NATURE-BASED INFRASTRUCTURE
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Sustainable Asset Valuation of Land Restoration and Climate-Smart Agriculture in Burkina Faso

TECHNICAL APPENDIX

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Sustainable Asset Valuation of Land Restoration and Climate-Smart Agriculture in Burkina Faso: Technical Appendix

June 2024

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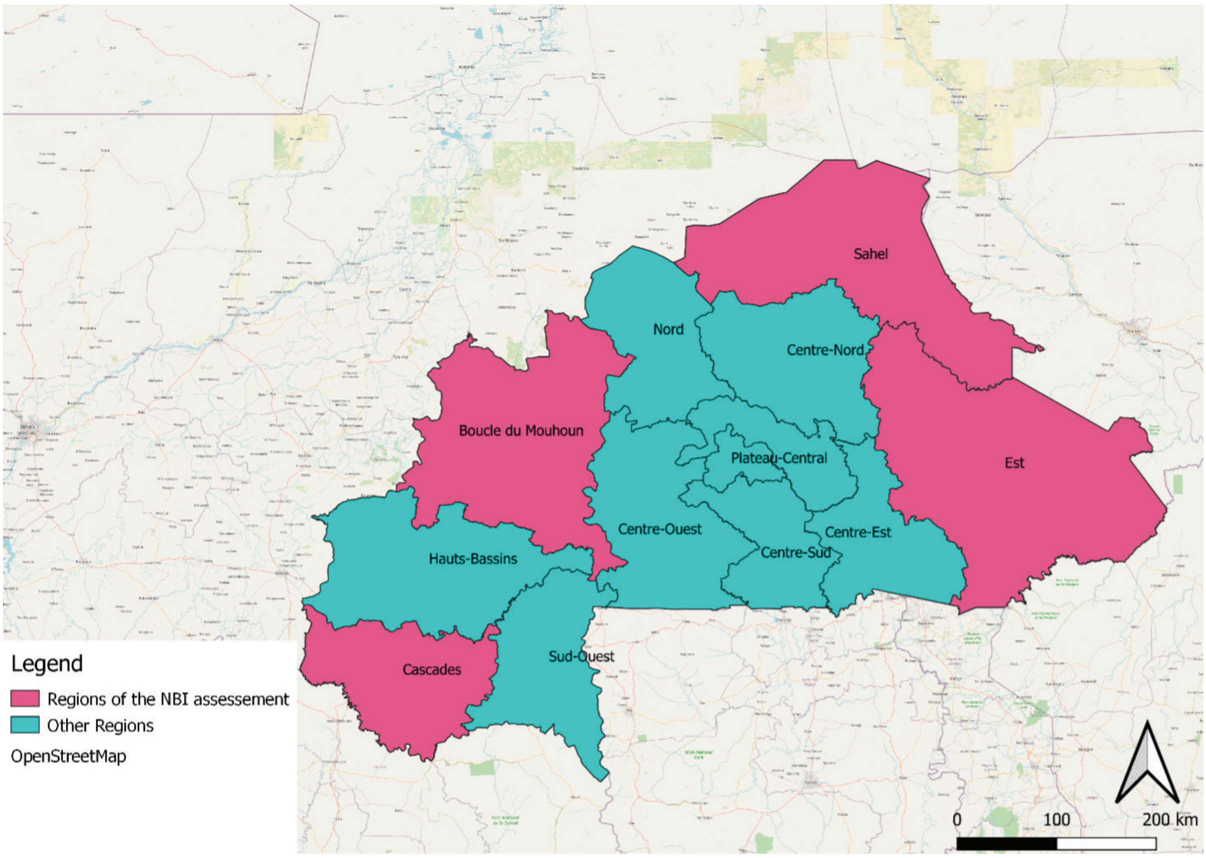
1.0 Model Setup

1.1 Study Area

The regions considered in this nature-based infrastructure (NBI) assessment are the northern regions of the Sahel, the Boucle du Mouhoun, the East, and the Cascades, shown in Figure 1.

Figure 1. Regions of this NBI assessment



Source: Authors.

In this spatial analysis, we considered only the region Boucle du Mouhoun.

1.2 Coordination System

Based on the world project coordinate system called V WGS 84 / Pseudo-Mercator -- Spherical Mercator – ESPG: 3857, here is the detail of the coordinate system:

```
PROJCS["WGS 84 / Pseudo-Mercator",
  GEOGCS["WGS 84",
    DATUM["WGS_1984",
      SPHEROID["WGS 84",6378137,298.257223563,
        AUTHORITY["EPSG","7030"]],
      AUTHORITY["EPSG","6326"]],
    PRIMEM["Greenwich",0,
      AUTHORITY["EPSG","8901"]],
    UNIT["degree",0.0174532925199433,
      AUTHORITY["EPSG","9122"]],
    AUTHORITY["EPSG","4326"]],
  PROJECTION["Mercator_1SP"],
  PARAMETER["central_meridian",0],
  PARAMETER["scale_factor",1],
  PARAMETER["false_easting",0],
  PARAMETER["false_northing",0],
  UNIT["metre",1,
    AUTHORITY["EPSG","9001"]],
  AXIS["X",EAST],
  AXIS["Y",NORTH],
  EXTENSION["PROJ4","+proj=merc +a=6378137 +b=6378137 +lat_ts=0.0
+lon_0=0.0 +x_0=0.0 +y_0=0 +k=1.0 +units=m +nadgrids=@null +wktext  +no_
defs"],
  AUTHORITY["EPSG","3857"]]
```

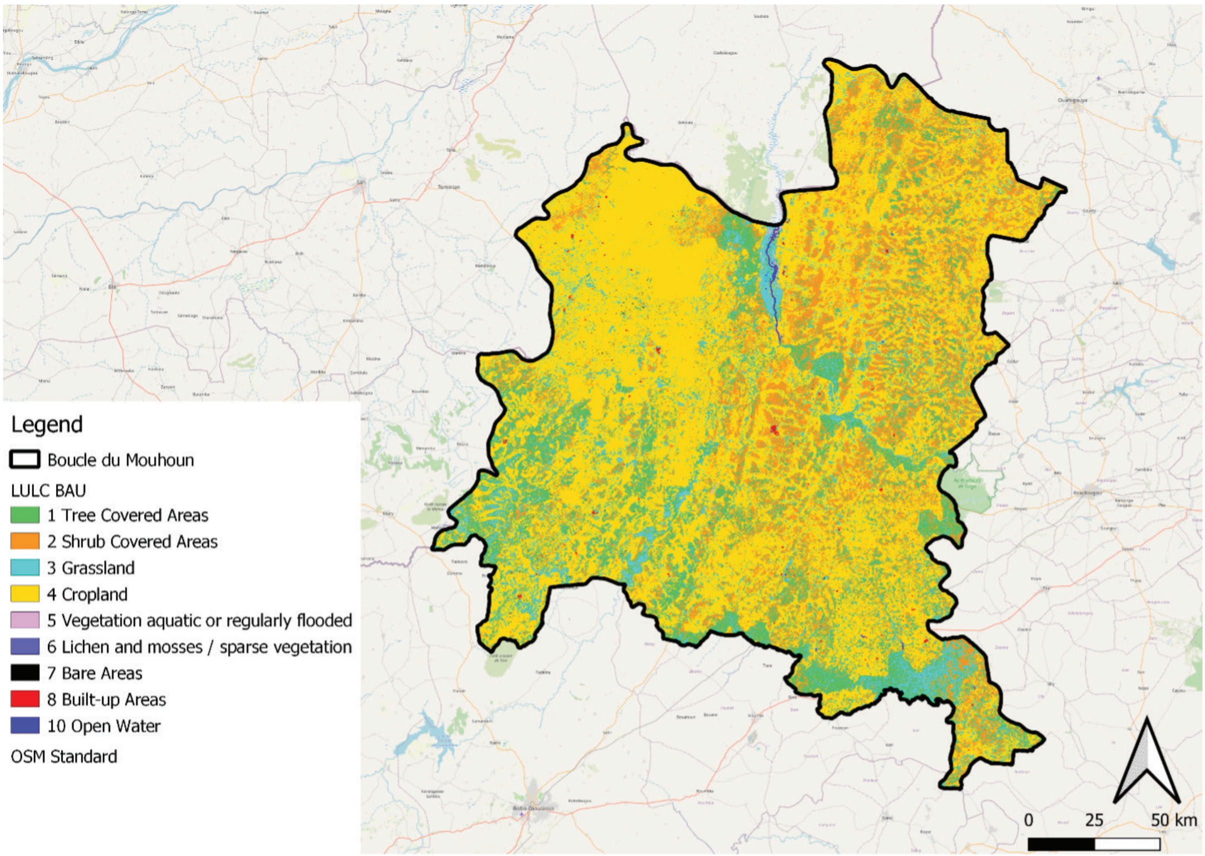
1.3 Current Land Cover Map

The land-use/land cover (LULC) map created by the CCI Land Cover team was used for this analysis (http://2016africalandcover20m.esrin.esa.int/). This is a prototype high-resolution LULC map at 20 m over Africa based on 1 year of Sentinel-2A observations from December 2015 to December 2016.

The legend of this map includes 10 generic classes that appropriately describe the land surface at 20m: "tree-covered areas," "shrub-covered areas," "grassland," "cropland," "vegetation aquatic or regularly flooded," "lichen and mosses/sparse vegetation," "bare areas," "built-up areas," and "open water."

Figure 2 shows the current LULC (business-as-usual [BAU]).

Figure 2. LULC, BAU



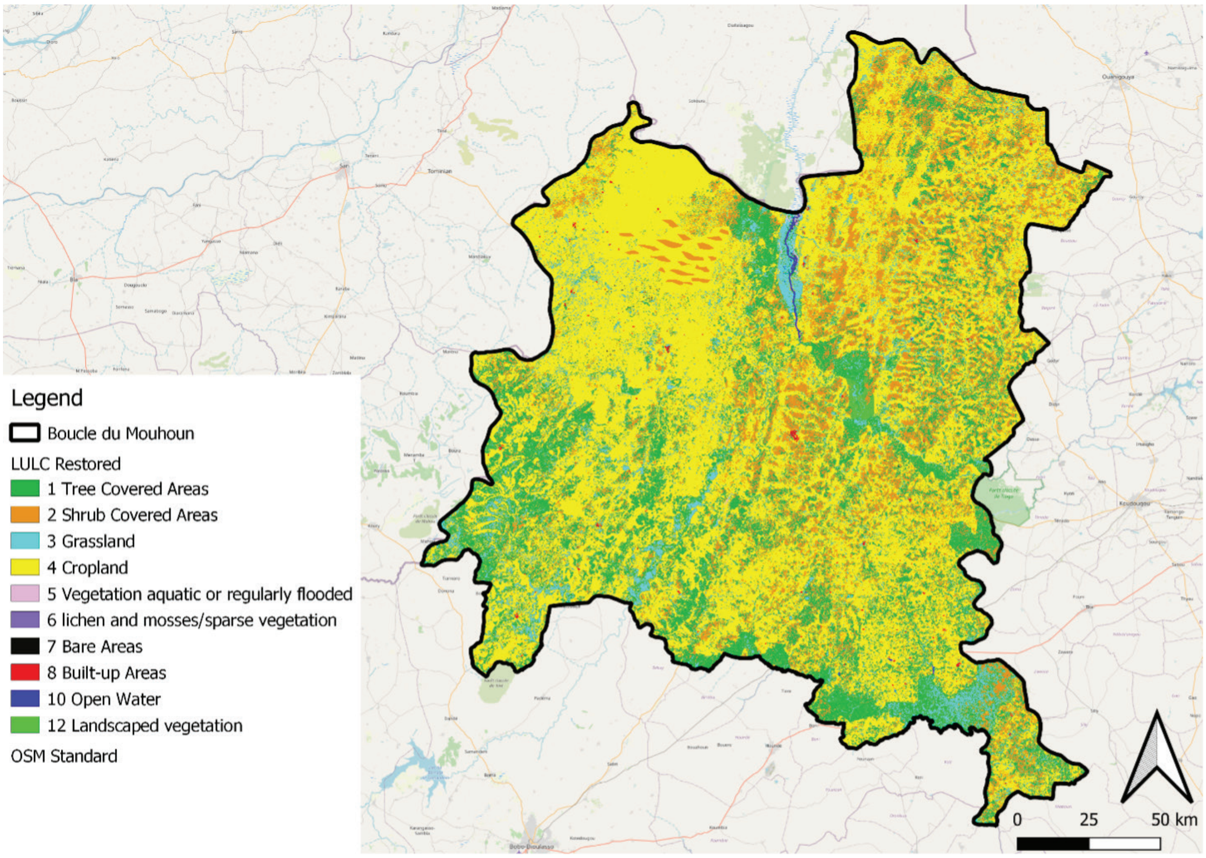
Source: Authors.

1.4 Future Land Cover Map

The restoration activities set in this NBI project (the development of 6,000 ha of landscaped vegetation; 700 ha of lowland development completion, and 10,500 ha of assisted natural regeneration) have been applied to create a future LULC (restored scenario, shown in Figure 3). Figure 3 shows where the restored areas have been located. We assumed that the restoration project would replace agricultural land.

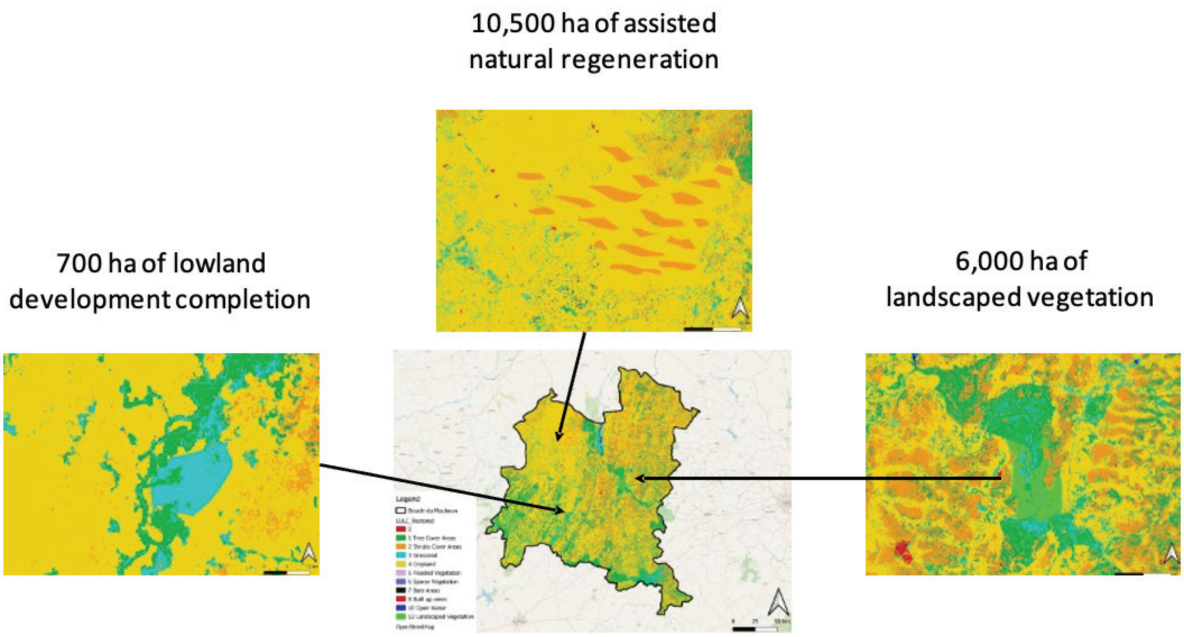
Please note that the 6,000 ha of landscaped vegetation have been considered as a new land cover, since these could be considered new trees (code 12), while the 700 ha of lowland have been considered as grassland, and the 10,500 ha of assisted natural vegetation as shrubs.

Figure 3. LULC Restored



Source: Authors.

Figure 4. Zoom in of the restoration areas



Source: Authors.

1.5 Software and Simulation

The ecosystem services map simulation has been performed using InVEST Software V.3.9.0 (https://naturalcapitalproject.stanford.edu/invest/). The inputs spatial data for the InVEST model have been prepared by utilizing QGIS-OSGeoW-3.4.2-1 (qgis.org/downloads/). The tabulated data will be managed and prepared in Microsoft Excel V. 2016.

2.0 Carbon Storage

2.1 Input Data Preparation and Processing

1. **LULC cover map –** See Sections 1.3 and 1.4.
2. **Carbon Pools –** Table of LULC classes containing data on carbon stored in each of the four fundamental pools for each LULC class
    - carbon aboveground: The values of carbon density in aboveground mass (Mg/ha or tons/ha) of each land-use type are shown in Table 1.
    - carbon belowground: The values of carbon density in belowground mass (Mg/ha or tons/ha) of each land-use type are shown in Table 1.
    - carbon stored in organic matter: The values of carbon density in dead mass (Mg/ha or tons/ha) of each land-use type are shown in Table 1.
    - carbon stored in soil: The values of carbon density in dead mass (Mg/ha or tons/ha) of each land-use type are shown in Table 1.

The unit of measurement for these coefficients is tons/ha. Average carbon coefficient values have been found in the Intergovernmental Panel on Climate Change (2006) *Guidelines for National Greenhouse Gas Inventories report*, Chapter 4, Agriculture, Forestry, and Other Land Use.

Table 1. Carbon pools

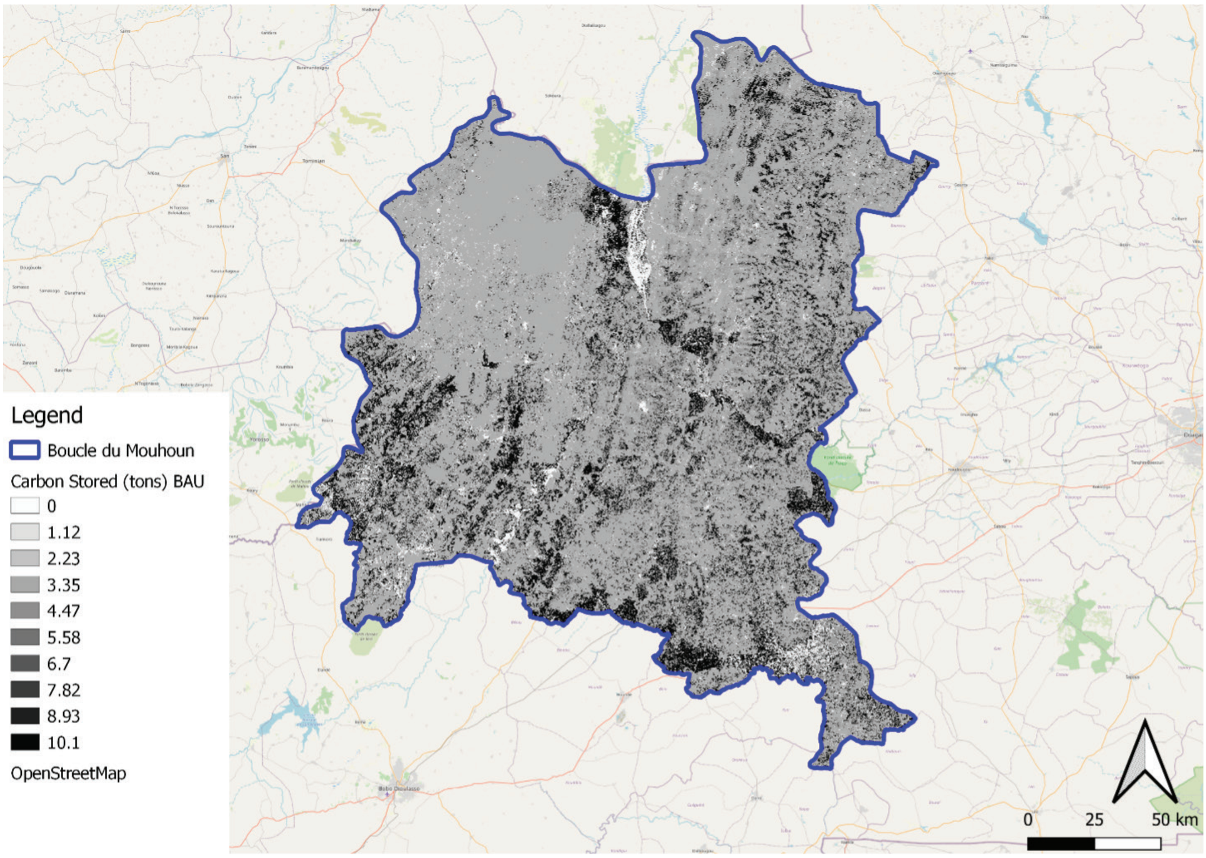
lucode	C_above	C_below	C_soil	C_dead
1	70.5	19.035	138.6701	2
2	32.9	8.883	44.58649	0
3	2.914	0.78678	1.36	0
4	9.87	2.6649	57.43733	0
5	56.4	15.228	64.97652	2
6	2.35	0.6345	13.03842	0
7	0	0	0	0
8	0	0	0	0
10	0	0	0	0
12	37.6	10.152	73.07	2

Source: Authors.

2.2 Results

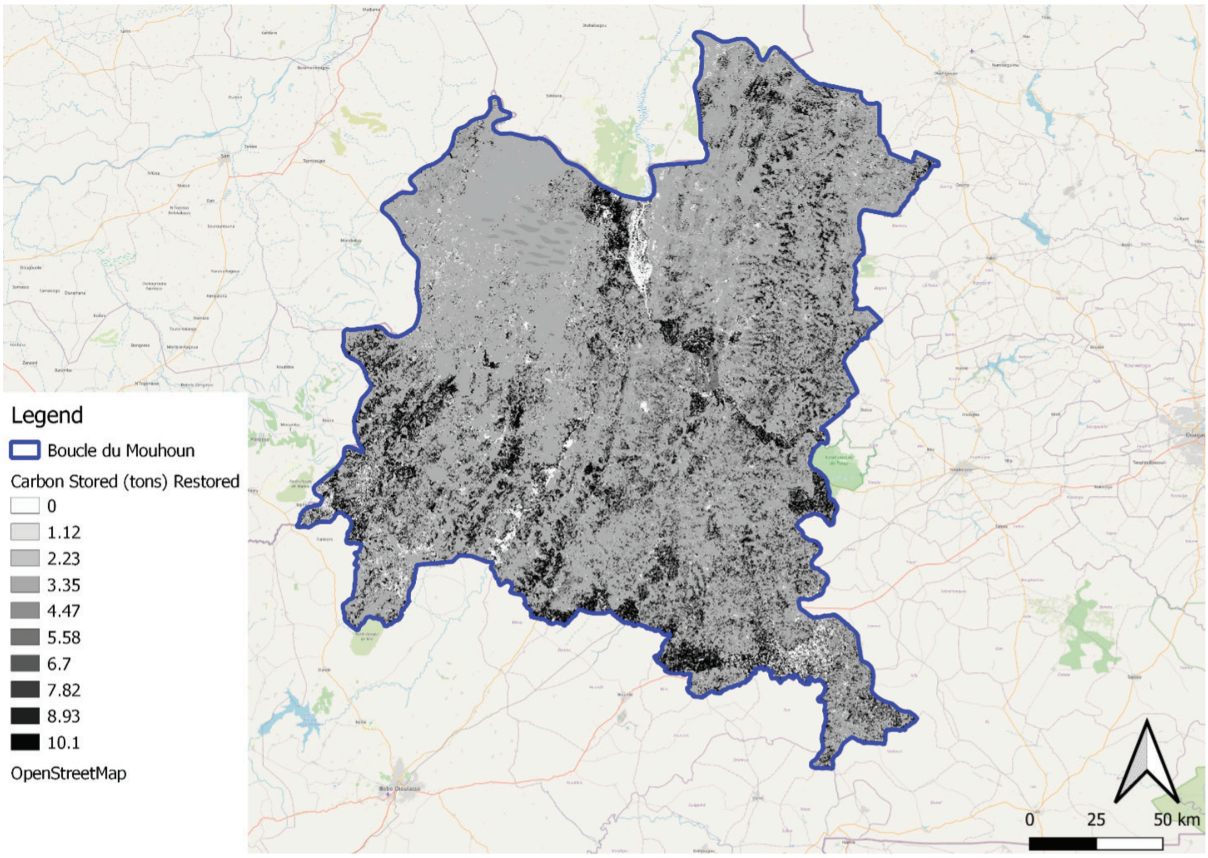
Figures 5 and 6 show the amount of carbon stored (in tons) in each pixel under the BAU and restored scenarios. They are a sum of all the carbon pools provided by the biophysical table.

Figure 5. Carbon model outputs (LULC BAU)



Source: Authors.

Figure 6. Carbon model outputs (LULC restored)



Source: Authors.

Table 2. Carbon pool statistics

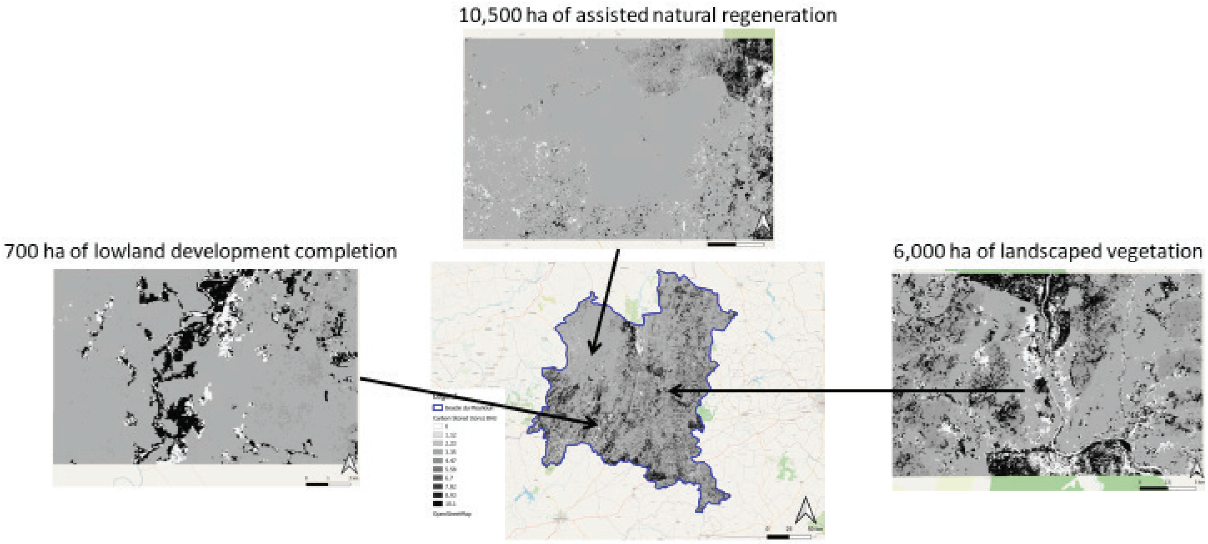
Scenario	Carbon stored (tons)	Change from BAU (%)	Change from BAU (tons)
BAU	349,970,071		
Restored	350,533,009	0.16%	562,938

Source: Authors.

As Table 2 shows, the carbon storage would increase by 0.16% (or more than 500,000 tons) from the BAU to the restored LULC scenario due to the replacement of cropland with the new ha of restored areas.

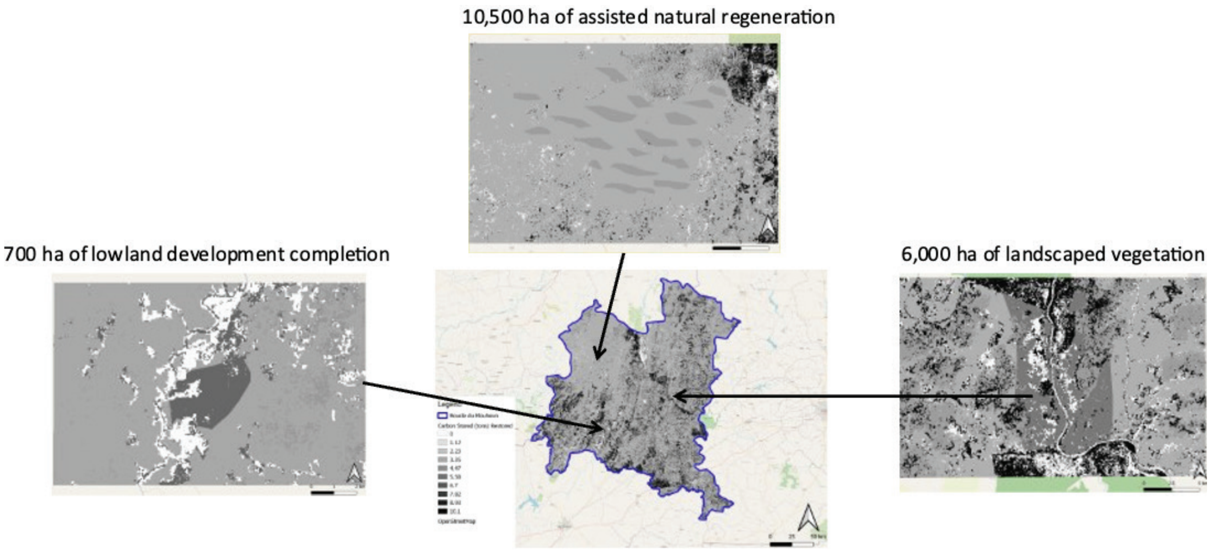
Figures 7 and 8 show the amount of carbon stored (in tons) in each pixel in the areas where restoration activities will occur, under the BAU and restored LULC scenarios, respectively. Table 3 shows the total change of carbon storage in the selected areas. As the table indicates, carbon storage will decrease only in the 700 ha of lowland vegetation, while it will increase in the other two areas.

Figure 7. Carbon storage – selected areas – LULC BAU



Source: Authors.

Figure 8. Carbon storage – selected areas – LULC restored



Source: Authors.

Table 3. Carbon pool statistics – Selected areas

10,500 ha of assisted natural regeneration

Scenario	Carbon stored (tons)	Change from BAU (%)	Change from BAU (tons)
BAU	15,996,446		
Restored	16,257,802	1.63%	261,356

6,000 ha of landscaped vegetation

Scenario	Carbon stored (tons)	Change from BAU (%)	Change from BAU (tons)
BAU	4,970,474		
Restored	5,311,434	6.86%	340,961

700 ha of lowland

Scenario	Carbon stored (tons)	Change from BAU (%)	Change from BAU (tons)
BAU	1,093,303		
Restored	1,053,923	-3.60%	(39,379)

Source: Authors.

3.0 Annual Water Yield

3.1 Input Data Preparation and Processing

1. **Precipitation –** A GIS raster data set with a non-zero value for average annual precipitation for each cell. Its value is expressed in millimetres (mm). The average precipitation (in mm) from 1970 to 2000 downloaded from WorldClim version 2 (www.worldclim.com) was used for this study. The dataset was released on June 1, 2016. The original spatial resolution of the data is 30 seconds x 30 seconds (which is approximately 1 km^2).
2. **Average annual reference evapotranspiration (ET0) –** A GIS raster data set with an annual average evapotranspiration value for each cell in mm. Reference evapotranspiration is the potential loss of water from the soil by both evaporation from the soil and transpiration by healthy alfalfa (or grass) if sufficient water is available. Its value is in mm. In this study, the global evapotranspiration of reference crops was adopted from the Global Aridity Index and Potential Evapotranspiration (ET0) Climate Database v2. The spatial resolution of the data is 30 arc-seconds (approximately 1 km at the equator). The data set can be found here: (https://figshare.com/articles/Global_Aridity_Index_and_Potential_Evapotranspiration_ET0_Climate_Database_v2/7504448/3)
3. **Root-restricting layer depth –** These terms were defined as an average root-restricting layer depth value for each cell. It is the soil depth at which root penetration is strangler inhibited because of physical or chemical characteristics. Root-restricting layer depth may be obtained from some soil maps. If a root-restricting layer depth is not available, soil depth can be used as a proxy. If several soil horizons are detailed, the root-restricting layer depth is the sum of the depths of non-restrictive soil horizons. Its value is in mm. In this study, the absolute depth to bedrock downloaded from soilgrid.org stored in cm was used to present for root-restricting layer depth.
4. **Plant-available water content (PAWC) –** This is the fraction of water that can be stored in the soil profile that is available for plants' use. PAWC can be measured from 0 to 1. The format of PAWC for the model is a GIS raster data set.

   PAWC is a fraction obtained from some standard soil maps. It is defined as the difference between the fraction of volumetric field capacity and permanent wilting point. The PAWC is often available as a volumetric value (mm). To obtain the fraction, it is necessary to divide it by soil depth. Soil characteristic layers are estimated by performing a weighted average from all horizons within a soil component. If PAWC is not available, raster grids obtained from polygon shapefiles of weight average soil texture (%clay, %sand, %silt) and soil porosity will be needed. In this study, the average calculation of available soil water capacity of the volumetric fraction of 2.0 (pF 2.0) from 0 to 2 m was used to represent the PAWC for water yield model simulation.

5. **LULC maps -** See Sections 1.3 and 1.4.
6. **Biophysical Table –** A table of LULC classes, containing data on biophysical coefficients used in this tool. These data are attributes of each LULC class rather than attributes of individual cells in the raster map. This table contains five variables, including [1] *lucode (Land use code)*, [2] *LULC_desc*, [3] *LULC_veg*, [4] *root_depth*, and [5] K_c. Table 4 shows the biophysical table used in this study. Values have been derived from Hoy et al. (2015).

   6.1 Lucode (Land use code): Unique integer for each LULC class (e.g., 1 for forest, 3 for grassland, etc.), must match the LULC raster above.

   6.2 LULC_desc: Descriptive name of LULC class (optional).

   6.3 LULC_veg: Values must be 1 for vegetated land use except for wetlands, and 0 for all other land uses, including wetlands, urban, water bodies, etc.

   6.4 root_depth: The maximum root depth for vegetated land-use classes, given in integer mm. This is often given as the depth at which 95% of a vegetation type's root biomass occurs. For land uses where the generic Budyko curve is not utilized (i.e., where evapotranspiration is calculated based on the equation below, rooting depth is not needed). In these cases, the rooting depth should be set to NA. The equation can be found here in:

   $$AET(x)=Min(Kc(\ell x)\cdot ET_0(x),P(x))$$

   where

$ET_0(x)$	is the reference evapotranspiration.
$Kc(\ell x)$	is the evaporation factor for each land use and land cover.
Kc	factor is the plant evapotranspiration coefficient for each LULC class. It is used to convert from reference evaporation to potential evaporation for each land use.

   6.5 Kc: The plant evapotranspiration coefficient for each LULC class, used to obtain potential evapotranspiration by using plant physiological characteristics to modify the reference evapotranspiration, which is based on alfalfa. The evapotranspiration coefficient is thus a decimal in the range of 0 to 1.5 (some crops evapotranspire more than alfalfa in some very wet tropical regions and where water is always available).

Table 4. Biophysical table used in this study

lucode	LULC_desc	LULC_veg	root_depth	Kc
1	lc_1	1	7,300	1.3
2	lc_2	1	5,100	0.4
3	lc_3	1	2,600	1
4	lc_4	1	2,100	0.65
5	lc_5	1	5,000	1.1
6	lc_6	1	100	0.05
7	lc_7	0	100	0.05
8	lc_8	0	1	0.05
10	lc_10	0	2,000	1
12	lc_12	1	7,300	1.1

Source: Authors.

Z parameter - Z is an empirical constant that captures the local precipitation pattern and hydrogeological characteristics, with typical values ranging from 1 to 30. It corresponds to the seasonal distribution of precipitation. This parameter is mainly used for model calibration; however, in this study, there is no observed data for the model calibration. Therefore, the recommended default value of the Z parameter equal to 5 was used.

3.2 Results

The main output of this model is a table containing biophysical output values per watershed, with the following attribute:

- *wyield_vol* (m^3): volume of water yield in the watershed.

Table 5. Water yield results

Scenario	wyield_vol (m^3)	Change from BAU
BAU	686,314,179	
Restored	683,682,599	-0.38%

Source: Authors.

Table 5 shows the results of the water yield model. The results show that the total volume of water yield will decrease by 0.38%. This decrease in water yield is caused by the increase in forest land and other land classes replacing cropland. The yield decreases because natural vegetation can, in fact, intercept precipitation and retain large amounts of water (Paul, 2016). While the decline in water yield (due to an increase in forest land, grassland, and shrubs) indicates that more water is retained in the landscape—which would constrain water availability for productive purposes (e.g., agriculture)—a limitation of the water yield model is that it does not consider monthly but only annual water flows.

4.0 Annual Nutrient Delivery Ratio

4.1 Input Data Preparation and Processing

1. **Digital elevation model (DEM) raster –** DEM: the hydrologically conditioned elevation data set distributed by HydroSHEDS (https://www.hydrosheds.org/) was downloaded on April 1, 2023, for InVEST sediment model input. The data was prepared for hydrological model input purposes, mainly for flow direction, accumulation simulation, river network and basin delineation. The data set was filled with missing data values, and seeded inland sinks and depressions on original SRTM-3 and DTED-1 DEM. The original spatial resolution of the dataset is 3 arc-second (approximately 90 m at the equator). The data is provided in geographic projection (latitude/longitude) referenced to the WGS84 horizontal datum and EGM96 vertical datum. Its elevation values are in metres.
2. **LULC maps -** See Sections 1.3 and 1.4.
3. **Nutrient runoff proxy raster (precipitation) –** A GIS raster data set with a non-zero value for average annual precipitation for each cell. Its value is in mm. In this study, the data utilized the same precipitation dataset as employed in the water yield model (annual mean value from 1970 to 2000). We also used the monthly mean value for August for the same period (1970–2000) and the future forecasted precipitation under the SSP5-8.5 scenario for the period 2041–2060 using the IPSL-CM5A-LR model.
4. **Watershed polygons –** A shapefile of polygons. This is a layer of watersheds such that each watershed contributes to a point of interest where water quality will be analyzed. Watersheds were downloaded from https://www.hydrosheds.org/
5. **Biophysical table –** A table of LULC classes containing data on water-quality coefficients used in this tool (Table 6). NOTE: these data are attributes of each LULC class rather than attributes of individual cells in the raster map. The table has the following fields:

    5.1 **Lucode –** unique identifier for each LULC class.

    5.2 **LULC_desc –** nominal name for each LULC class.

    5.3 **load_n / load_p –** The nutrient loading for each land use. If nitrogen is being evaluated, supply values in load_n, for phosphorus, supply values in load_p. The potential for terrestrial loading of water quality-impairing constituents is based on nutrient export coefficients. The nutrient loading values are given as integer values and have units of kg. ha-1 yr -1. The values of the nutrient load were assumed.

5.4 **eff_n / eff_p –** The vegetation filtering value per pixel size for each LULC class, as an integer percent between zero and 1. If nitrogen is being evaluated, supply values in eff_n, for phosphorus, supply values in eff_p. This field identifies the capacity of vegetation to retain nutrients, as a percentage of the amount of nutrient flowing into a cell from upslope. For example, if the user has data describing that wetland of 5,000 m^2 retains 82% of nitrogen, then the retention efficiency that they should input into this field for eff_n is equal to (82/5000 * (cell size)^2). In the simplest case, when data for each LULC type are not available, high values (60 to 80) may be assigned to all natural vegetation types (such as forests, natural pastures, wetlands, or prairie), indicating that 60–80% of nutrient is retained. An intermediary value also may be assigned to features such as contour buffers. All LULC classes that have no filtering capacity, such as pavement, can be assigned a value of zero. The values of the capacity of vegetation to retain nutrients by LULC were assumed.

5.5 **crit_len_n (and/or crit_len_p)** (at least one is required): The distance after which it is assumed that a patch of a particular LULC type retains nutrient at its maximum capacity, given in metres. If nutrients travel a distance smaller than the retention length, the retention efficiency will be less than the maximum value eff_x, following an exponential decay.

This value represents the typical distance necessary to reach the maximum retention efficiency. It was introduced in the model to remove any sensitivity to the resolution of the LULC raster. In the absence of local data for land uses that are not forest or grass, it is possible to simply set the retention length constant, equal to the pixel size: this will result in the maximum retention efficiency being reached within a distance of one pixel only. Therefore, the value of 20 m was used for this parameter. It is the value of cell size used for model simulation.

5.6 **proportion_subsurface_n or p (optional):** The proportion of dissolved nutrients over the total amount of nutrients, expressed as a floating-point value (ratio) between 0 and 1. By default, this value should be set to 0, indicating that all nutrients are delivered via surface flow.

Table 6. Biophysical table – annual nutrient delivery ratio

lucode	LULC _desc	LULC _veg	load _n	load _p	eff _n	eff _p	load_ subsurface_n	load_ subsurface_p	proportion_ subsurface_n	proportion_ subsurface_p	crit_ len_p	crit_ len_n
1	lc_1	1	1.61	0.001	0.4	0.4	0	0	0	0	20	20
2	lc_2	1	0.005	0.005	0.3	0.3	0	0	0	0	20	20
3	lc_3	1	0.005	0.005	0.3	0.3	0	0	0	0	20	20
4	lc_4	1	11	3	0.15	0.15	0	0	0	0	20	20
5	lc_5	1	0.5	0.001	0.3	0.3	0	0	0	0	20	20
6	lc_6	1	0.07	0.001	0.05	0.05	0	0	0	0	20	20
7	lc_7	0	0.07	0.001	0.05	0.05	0	0	0	0	20	20
8	lc_8	0	10	2	0.05	0.05	0	0	0	0	20	20
10	lc_10	0	0	0	0.6	0.6	0	0	0	0	20	20
12	lc_12	1	1.61	0.001	0.4	0.4	0	0	0	0	20	20

Source: Authors.

6. **Threshold flow accumulation value:** Integer value defining the number of upstream pixels that must flow into a pixel before it is considered part of a stream. This is used to generate a stream layer from the DEM. This threshold expresses where hydrologic routing is discontinued, i.e., where retention stops and the remaining pollutant will be exported to the stream. The default is 1 over the pixel area (in km^2), i.e., ~1,000 for 30 m resolution. If the user has a map of stream lines in the watershed of interest, they should "calibrate" the threshold value by comparing the map with the stream.tif map output by the model. The default value of 1,000 was used for the simulation.
7. **Subsurface maximum retention efficiency (nitrogen or phosphorus):** the maximum nutrient retention efficiency that can be reached through subsurface flow, a value between 0 and 1. This field characterizes the retention due to biochemical degradation in soils. The default value of 0.8 was used for this study.
8. **Subsurface_crit_len (nitrogen or phosphorus) (in metres):** the distance (travelled subsurface and downslope) after which is assumed that soil retains nutrient at its maximum capacity. If dissolved nutrients travel a distance smaller than subsubsurface_crit_len, the retention efficiency is lower than the maximum value defined above. Setting this value to a distance smaller than the pixel size will result in the maximum retention efficiency being reached within one pixel only. The default value of 150 suggested for the model for the spatial resolution lower than 150 metres was used in this analysis.
9. **Borselli k parameter:** calibration parameter that determines the shape of the relationship between hydrologic connectivity (the degree of connection from patches of land to the stream) and the sediment delivery ratio (percentage of soil loss that actually reaches the stream). The default value is 2.

4.2 Results

The main output of this model is the following:

- N_export_tot (kg/pixel/year): total nitrogen export from the watershed
- P_export_tot (kg/pixel/year): total phosphorus export from the watershed

Table 7. Nutrient export using the average annual precipitation 1970-2000 as nutrient runoff proxy raster

Nutrient export using average annual precipitation 1970–2000

Scenario	Nitrogen export (kg/year)	Change from BAU
BAU	6,914,646	
Restored	6,861,781	-0.76%
Scenario	**Phosphorus export (kg/year)**	**Change from BAU**
BAU	1,800,808	
Restored	1,785,960	-0.82%

Source: Authors.

Table 8. Nutrient export using the average monthly precipitation (August 1970-2000) as nutrient runoff proxy raster

Nutrient export using average monthly precipitation (August) 1970–2000		
Scenario	**Nitrogen export (kg/year)**	**Change from BAU**
BAU	6,921,687	
Restored	6,864,798	-0.82%
Scenario	**Phosphorus export (kg/year)**	**Change from BAU**
BAU	1,804,476	
Restored	1,788,447	-0.89%

Source: Authors.

Table 9. Nutrient export using average monthly precipitation (August 2041–2060) as nutrient runoff proxy raster

Nutrient export using average monthly precipitation (August) 2041–2060		
Scenario	**Nitrogen export (kg/year)**	**Change from BAU**
BAU	7,034,131	
Restored	6,978,910	-0.79%
Scenario	**Phosphorus export (kg/year)**	**Change from BAU**
BAU	1,833,133	
Restored	1,817,557	-0.85%

Source: Authors.

Table 7 shows the total nitrogen and phosphorus exports under the BAU and restored LULC scenarios. The results indicate that exports of both nutrients would decrease slightly by less than 1% in the restored scenario, compared with the current landscape. Similar absolute results are shown in Table 8, where, in this case, the average monthly precipitation (August) for the same period has been used instead of the annual values. Finally, Table 9, which shows nutrient export using the average monthly precipitation (August) for the period 2041–2060, indicates that the declines of nitrogen and phosphorus exports from the BAU to the restored scenarios are similar to the ones shown in Tables 7 and 8. However, the absolute values are larger due to the stronger forecasted precipitation.

5.0 Annual Sediment Delivery Ratio

5.1 Input Data Preparation and Processing

1. **DEM raster –** DEM: the hydrologically conditioned elevation data set distributed by HydroSHEDS (https://www.hydrosheds.org/) was downloaded on April 1, 2023 for InVEST sediment model input. The data was prepared for hydrological model input purposes, mainly for flow direction, accumulation simulation, river network, and basin delineation. The data set was filled with missing data values and seeded inland sinks and depressions on original SRTM-3 and DTED-1 DEM. The original spatial resolution of the dataset is 3 arc-second (approximately 90 metres at the equator). The data is provided in geographic projection (latitude/longitude) referenced to the WGS84 horizontal datum, and EGM96 vertical datum. Its elevation values are in metres.
2. **Rainfall erosivity index (R) raster –** A GIS raster dataset containing the erosivity index for each cell. This variable depends on the intensity and duration of rainfall in the area of interest. The greater the intensity and duration of the rain storm, the higher the erosion potential. The erosivity index is widely used, but in case of its absence, there are methods and equations to help generate a grid using climatic data. It value is $MJ*mm*(ha*h*yr)^{-1}$. The R factor dataset in spatial resolution of 25 km downloaded from https://www.nature.com/articles/s41467-017-02142-7 was employed for this study. The technical report of the data also can be found here: https://static-content.springer.com/esm/art%3A10.1038%2Fs41467-017-02142-7/MediaObjects/41467_2017_2142_MOESM1_ESM.pdf
3. **Soil erodibility (K) raster –** A raster data set of soil erodibility. It is a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff. Its value is in $T.ha.h.(ha.MJ.mm)^{-1}$. The spatial resolution of 25 km of soil erodibility downloaded from https://www.nature.com/articles/s41467-017-02142-7 was used in this study.
4. **LULC maps -** See Sections 1.3 and 1.4.
5. **Biophysical table –** A table containing model information corresponding to each of the LULC types (see Table 10). The table has the following fields:

    5.1 **Lucode (land-use code) –** unique integer to identifier for each LULC class.

    5.2 **LULC_desc –** nominal name for each LULC class.

    5.3 **usle_c –** It refers to cover management factor, sometimes called cropping management factor (C factor) for the universal soil loss equation (USLE). This value is used to calculate the cover management in USLE. The C factor represents the effect of surface cover and roughness on soil erosion. The cover factor is the most common factor used to assess the impact of best management practices (BMPs) on reducing erosion because the C factor represents the effect of land use on soil erosion (Renard, 1997). Erosion control blankets and surface-applied BMPs, such as blown straw, are represented as C factors within USLE. By definition, C = 1 under standard fallow conditions. As the surface cover is added to the soil, the C factor value approaches zero. For example, a C factor of 0.20 signifies that 20% of the amount of erosion will occur compared to continuous fallow conditions. C factors vary from region to region because they are strongly influenced by different Rainfall Erosivity Index (R factors) (Wischmeier & Smith, 1978). In the InVEST model, its value is stored in a float value ranging from 0 to 1.

5.4 **usle_p –** It refers to management practice, support, or conservation practice factor (P factor) in USLE. The P factor reflects the impact of support practices on the average annual erosion rate. P is the ratio of soil loss with a support factor to that with straight row farming up and down slope. Strip-cropping, contouring, and terracing are all activities that are considered support practices by USLE. The support factor is unitless, and its value is stored in a float value ranging from 0 to 1.

5.5 **sedret_eff –** the sediment retention factor for each LULC class. The column contains information in a float value ranging from 0 to 1. It refers to the capacity of each LULC class to retain sediment. This value is a percent per pixel area. The value of 1 for LULC class means that the class contains the most natural vegetation (forest, natural pastures wetlands, and prairie) in that class. The value of 0 means otherwise. The LULC class with a value of 0 should be pavement, roads, or urban areas.

Table 10. Biophysical table annual sediment delivery ratio

lucode	LULC_veg	usle_c	usle_p	sedret_eff
1	1	0.013	0.07	0.7
2	1	0.15	0.15	0.6
3	1	0.2	0.17	0.8
4	1	0.5	0.4	0.25
5	1	0.013	0.07	0.8
6	1	0.2	0.2	0.35
7	0	0.8	0.25	0.25
8	0	0.5	0.1	0.05
10	0	0	0.01	0.6
12	1	0.013	0.07	0.7

Source: Authors.

6. **Threshold flow accumulation –** The number of upstream cells that must flow into a cell before it is considered part of a stream, which is used to classify streams from the DEM. This threshold directly affects the expression of hydrologic connectivity and the sediment export result: when a flow path reaches the stream, sediment deposition stops, and the sediment exported is assumed to reach the catchment outlet. It is important to choose this value carefully so that modelled streams come as close to reality as possible. The default value of 1,000 was used for this simulation.
7. **Borseli K parameter (kb) and Borseli IC0 parameter (IC_0) –** two calibration parameters that determine the shape of the relationship between hydrologic connectivity (the degree of connection from patches of land to the stream) and the sediment delivery ratio (percentage of soil loss that actually reaches the stream). The default values of kb=2 and IC_0=0.5 were used in the simulation.
8. **Max SDR (sediment delivery ratio) value (SDRmax) –** the maximum SDR that a pixel can reach, which is a function of the soil texture. More specifically, it is defined as the fraction of topsoil particles finer than coarse sand. This parameter can be used for calibration in advanced studies. Its default value of 0.8 was used.

5.2 Results

Table 11. Sediment export statistics

Scenario	Sediment export (tons)	Change from BAU
BAU	26,742,438	
Restored	26,675,547	-0.25%

Source: Authors.

Table 11 shows the total sediment export (tons) under both the BAU and restored LULC scenarios, indicating that it will decrease by 0.25%. This change can be explained by the modification in land cover under the restored scenario. The sediment retention efficiency is the ability of vegetation to retain sediment flowing into a pixel from upslope, and it is specific for every land class, with forest land having the largest efficiency (Terrado et al., 2014). Therefore, since forest, shrubs, and grassland increase (replacing cropland), sediment export decreases as a consequence.

6.0 References

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