Flooded`"
    - "`Wastewater treatment`"
- `Shunts_01`: field (int) with the information whether there are (1) shunts or not (0) on the wetland; the presence of shunts in the wetland (only where the water table > 20 cm)

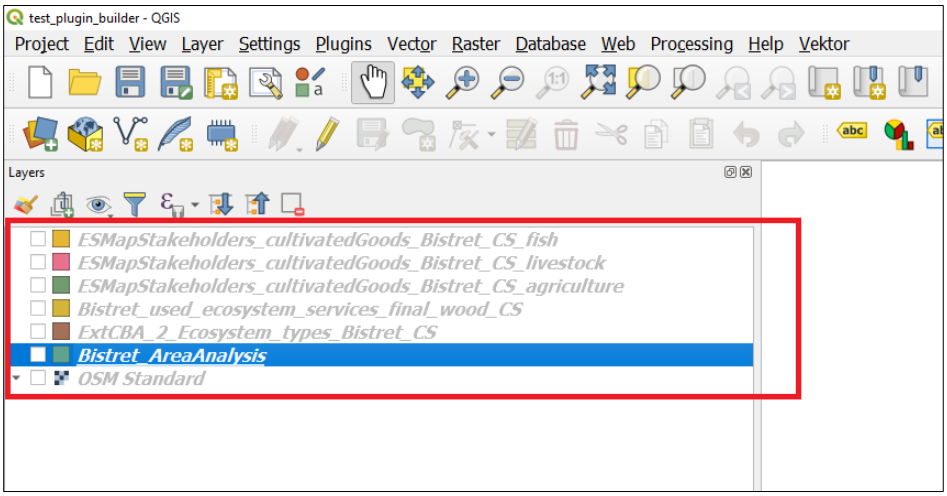
Note: In this case, it is also possible to tell the plugin that no file is available



4.2. Import input data

1. Choose the study area you want to work on. You can choose between the following:

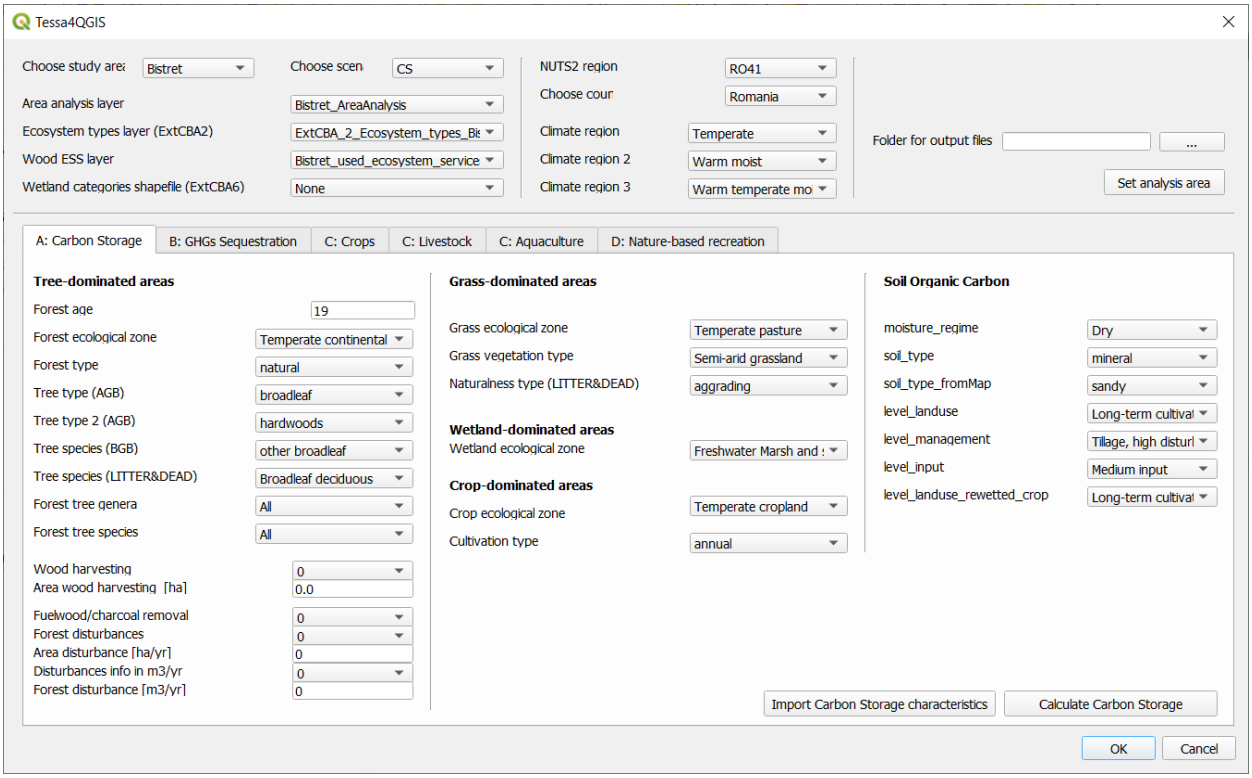
   a. Bistret
   b. Begecka Jama
   c. Krka
   d. Middle Tisza
   e. Morava
2. Choose the scenario:
   a. CS: current state
   b. RS1: restoration scenario 1 (realistic)
   c. RS2: restoration scenario 1 (optimistic)
3. Choose the shapefiles from the drop-down window, according to the description in the previous chapter. In order to find the desired shapefile from the drop-down menu, the file has to be imported in the QGIS project first.



4. Choose the NUTS2 region according to the sudy area (e.g. Bistret is located in the area RO41)
5. Choose the country in which the study area is located.
6. Choose the climate region. For different procedures, different climate region's classifications are used. Therefore, the climate region has to be selected from three different drop-down menus.
7. Select the folder for output data that was earlier prepared. This should include the empty folders shown earlier.
8. After everything is ready, click on the button `Select analysis area`.

5. Carbon storage tab (A)

In the context of the TESSA toolkit, the ecosystem service of "global climate regulation" refers to the exchange of carbon dioxide and other greenhouse gases between the atmosphere and the plants, the animals and soil within ecosystems. In this tool however, the tasks of this whole "global climate regulation" ESS were divided into two blocks: the "A: Carbon storage" package and the "B: Greenhouse gases" package.



5.1. Select input data

Input data should be selected from the drop-down menus or added in the empty windows. The input data are divided according to habitat type. The table below presents a description of the input data.

Variable	Options/entries
Tree-dominated areas	
Forest age	Integer number Age of the forest Important limit: 20 years
Forest ecological Zone	Grassland drained nutrient-poor Grassland deep-drained nutrient-rich Grassland shallow-drained nutrient-rich"

Forest type	pastural plantations
Tree, classification type 1 for Above-Ground Biomass (AGB) estimation	broadleaf conifer
Tree, classification type 2 for Above-Ground Biomass (AGB) estimation	Hardwoods Pines other conifers larch firs spruces
Tree species for estimation of Below-Ground Biomass (BGB)	Other broadleaf Conifers Eucalyptus spp Quercus spp
Tree species for estimation of Litter and Dead Wood Biomass (LITTER&DEAD)	Broadleaf deciduous Needleleaf evergreen
Forest tree genera	All Alnus Pinus
Forest tree species	All (for now, only possible option)
Wood Harvesting	Bool: 0/1 Says whether wood harvesting is taking place in the area
Area wood harvesting	Area in which wood harvesting is taking place (hectares)
Fuelwood/charcoal removal	Bool: 0/1 Says whether there is fuelwood and charcoal removals taking place in the area
Forest disturbances	Bool: 0/1 Were there any disturbances (illnesses, fire, etc.) to the forest? Says whether disturbances happened
Area disturbance [ha/yr]	Float number Area affected by disturbance
ABG_Disturbance_ton_dry_mass_per_ha	Float number Above-ground affected
Grass-dominated areas	
Grass ecological zone	Temperate grassland Temperate non-forest Temperate pasture
Grass vegetation type	Semi-arid grassland Steppe/tundra/prairie grassland
Naturalness type for estimation of Litter and Dead Wood Biomass (LITTER&DEAD)	native aggrading managed
Wetland-dominated areas	
Wetland ecological zone	Freshwater Marsh and swamp Northern peatland
Crop-dominated areas	
Crop ecological zone	Temperate cropland Wetland rice
Cultivation type	Annual

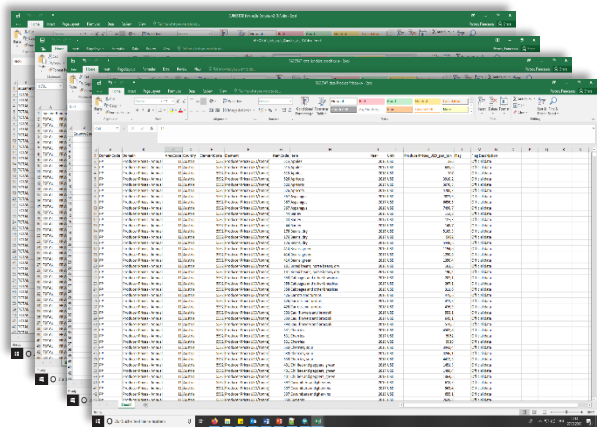
	Perennial Note: For annual cultivations, the above- and below-ground biomass and the dead biomass are assumed to stay constant; therefore, the rate of increase will be 0 tons dry matter per hectare.
Soil organic carbon	
Moisture regime	Dry Moist
Soil type	Mineral Organic
Soil type (from map)	Sandy High activity clay Low activity clay Spodic Volcanic Wetland
Landuse level	Long-term cultivated Paddy rice Perennial Crop Set Aside
Management level	Tillage, high disturbance Tillage, high disturbance No tillage
Input level	Low input Medium input High input, no manure High input, with manure
Landuse level (rewetted crop)	Long-term cultivated Rewetting, years 1-20 Rewetting, years 21-40

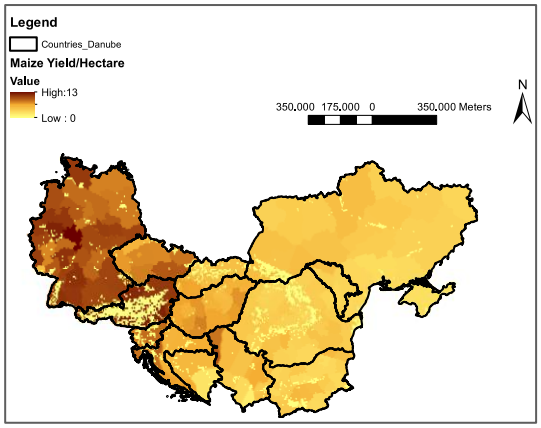
5.2. Import input data

To import all given information, click on the button `Import carbon storage characteristics`. When clicking on the button, not only the entries on the GUI, but also publicly available data are imported. These include information about each Danube country or the corresponding NUTS2 areas from different institutions and databases:

- IPCC
- FAOSTAT
- EUROSTAT
- EarthStat
- AQUASTAT
- Etc.

For the ESS assessment, a consistent quantity of input data is necessary, such as agricultural production, population density, or emission factors of different greenhouse gases.





The imported tables (in form of layers) are:

- a table suggested in TESSA (Peh et al. 2017), `table_Anderson_Teixera_2011`, with estimates of carbon dioxide flux (CO_2), methane flux (CH_4) and nitrous oxide flux (N_2O) of various habitat types by ANDERSON-TEIXEIRA and DeLUCIA (2011);
- tables from IPCC:
  - `IPCC_table_2_2`: Tier 1 default values for litter and dead wood carbon stocks (IPCC 2006)
  - `IPCC_table_2_3`: Default reference (under native vegetation) soil organic C stocks (SOCREF) for Mineral Soils (IPCC 2006)
  - `IPCC_table_4_3`: Carbon fraction of aboveground forest biomass (IPCC 2006)
  - `IPCC_table_4_4`: Ratio of below-ground biomass to above-ground biomass (R) (IPCC 2006)
  - `IPCC_table_4_5`: Default biomass conversion and expansion factors (BCEF) (IPCC 2006)
  - `IPCC_table_4_7`: Above-ground biomass in forests (IPCC 2006)
  - `IPCC_table_5_2_2014`: Default reference soil organic carbon stocks (SOCREF) for Wetland Mineral Soils under native vegetation (0-30 cm depth) (IPCC 2014)
  - `IPCC_table_6_1`: Default expansion factors of the ratio of below-ground biomass to aboveground biomass (R) for the major grassland ecosystems of the world (IPCC 2006)
  - `IPCC_table_6_2`: Relative stock change factors for grassland management (IPCC 2006)
- tables with data from FAO:

- `table_FAO_FRA2015`: forest area size and growing stock of forests from FAO's Global Forest Resources Assessment 2015 (FAO 2016)
- `table_FAOSTAT_wood`: total wood production (removals of fuelwood, roundwood, and charcoal) (FAO 2019)
- `table_FAOSTAT_landuse`: areas of different land uses (e.g. total agricultural land) in hectares (FAO 2019)
    - `table_FAOSTAT_MAI`: trees' growing rates table from the planted forest database (PFDB) (FAO 2003)

Imported spatial data are:

- `Danube_countries`: the shapefile of the Danube countries
- `SoilOrganicCarbon_ras`: raster of organic carbon stored in soils (FAO and ITPS 2018)

5.3. Processes

After importing carbon storage characteristics, click on `Calculate carbon storage`. The estimations below are conducted when running the code.

5.3.1. Carbon stocks for AGB, BGB, LB and DWB

The first sections of the code have the goal to estimate the carbon stocks of the area taken into consideration. This estimation is done (as suggested by TESSA, which follows the Tier 1 methodology of the IPPC reports (IPCC 2006)) by separating the biomass stocking into four parts: the above-ground biomass (AGB), the below-ground biomass (BGB), the litter biomass (LB), and the dead wood biomass (DWB). For each part, the carbon stocks estimates are read from the IPPC tables (IPCC 2006) that were previously uploaded. For some land uses and habitats, the IPCC reports did not provide the default factors for biomass calculation; therefore, the estimates of carbon dioxide flux (CO_2), methane flux (CH_4) and nitrous oxide flux (N_2O) of various habitat types were found in the estimates done by ANDERSON-TEIXEIRA and DeLUCIA (2011), found in TESSA (Peh et al. 2017).

Note: the carbon stocks are a static calculation of the status quo of the carbon stored into the pilot area. Per se, they don't have a role in the extended CBA**.**

5.3.2. Carbon stocks of soil: soil organic carbon

In another way than what was done in the previous section, the total soil organic carbon is not estimated through look-up tables (recommended by TESSA), due to the lack of data availability, but it is extracted from the GLOSIS - GSOCmap (v1.5.0), a global soil organic carbon map (GSOCmap) created by FAO and ITPS (2018).

Note: A way has not been found yet, how to estimate the changes in the soil carbon stocks in the case of a restoration scenario for the Danube Floodplain project.

5.3.3. Total carbon stocks

By summing up the carbon stocks found in sections 5.3.1 and 5.3.2, the total carbon stocks are calculated in [tons].

OUTPUT The results are saved in the layer `A_climate_output01_carbon_stocks`, where the carbon stocks [tons C] are found according to the habitat section in the shapefile, and in the `A_climate_output01_carbon_stocks.txt`, where the results are summed up.

5.3.4. Calculate the carbon increment (in tree-dominated areas)

For purposes of the extended CBA, it is important to detect the changes in carbon stock in the area of analysis. Therefore, the estimations deal with the aspects of carbon increment and carbon losses. We assume that the change of carbon stocks takes place in the tree-dominated areas only.

To calculate the growth of carbon stocks, the code uses the growing rates of planted trees (Mean Annual Increment, MAI, expressed in [m3/ha/yr]) taken from the Planted Forests Database (PFDB) made available by FAO (2003). This requires information on the trees' genera and species.

After obtaining the MAI, the Carbon Fraction (CF) to dry matter of wood was read (in [ton Carbon/ton dry matter]) from table 4.3 of the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2014). Required are also the biomass conversion and expansion factors (BCEF_R), expressed in tons of biomass removal (m3 of biomass removals)-1 [ton/m3] and extracted from table 4.5 of the IPCC report (IPCC 2014). They are default value for conversion of wood and fuelwood removals in merchantable volume to total above-ground biomass removals. The BCEF_R is chosen based on the forests' growing stock level in [m3/ha/year], estimated by the Global Forest Resources Assessment (FRA) (FAO 2016).

Finally, the increment of the carbon stock in tree-dominated areas is calculated in [ton C/year] by the formula:

Annual growing stock [m3 dry matter/ha/year]	X	BCEF_R [ton dry matter / m3 dry matter]	X	CF [ton C/ ton dry matter]	X	Area [ha]

OUTPUT The results are saved in the file `A_climate_output01_Annual_GrossCarbonSequestration.txt`, where the results are summed up and reported in [ton C/year].

5.3.5. Calculate the carbon losses (in tree-dominated areas)

The carbon losses due to disturbances in the pilot area are based on the suggestions of the TESSA Toolkit (Peh et al. 2017), which was based on IPCC's default Tier 1 methods (IPCC 2014). The procedure assumes that the change of carbon stock takes place in the tree-dominated area only. Disturbances can come from wood removals, fuelwood collection and charcoal removals, or other disturbances (e.g. illnesses, fires, etc.).

The procedure follows the same concept of the carbon increment, but in this case, instead of considering the growing rate, we consider the removals. These were derived in the estimation from different sources. The "Forestry Production and Trade" section of the FAOSTAT database (FAO 2019) provides data on the national level on annual roundwood removals, annual fuelwood removals, and annual charcoal removals [m3/year]. The data are then scaled from the country values to the pilot area. The values for the reference year 2017 (default year).

Other disturbances (such as illnesses and fires) can only be estimated; this requires that the user provides the entries on these following variables:

- the size of the area affected by disturbances;
- the biomass in [tons dry mass/hectare] that is removed by the disturbance in the above-ground biomass area, which is affected by the disturbance;
- the fraction of hectares in respect to the hectares of the area of disturbance in the pilot area that are affected by the disturbance itself.

The total carbon stock losses are then calculated as the sum of the carbon losses due to the three disturbances types wood removal, fuelwood and charcoal removal, and losses due to other disturbances.

OUTPUT The results are saved in the in the layer `A_climate_output01_carbon_stocks` and in the file `A_climate_output01_Annual_CarbonLoss.txt`, where the results are summed up and reported in [ton C/year].

5.3.6. Calculate net carbonsequestration

Based on sections above, the net carbon sequestration is calculated for the existing scenario (whether it is the current state scenario or any other restoration scenario) as follows:

Annual Net Carbon Sequestration of Pilot Area	=	Annual Gross Carbon Sequestration of Pilot Area	-	Annual Carbon Loss (Total)
[ton C/yr]		[ton C/yr]		[ton C/yr]

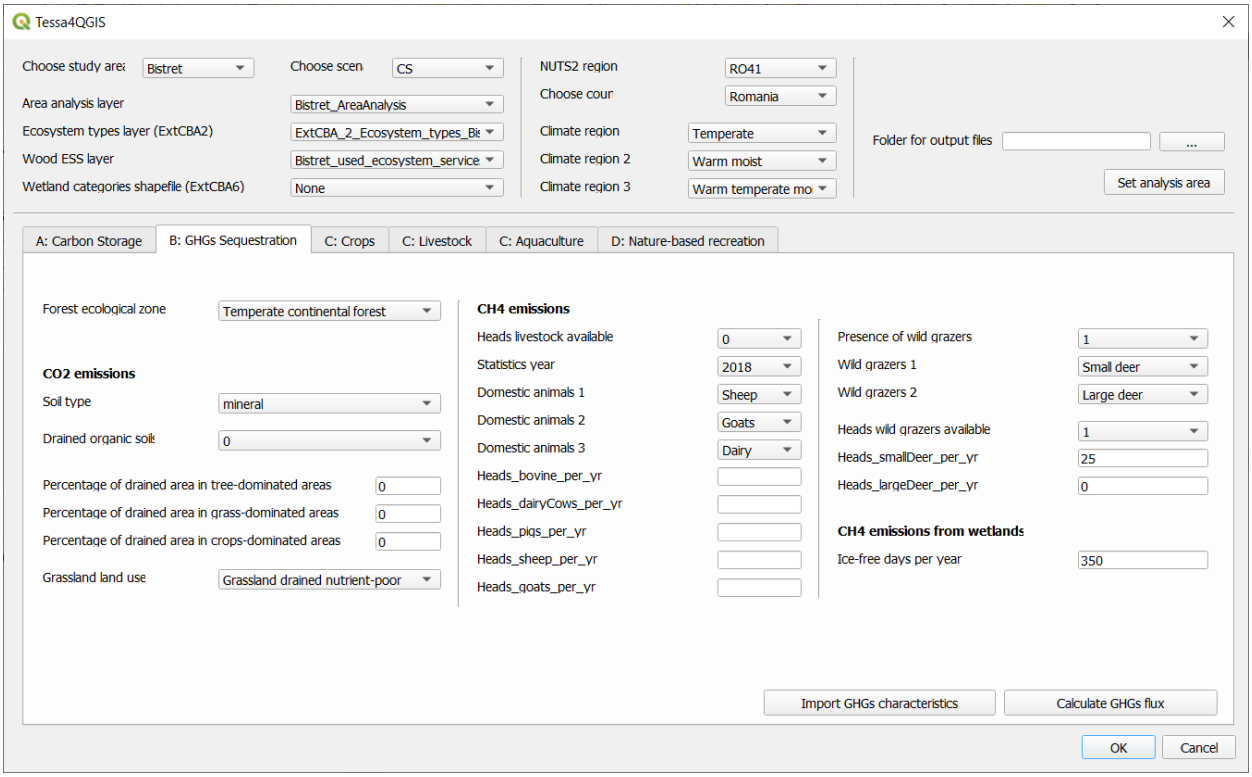
OUTPUT The results are saved in the layer `A_climate_output01b_carbon_seq`, and in the file `A_climate_output01_Annual_NetCarbonSequestration.txt`, where the results are summed up and reported in [ton C/year] and carbon increase is positive, carbon loss is negative, i.e. negative net values represent C emissions, and positive net values represent C sequestration.

Note: If an issue occurs during the procedure, you may modify the python code in the Tessa4QGIS file and rerun it (after uploading the plugin with the "Plugin reloader" plugin, which also has to be installed. If there is any error during the process you can edit the python code in the Tessa4QGIS file and run that file again.

6. Greenhouse Gases Sequestration tab (B)

The goal of this package is to estimate the quantity and corresponding monetary value of greenhouse gases (GHGs) sequestered from the atmosphere in the floodplain areas. The procedure follows the steps suggested by the second part of the section on "global climate regulation" ESS in the TESSA Toolkit (Peh et al. 2017).

Note: Part B of the tool can be only run if Part A has been already run and the results are left in the path given for the `../Output folder/A_climate_carbon_stocks`.



6.1. Select input data

Input data should be selected from the drop-down menus or added in the empty windows. The input data are divided according to habitat type. The table below presents a description of the input data.

Variable	Entry
Climate	
Forest ecological zone	Grassland drained nutrient-poor Grassland deep-drained nutrient-rich Grassland shallow-drained nutrient-rich"

CO_2 emissions	
Presence of drained organic soils in the area	Bool 0/1
Soil type	Mineral Organic
Percentage of drained land use that is now tree-dominated	Value from 0 to 1 The value of the percentage refers to the area (in hectares) of the specific habitat (and not to the total drained area).
Percentage of drained land use that is now grass-dominated	Value from 0 to 1 The value of the percentage refers to the area (in hectares) of the specific habitat (and not to the total drained area).
Percentage of drained land use that is now crops-dominated	Value from 0 to 1 The value of the percentage refers to the area (in hectares) of the specific habitat (and not to the total drained area).
Land Use of the grasslands present in the area	Grassland drained nutrient-poor Grassland deep-drained nutrient-rich
CH_4 emissions	
Year chosen for the statistics of CH_4 emissions	2018 (only choice)
Domestic Animals present in the pilot area	All possible entries: • Buffalo • Sheep • Goats • Camels • Horses • Mules and Asses • Deer • Alpacas • Swine • Dairy • Other cattle
Heads domestic animal per year	Float number
Presence of Wild Grazers in the pilot area	Bool 0/1
Wild grazers present in the pilot area	Small deer Large deer
Number of heads wild grazers available	Bool 0/1
Heads large deer per hectare per year	Float number
Heads small large deer per hectare per year	Float number
CH_4 emissions from wetlands	
Ice-free days per year	365

6.2. Import input data

To import all given information, click on the button `Import GHGs characteristics`. When clicking on the button, not only the entries on the GUI, but also publicly available data are imported. These include information about each Danube country or the corresponding NUTS2 areas from different institutions and databases. The imported tables (in form of layers) are:

- IPCC tables:
  - `IPCC_table_2_1_2014`: Tier 1 CO_2 emission/removal factors for drained organic soils in all land-use categories (IPCC 2014)
  - `IPCC_table_2_3_2014`: Tier 1 CH_4 emission/removal factors for drained organic soils (EFCH4_land) in all land-use categories (IPCC 2014)
  - `IPCC_table_2_4_2014`: Default CH_4 emission factors for drainage ditches (IPCC 2014)
  - `IPCC_table_3_3_2014`: Default emission factors for CH_4 from rewetted organic soils (all values in kg CH_4-C ha-1 yr-1) (IPCC 2014)
  - `IPCC_table_10_10`: Enteric fermentation emission factors for Tier 1 method (IPCC 2006)
  - `IPCC_table_10_11`: Tier 1 enteric fermentation emission factors for Cattle (IPCC 2006)
  - `IPCC_table_3A_2`: CH_4 measured emissions for flooded land (IPCC 2006)
- Table from Eurostat: `EUROSTAT_table_animals_NUTS2`: heads of domestic animals in the NUTS 2 regions (Eurostat 2020a)
- Table from FAOSTAT: `FAO_table_agricultureEmissions`: emissions of different GHGs from agricultural practices (FAO 2019)
- Tables adapted by TESSA (Peh et al. 2017):
  - `table_TESSA_wildGrazers`: CH_4 emission factors of wild grazers in accordance with the methodology suggested in the TESSA Toolkit (M11, Table B) (Peh et al. 2017)
  - `table_TESSA_naturalWetlands`: CH_4 emission factors of natural wetlands in accordance with the methodology suggested in the TESSA Toolkit (M11, Table A) (Peh et al. 2017)

Imported spatial data are:

- `NUTS2_regions`: shapefile of the NUTS regions' boundaries (as polygons), level 2 (Eurostat 2019)

6.3. Processes

After importing carbon storage characteristics, click on `Calculate GHGs flux`. The estimations below are conducted when running the code.

6.3.1. CO_2 emissions from drained soils

According to the different type of land use, the emission factors are extracted from Table 2.1 of Chapter 2 of IPCC (2014), and the emissions of CO_2 are calculated by multiplying the emission factor times the area of the land use, with a result expressed in [tonCO_2/yr].

OUTPUT The results are saved in the layer `B_climate_output02_GHG`

6.3.2. CH_4 Emissions from grazing animals

This emissions of CH_4 due to the presence of grazing animals are estimated in the pilot area. This estimation is divided into two sections: one for the domestic animals, and one for the wild grazers.

In this case, also a reliable estimate of the number of domestic animals present and/or a population estimate for wild grazers is necessary. Therefore, the Eurostat database on was used to extract the information on the heads of domestic animals counted per hectare (Eurostat 2020a) in the NUTS2 regions (Eurostat 2019). Besides that, the estimation of emitted CH_4 from domestic grazers requires Tables 10.10 and 10.11 of Chapter 10 of the IPPC reports (FAO 2006), which present the information on the emission factors in [kgCH_4/head/yr].

By knowing the number of grazers' heads, it is possible to calculate the emissions of CH_4 in one hectare per year [tonCH_4/ha/yr] due to domestic grazers, by multiplying that value times the emission factor corresponding to the grazer type and adjusting the units of measure.

The same procedure used for the domestic grazers is used for the wild grazers. However, the user is also supposed to state in advance, whether wild grazers are assumed to be present in the pilot area or not. The emission factors for this section are however not provided by the IPPC reports, but are found in the TESSA Toolkit (Peh et al. 2017). In order to provide a reliable value of wild grazers heads present in the pilot area each year, the estimates have to be provided by the user, and are not extracted from publicly available statistics.

Finally, the emissions from both kinds of grazers are summed up into one value to express the total emissions of CH_4 per year caused by the presence of grazers in the pilot area. The

estimate of CH_4 emissions from grazers is then assumed to be present only on the grass-dominated sections of the pilot areas.

OUTPUT The results are saved in the layer `B_climate_output02_GHG` and in the file `CH4emissions_totalGrazers_tonCH4_per_yr_RS2.txt`

6.3.3. CH_4 Emissions from wetlands

Important to estimate the CH_4 emissions from wetlands is to know the type of wetland that characterizes the pilot area. For this, the optimal way to import this information into the tool is by creating a shapefile of the wetlands divided according to their different categories. Combinations for wetland characteristics can be seen in the table below.

Combinations of wetland category in accordance with the methodology suggested in the TESSA Toolkit, section climate regulation - M11a

Habitat	Hab. Code	Category	Specified	Shunts	Land Use	Nutrients
wetland dominated	5	Natural inland	Distance to water table more than 20 cm	NO	NaN	NaN
wetland dominated	5	Natural inland	Distance to water table more than 20 cm	YES	NaN	NaN
wetland dominated	5	Natural inland	Distance to water table less than 20 cm	NaN	NaN	NaN
wetland dominated	5	Managed drained	Drained not rewetted	NaN	Cropland drained	NaN
wetland dominated	5				Forest Land drained	
wetland dominated	5				Grassland drained nutrient-poor	
wetland dominated	5				Grassland deep-drained nutrient-rich	
wetland dominated	5				Grassland shallow-drained nutrient-rich	
wetland dominated	5				Peatland Managed for Extraction	
wetland dominated	5	Managed drained	Drained and rewetted	NaN	NaN	Rich
wetland dominated	5	Managed not drained	Flooded	NaN	NaN	NaN

wetland dominated	5	Managed not drained	Wastewater treatment	NaN	NaN	NaN
crop dominated (rice field)	4	Managed not drained	Rice field	NaN	NaN	NaN

It is also possible to describe the wetland as a rice field, which is always managed, but the data on emission factors refer to tropical/sub-tropical climates, therefore, not the case of the Danube Floodplain pilot areas.

This section of the tool does not deal with drained peatlands, which would require a separate methodology than the one used for the wetlands. Since it was not required by the pilot areas of the Danube Floodplain project, no estimation of the emissions from drained peatlands is available yet.

The estimation of emitted CH_4 from **natural** wetlands requires the table of the emission factors taken from the TESSA Toolkit (Peh et al. 2017), which presents the information on the emission factors in [$kgCH_4$/head/yr].

For the other wetland types, Tables 2.3 and 3.3 from the IPCC reports (IPCC 2014) are used to get the emission factors of Drained not rewetted and Drained and rewetted wetlands respectively.

For Managed not drained wetlands, only the case of flooded wetlands has been explored so far. This requires the IPCC table 3.A.2 from the IPCC Report's Volume 4's Appendix 3: CH_4 Emissions from Flooded Land: Basis for Future Methodological Development (IPCC 2006).

For the managed not drained wetlands Used for wastewater treatment or for rice fields, no package was written yet, due to the complexity of the process. It is possible to create a code for an estimation, in case that is necessary for the purposes of the Danube Floodplain project.

OUTPUT The results are saved in the layer `B_climate_output03_CH4`

6.3.4. N_2O emissions from agriculture

An excursion from the TESSA's methodology was done for the estimation of the N_2O, due to the complexity of the tasks and to the high requirements of data. The alternative to the TESSA-suggested methods was the use of FAO estimated data that were found on the FAOSTAT data portal (FAO 2019). The FAO dataset requires the following information to extract the emissions information:

- Desired year for the statistics, now set at "2017" by default;
- Source of the N_2O emissions, here set as "Agriculture total";
- The country in which the pilot area is located.

This requires the information on the agricultural land area which is extracted from the CORINE 2018 (EEA 2019) with the codes 211 to 244. The raster is then used to extract the area size of croplands in the corresponding country of the pilot area.

The emissions for the whole country per year [tonN_2O/yr] are then scaled to the pilot area assuming that the crop-dominated and the grass-dominated areas are emitting N_2O (the total agriculture emissions come from the use of fertilizers and from the grazing animals that are located in the grass-dominated areas).

For all other habitat types, it is assumed that no N_2O emissions are produced.

OUTPUT The results are saved in the layer `B_climate_output02_GHG`

6.3.5. CO_2 equivalent and overall GHG flux

According to the methodology of Climate M14 in the TESSA Guidelines (Peh et al. 2017), the overall flux of greenhouse gases is estimated in the last part of package B of the tool. For each separate habitat at the site, the code pulls together all data on annual greenhouse gas fluxes and expresses them in a single figure and in a map. This requires the steps described in the following sections.

6.3.5.1. *Carbon sequestration from trees*

The carbon sequestration from trees is calculated in package A of the tool. Each atom of carbon sequestered represents one molecule of CO_2 removed from the atmosphere. So, the process takes the figure that was calculated for net carbon sequestration (t C y-1) and expresses this in terms of CO_2 (t CO_2y-1) by multiplying the values by $\frac{44}{12}$. This is because the molecular weights of C and O are 12 and 16 respectively.

6.3.5.2. *Methane emissions from wetlands*

The emissions of methane from soil are converted into CO_2 equivalent by multiplying the value of tons CH_4/year times 28, the GWP100 of methane. The values are taken from the layer called "`B_climate_output03_CH4`", created previously. For the total value, the emissions are summed up over the area.

6.3.5.3. *Emissions from all other habitats*

In a third step of this section, the remaining estimations saved in the layer "`B_climate_output02_GHG`" are converted to carbon dioxide equivalents, so that they can be added together to calculate the overall greenhouse gas flux. According to TESSA (Peh et al. 2017), the IPCC now publishes two GWP100 values, one that takes into account climate-carbon feedbacks (which measure the indirect effects of changes in carbon storage due to changes in climate) as well as one that doesn't. In the case of this tool, no climate-carbon feedbacks were considered, being the GWP100 for methane 28, for nitrous oxide 265, and for carbon dioxide 1. All values are then summed over the area from which the emissions are estimated, to get a singular value that can be used for the extended CBA.

OUTPUT The results are saved in the layer `B_climate_output02_GHG` and in the file `EqCO2_TotalGHG_Sequestration_tonCO2_per_yr_CS.txt`, where the Annual Total Net GHG flux (negative values stand for GHG emissions in the atmosphere) is saved.

6.3.6. *Monetary value of Carbon storage and GHGs flux*

The monetary value of the stored carbon and the GHGs flux can be calculated by multiplying the estimated CO_2 equivalents times the values of the CO_2 emissions taxation systems documented in the report of the World Bank (World Bank 2020b). The Slovenian Carbon tax rounded up to the nearest integer is 19 USD^{2020} per metric tons of carbon dioxide equivalent (tCO_2e) (World Bank 2020b) as well as the European Union (EU) Emissions Trading System (ETS) for the year 2020 (World Bank 2020a). Since the overarching framework of the international carbon market remains unclear and decisions for future prices in the EU are postponed to 2021 (World Bank 2020b), we used the values from 2018 (16 USD^{2020}/tCO_2e) and 2019 (25 USD^{2020}/tCO_2e) to estimate error calculations of the values of stored carbon and GHGs flux services.

7. Cultivated Goods (C) tabs: Crops, Livestock, and Aquaculture

This package is divided into three parts, based on the most important (and possible to estimate) provided goods: agricultural, livestock, and aquaculture goods. Part C of the code tries to follow the TESSA guidelines (Peh et al. 2017) as much as possible, according to the data availability.

7.1. Prepare and select input data

7.1.1. Stakeholder ESS maps

A set of important input data is given by the shapefiles of ESS maps, result of the stakeholder meetings that took place in the pilot areas between January and February 2019. For more information on the meetings, the methods of stakeholder engagement, and the resulting maps, please refer to the Deliverable D4.2.1 "Stakeholder analysis of the ecosystem service workshop in pilot areas" of the Danube Floodplain Project. The ESS maps provide information on which areas agricultural products, animal products, and fish area provided as ESS in the study area. These maps should be uploaded in the following form.

`ESMapStakeholders_cultivatedGoods layer`: the shapefile of the ecosystem services (ESS) maps with the information on the area size on which product is retrieved in the area. It should include the following layers:

- `ESS`: field (char) with the options
  - "agricultural product",
  - "animal product", or
  - "fish";
- `Area_ha`: field for the size of the wood areas in hectares.

Choose the shapefile from the drop-down window. In order to find the desired shapefile from the drop-down menu, the file has to be imported in the QGIS project first.

7.1.2. Other input data

The user should provide the basic knowledge on the crop, livestock, and fish types found in the pilot area. The input should be selected from the drop-down menus. The table below presents a description of the input data.

Variable	Entry
Crops	
List of most important crops	Apple, barley, bean, greenbean, cerealnes, sourcherry, chilleetc, mixedgrain, grape, lupin, maize, greencorn, oats, oilseednes, pea, plum, poppy, potato, pulsenes, rapeseed, rasberry, rye, soybean, sugarbeet, sunflower, triticale, walnut, wheat
FAOstats_year_producerPrices	2017 (only choice)
FAOstats_year_landUse	2017 (only choice)
FAOstats_year_govExp	2017 (only choice)
FAOstats_year_machin	2008 (only choice)
FAOstats_year_stocks	2017 (only choice)
FAOstats_year_production	2017 (only choice)
Livestock	
List of most important livestock	Asses, Beehives, Buffaloes, Camels, Cattle, Chickens, Ducks, Geese and guinea fowls, Goats, Horses, Mules, Pigs, Rabbits and hares, Sheep, Turkeys
List of livestock products	Beeswax , Eggs, hen, in shell, Eggs, other bird, in shell , Honey, natural , Meat, ass , Meat, bird nes , Meat, buffalo , Meat, cattle , Meat, chicken , Meat, duck , Meat, game , Meat, goat , Meat, goose and guinea fowl , Meat, horse , Meat, pig , Meat, rabbit , Meat, sheep , Meat, turkey , Milk, whole fresh buffalo , Milk, whole fresh camel , Milk, whole fresh cow , Milk, whole fresh goat , Milk, whole fresh sheep, Silk-worm cocoons, reelable
Aquaculture	
List of most important fish	unknown Carps, barbels and other cyprinids Salmons, trounts, smelts …

7.2. Import input data

To import all given information, click on the button `Import Crops characteristics`, `Import Livestock characteristics`, or `Import Aquaculture characteristics`. When clicking on the button, not only the entries on the GUI, but also publicly available data are imported. These include information about each Danube country or the corresponding NUTS2 areas from different institutions and databases. The imported tables (in form of layers) are:

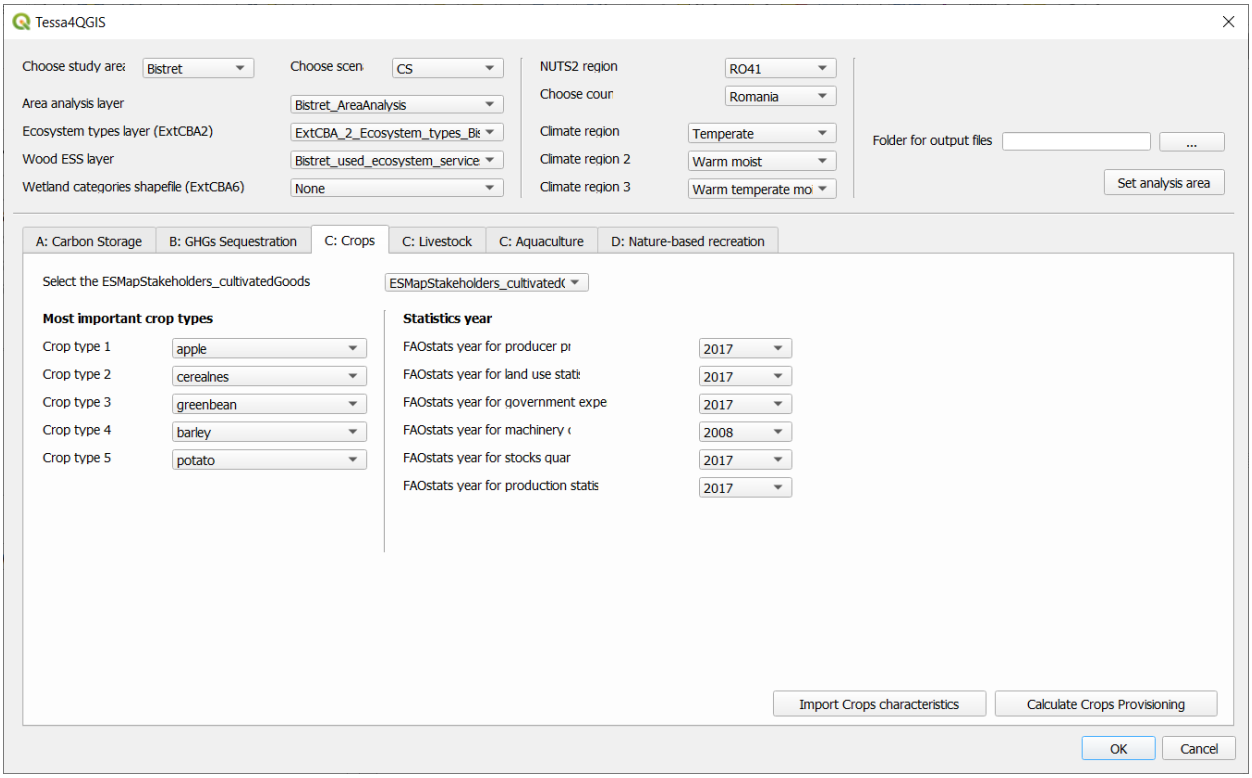
- FAOSTAT tables for agriculture:
  - `table_FAOSTAT_names`: translation of the crop types' names from FAOSTAT to EarthStat
  - `table_FAOSTAT_landuse`: land use areas in each country
  - `table_FAOSTAT_prices`: national market prices of primary crop products
- FAOSTAT tables for livestock:
  - `table_FAOSTAT_stocks`: number of livestock heads at the national level
  - `table_FAOSTAT_production`: quantity of livestock primary products at the national level
  - `table_FAOSTAT_prices`: national market prices of primary livestock products
  - EUROSTAT tables for aquaculture:
    - `table_fishProduction`: quantity of aquaculture primary products at the NUTS2 level
    - `table_fishEur`: market prices of primary aquaculture products at the NUTS2 level
    - `table_EUROSTAT_fishNames`: legend of the EUROSTAT's fish codes into the species' names

The imported spatial data are:

- `Danube_countries`: the shapefile of the Danube countries
- `harvestedArea_rasters`: EarthStat raster files of the harvested areas, one file for each indicated most important crops (Monfreda et al. 2008)
- `yieldPerHectare_rasters`: EarthStat raster files of the yield, one file for each indicated most important crops (Monfreda et al. 2008)

7.3. Processes

7.3.1. Agricultural products



From the list of crop types, the code uploads to QGIS two maps per crop type published by EarthStat (Monfreda et al. 2008):

- A raster map of the harvested hectares [ha/pixel]
- A raster map of the yield [tons/ha]

The EarthStat maps were created by combining national, state, and county level census statistics with a global data set of croplands on a 5 minute by 5 minute (~10 km by 10 km) latitude/longitude grid. The resulting datasets depict circa the year 2000 of 175 distinct crops of the world (Monfreda et al. 2008). For the purposes of the Danube Floodplain project, the world maps were cropped earlier to the extension of the main countries of the Danube River Basin. The two maps are then used to extract the average value of harvested hectares and of yielded crop per each entry of the stakeholders ESS shapefile with a recognized ESS = "agricultural product" for all crop types. With this information, it is then possible to calculate the total yield of each listed crop type for the selected areas in [tons/year].

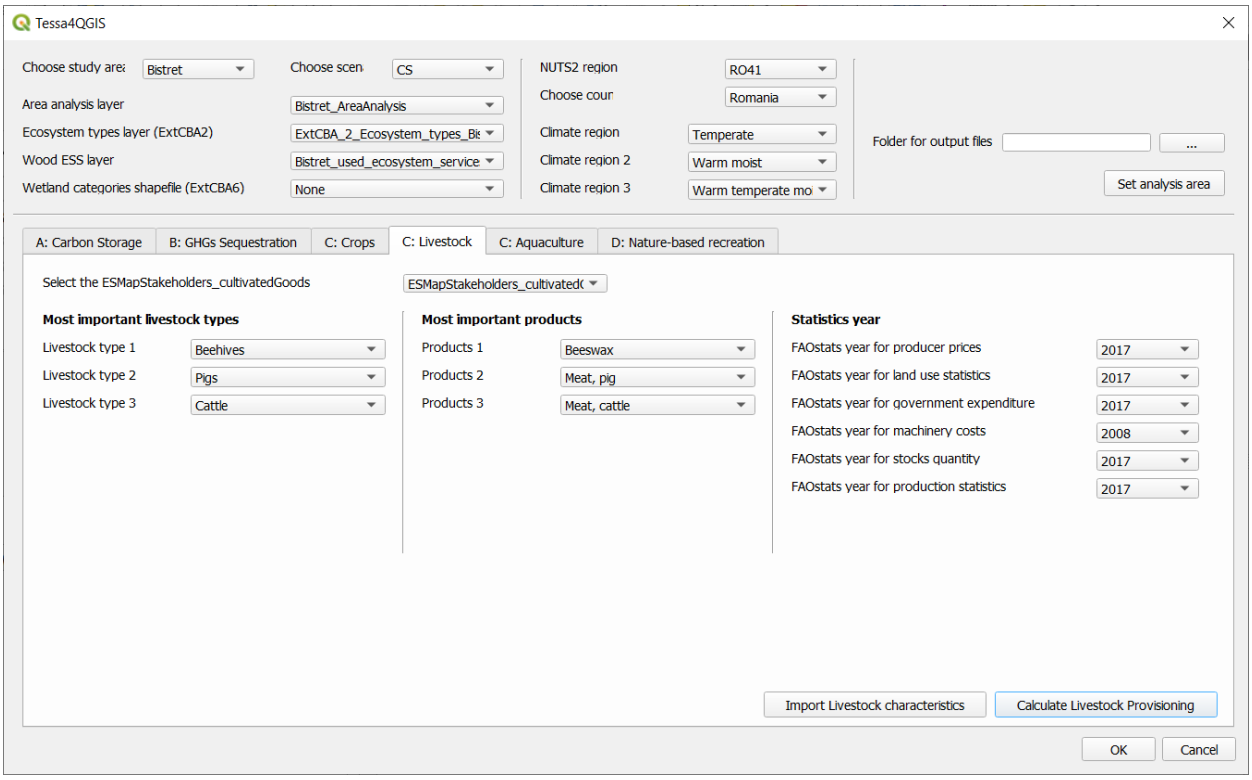
The ESS value of crops production is then estimated with the market-based valuation methodology of market prices. The necessary data are found in the "Trade - Crops and

livestock products" section of the FAOSTAT database (FAO 2019), which provides the producer prices per unit [USD/ton]. The code extracts the data from the uploaded FAOSTAT table and calculates the total earnings of crops cultivation in the pilot area by multiplying the market prices times the production for each crop type. In case, the product does not show a price in the FAOSTAT tables for the specific country, the code makes an average of the prices of the other Danube countries for all provided years (2016 to 2018).

The information on the size of the agricultural land is provided by the statistics on the land uses' area sizes of FAOSTAT (FAO 2019).

OUTPUT The results are saved in the text file `GrossPrices_agriculture_per_yr_CS.txt` and in the shapefile layer `C_cultivated_output04_agriculture`.

7.3.2. Livestock products



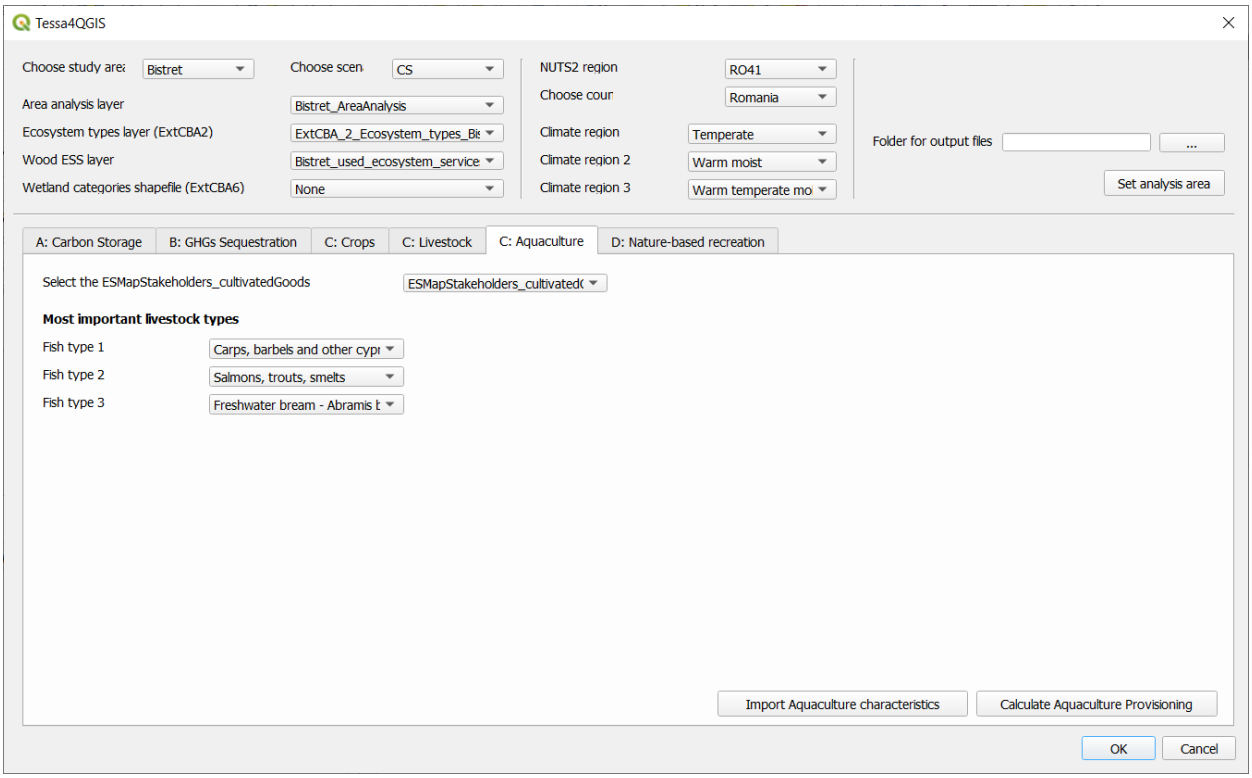
Due to the missing data from the local stakeholders, this section uses as input data the national data from the FAOSTAT database (FAO 2019) that are then scaled according to the size of the area recognized by the stakeholders (in the stakeholder ESS map). The tables used from FAOSTAT provide:

- livestock quantity [Number of stock's heads];
- primary production according to livestock type and product [ton].

The ESS value of livestock products is estimated with the market-based valuation methodology of market prices. The necessary data are found in the "Trade - Crops and livestock products" section of the FAOSTAT database (FAO 2019), which provides the producer prices per unit [USD/ton]. In case, the product does not show a price in the FAOSTAT tables for the specific country, the code makes an average of the prices of the other Danube countries for all provided years (2016 to 2018).

OUTPUT The results are saved in the text file `GrossPrices_livestock_per_yr_CS.txt` and in the shapefile layer `C_cultivated_output05_livestock`.

7.3.3. Aquaculture



Due to the missing data from the local stakeholders, this section uses as input data, the national data from the Eurostat database (Eurostat 2020b) that are then scaled according to the size of the area recognized by the stakeholders (in the stakeholder ESS map). The Eurostat tables provide information on:

- The fish production [tons liveweight produced per year]
- The revenue of the fish production in the country [Euros from the first transaction per year].

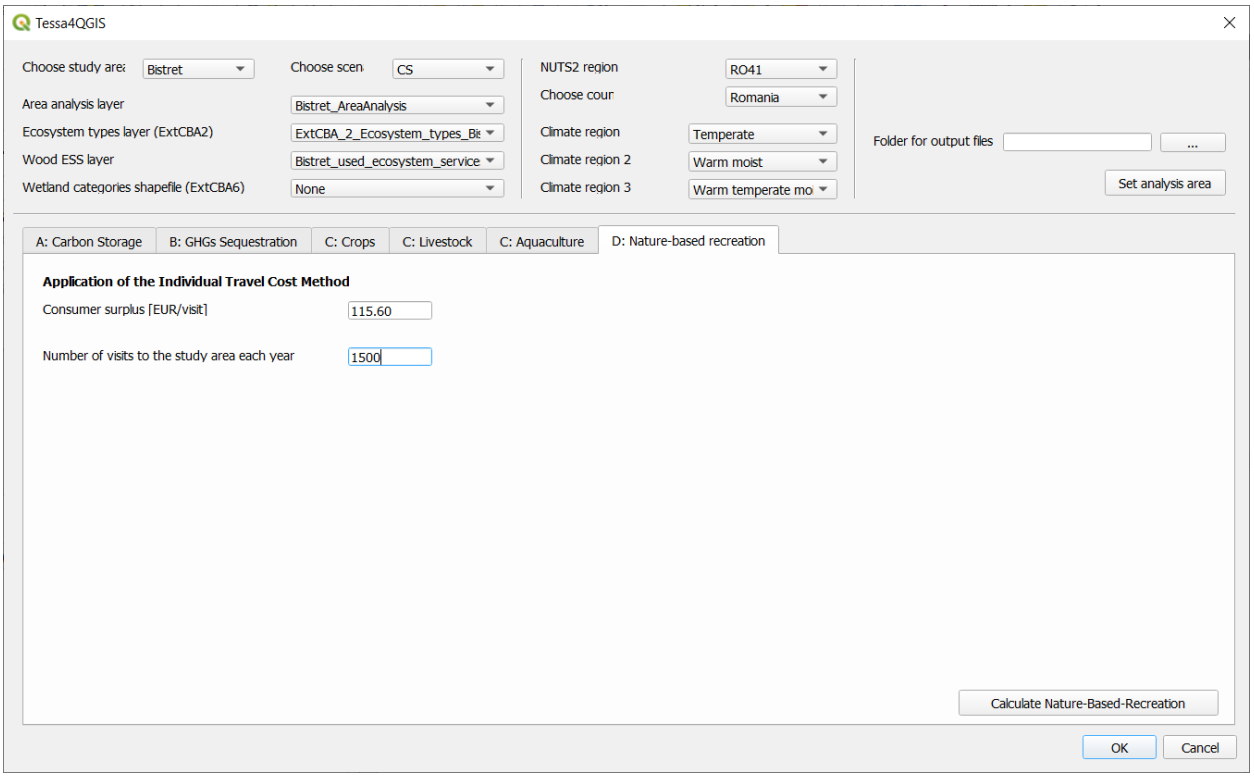
If the fish species is unknown, the code takes as fish type “all aquatic species”.

OUTPUT The results are saved in the text file `GrossPrices_fish_per_yr_CS.txt` and in the shapefile layer `C_cultivated_output06_fish`.

7.3.4. Provisioning of total cultivated goods ESS

COMING UP The whole amount of the cultivated goods can be estimated by summing up the three output layers and the three total values of provided ESS

8. Nature-based recreation



Following TESSA's guidelines, the individual travel cost method (ITCM) can be applied to assess the nature-based recreation (e.g. exercising, experiencing nature, etc.) provided by the floodplain areas and their restoration. This method was based on interviews that were conducted online from 7th August 2020 to 1st September 2020 for the pilot areas Begecka Jama, Krka, and Morava, and from 5th November 2020 to 31st December 2020 for the Bistret pilot area. To retrieve data on the restoration scenarios, the interviews included a section in which the respondents described their potential reaction to the hypothetical floodplain restorations. The ITCM requires as input data the count of the visits of an individual to a site in a year, the corresponding travel cost (TC) to the site (sum of the cost to get to the site with fuel prices for each country from the European Commission (IEA 2020) and additional expenses). As described for example in Hanauer and Reid (2017) or Borzykowski et al. (2017), each respondent can be represented by applying the function of equation (7):

$$number\ of\ visits\ per\ year = \alpha + \beta \times TC \qquad (7)$$

where α is the intercept and β is the coefficients estimate. Based on the fitted Poisson model, the consumer surplus per visit can be calculated as the negative inverse of the constant (-1/β) of the TC variable. The consumer surplus for the study areas of the Danube Floodplain Project was estimated as follows (Danube Floodplain 2021a):

	Begecka Jama	Bistret	Krka	Morava
Consumers surplus [EUR^{2019}/visit]	122.70	77.18	128.09	55.27

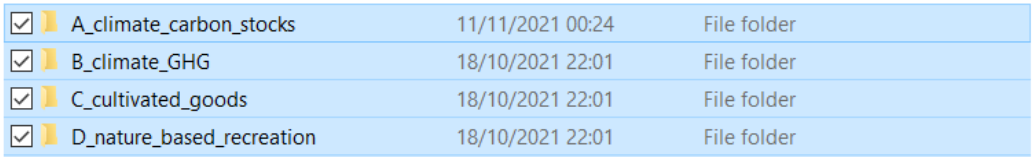
Multiplying the consumer surplus by the total number of visits gives a total consumer surplus for the site. To estimate the total number of visits, local tourism agencies or hotels can be consulted.

COMING UP

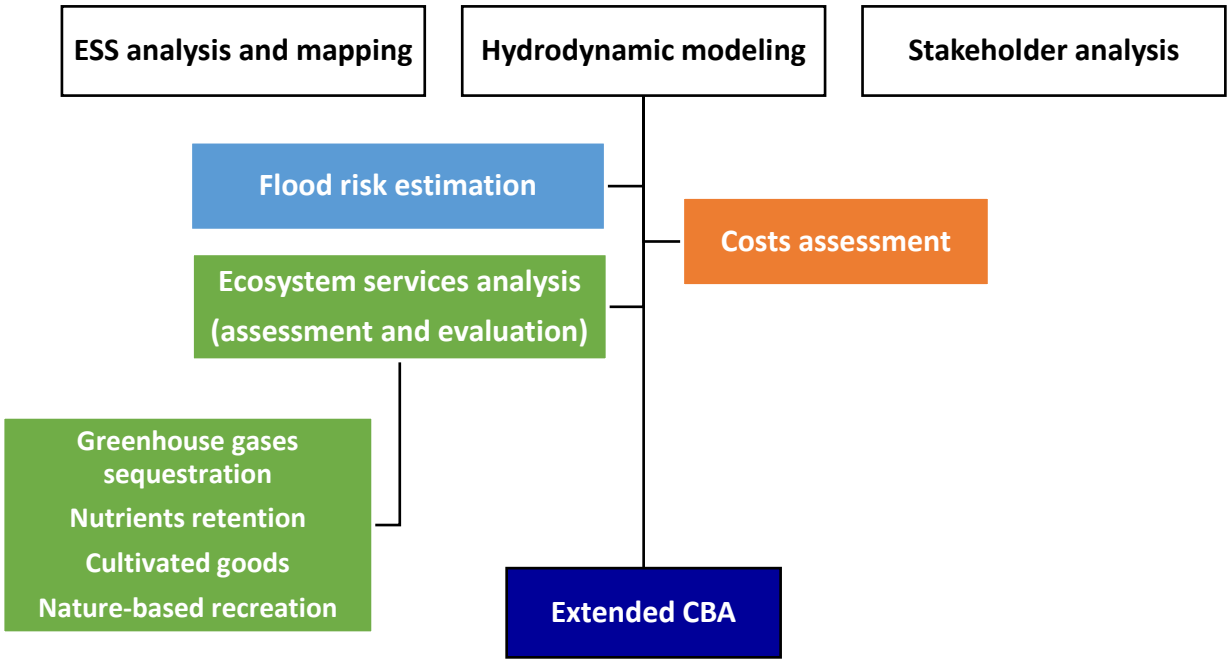
The Individual Travel Cost Method will be included in the code in the future, so that data from stakeholder interviews can be statistically analyzed directly. This would allow to estimate the consumer surplus with the plugin itself.

Outcome

At the end, the layers can be found in the in the `Outputs` folder that you created and to which you referenced the `output path`. In this folder, all results should be included:



Otherwise, you can also modify and download the maps from QGIS3 directly. The **layers** can be used for the subsequent elaboration of the results in the extended cost benefit analysis (CBA), if summed up with the **estimations of the avoided flood risk**, and then compared with the **costs of the scenarios**.



Publication bibliography

ANDERSON-TEIXEIRA, KRISTINA J.; DeLUCIA, EVAN H. (2011): The greenhouse gas value of ecosystems. In *Global Change Biology* 17 (1), pp. 425–438. DOI: 10.1111/j.1365-2486.2010.02220.x.

Borzykowski, Nicolas; Baranzini, Andrea; Maradan, David (2017): A travel cost assessment of the demand for recreation in Swiss forests. In *Rev Agric Food Environ Stud* 98 (3), pp. 149–171. DOI: 10.1007/s41130-017-0047-4.

Danube Floodplain (2021a): Deliverable 4.3.1. Report on assessment results of the CBA applied to the pre-selected pilot areas including ESS, stakeholders and biodiversity as input for D 4.4.1 and therefore part of the feasibility studies in output 4.1.

Danube Floodplain (2021b): Deliverable 4.3.2. Method documentation describing the implementation of ESS and biodiversity to traditional CBA as input for D 4.3.4 and therefore of output 5.1.

EEA (2019): Corine Land Cover (CLC) 2018. File number Version 20.

Eurostat (2019): NUTS 2016. With assistance of Statistical Office of the European Union. European Union. Available online at https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statistical-units/nuts#nuts16, checked on 3/8/2019.

Eurostat (2020a): Main livestock indicators by NUTS 2 regions. Eurostat Statistical Database. With assistance of Statistical Office of the European Union (ef_lsk_main). Available online at https://ec.europa.eu/eurostat/data/database.

Eurostat (2020b): Production from aquaculture excluding hatcheries and nurseries (from 2008 onwards). Eurostat Statistical Database. With assistance of Statistical Office of the European Union (fish_aq2a). Available online at https://ec.europa.eu/eurostat/data/database.

FAO (2003): Planted forests database (PFDB). Structure and Contents. With assistance of A Del Lungo, M Varmola. Forest Resources Development Service, Forest Resources Division, FAO. Rome (Planted Forests and Trees Working Papers, 25). Available online at http://www.fao.org/3/y9933e/y9933e00.htm.

FAO (2006): Global Forest Resources Assessment 2005. Progress towards sustainable forest management. Rome: Food and Agriculture Organization of the United Nations (FAO forestry paper, 147).

FAO (2016): Global Forest Resources Assessment 2015. How are the world's forests changing? Second edition (Global forest resources assessment, 2015). Available online at http://www.fao.org/3/a-i4793e.pdf.

FAO (2019): FAOSTAT. Statistical Database. FAO. Rome. Available online at http://www.fao.org/faostat/en/#home.

FAO and ITPS (2018): Global Soil Organic Carbon Map (GSOCmap). Technical Report. FAO and ITPS. Rome. Available online at http://www.fao.org/3/I8891EN/i8891en.pdf.

Gelhaus, Marion (2020): Shapefiles of the ecosystem services (ESS) maps as a result of the stakeholder workshops in the Danube Floodplain pilot areas. Project file.

Hanauer, Merlin M.; Reid, John (2017): Valuing urban open space using the travel-cost method and the implications of measurement error. In *Journal of environmental management* 198 (Pt 2), pp. 50–65. DOI: 10.1016/j.jenvman.2017.05.005.

IEA (2020): Fuel Consumption of Cars and Vans – Analysis. Available online at https://library.wmo.int/doc_num.php?explnum_id=7332, updated on 2020, checked on 2020.

IPCC (Ed.) (2006): 2006 IPCC Guidelines for National Greenhouse Gas Inventories. With assistance of National Greenhouse Gas Inventories Programme, Eggleston, H. S., Buendia L., Miwa K., Ngara T., Tanabe K. Hayama, Japan: Institute for Global Environmental Strategies.

IPCC (Ed.) (2014): 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands. With assistance of T. Hiraishi, T. Krug, K. Tanabe, N. Srivastava, J. Baasansuren, M. Fukuda, T. (eds) G. Troxler. Switzerland: IPCC. Available online at https://www.ipcc.ch/publication/2013-supplement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories-wetlands/.

Monfreda, Chad; Ramankutty, Navin; Foley, Jonathan A. (2008): Farming the planet: 2. Geographic distribution of crop areas, yields, physiological types, and net primary production in the year 2000. In *Global Biogeochem. Cycles* 22 (1), n/a-n/a. DOI: 10.1029/2007GB002947.

Peh, K. S.-H.; Balmford, A. P.; Bradbury, R. B.; Brown, C.; Butchart, S. H. M.; Hughes, F. M. R. et al. (2017): Toolkit for Ecosystem Service Site-based Assessment (TESSA). Version 2.0 (Version 2.0). Available online at http://tessa.tools.

World Bank (2020a): Carbon Pricing Dashboard. Up-to-date overview of carbon pricing initiatives. Available online at https://carbonpricingdashboard.worldbank.org/map_data, checked on 9/8/2020.

World Bank (2020b): State and Trends of Carbon Pricing 2020. (May). With assistance of World Bank. Washington, DC.