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MAFE-T
(Mapping Alternatives For Equivalents – Terrestrial)

A tool for integrating biodiversity and ecosystem services into impact assessment and offset portfolio design in Colombia

User's Guide

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Overview

MAFE-T (Mapping Alternatives For Equivalents – Terrestrial) is a free, open-source, stand-alone software tool that will run on recent Windows operating systems (Windows Vista and later). MAFE-T enables users to estimate the impacts of development activities on terrestrial ecosystems and several of the services they provide, and then to select offsets to efficiently mitigate losses. MAFE-T tracks how people are affected by the environmental impacts of development and mitigation activities, making the consequences of development more transparent and enabling mitigation portfolios to be designed in a way that maintains or restores environmental benefits in a socially equitable manner.

MAFE-T was developed to support offset portfolio selection in Colombia based on its national offset policy and manual. The software tool includes by default all the data necessary to run analyses anywhere in Colombia. The only required user-provided data input is a map of the proposed development site whose impacts should be mitigated. This user's guide provides information on running MAFE-T, assembling required and optional inputs and interpreting tool results. Additional questions about the tool should be posted on the Natural Capital Project User Forum (http://ncp-yamato.stanford.edu/natcapforums/), where NatCap scientists and tool developers can provide an answer.

OPAL (Offset Portfolio Analyzer and Locator), a sister tool to MAFE, has added flexibility and the capacity to be used beyond Colombia to support offset portfolio design in diverse contexts around the world with user-provided environmental and social data. For those interested in this added flexibility, OPAL can be found here: http://ncp-dev/~dataportal/nightly-build/adept/installer/OPAL_69_0.2.0_7f1014106a75_x86_Setup.exe .

MAFE-T Workflow

MAFE-T was developed to support Colombia's national offset policy and includes country-wide default data (see the "Information on Colombia default data" section for details). For analyses in Colombia using default data, MAFE-T can be used to estimate development impacts on and select offsets for biodiversity, carbon storage, sediment retention and nitrogen retention with only one required input: the project footprint. It is important to note that the default data only accounts for impacts to biodiversity through the loss of primary vegetation. Mitigation of impacts to secondary vegetation may be required, and must be determined separately.

In this case, the workflow will be as follows:

Assemble input data →Run MAFE-T → Select offset portfolio and explore net balance

To override default ecosystem service data in Colombia with newer or higher quality data, some additional steps and data inputs are needed (see "Running MAFE-T" and "Static maps: default maps and & generating custom maps" sections). In this case, the workflow will be as follows:

Assemble input data → Create static ecosystem service maps → Evaluate static map quality → Run MAFE-T with custom data → Select offset portfolio and explore net balance

Downloading and installing MAFE-T

1. Download from website (http://ncp-dev/~dataportal/nightly-build/MAFE-T/installer/?C=M;O=D)

2. Double click downloaded file to install MAFE-T

3. Select installer language, and click "Next" to advance.

4. Click "I Agree" to accept the license agreement.

5. Choose whether to install default national static map data for Colombia by checking or unchecking the associated boxes. If any of these datasets are not installed, the user must later provide their own equivalent static map data, either from another source or generated using the helper tools included with MAFE-T (see "Static maps: default maps and & generating custom maps" for more information).

6. For each static map dataset chosen, select the installation method. Selecting "Download during install" will download the data from the Natural Capital Project's online servers. Note that the static data for Colombia included here are xx GB to download and require xx GB of disk space. If you don't have a fast internet connection or otherwise prefer to download the data from a local source (e.g., DVD or local disk), select "Use a local file" and point to the appropriate zip file. In this case, the zip files must have been saved previously from http://ncp-dev.stanford.edu/~dataportal/nightly-build/adept/data/ or another source.

7. Click "Install" to start the installation.

8. To download optional sample data, download and unzip sample_data.zip from http://ncp-dev.stanford.edu/~dataportal/nightly-build/adept/data/

Running MAFE-T

1. Launch MAFE-T from the start menu

2. Select **workspace (required)** where output files will be saved

3. Input **project footprint (required)**
   The project footprint must be a polygon shapefile of the area of development. If the shapefile contains multiple features, the analysis will consider the impacts of all polygons.

4. Select **impact type (required)**

Options are either "Road/Paved" for development that results in paved surfaces or "Mine/Bare" for development that results in exposed ground.

5. Input **area of influence (optional)**

The area of influence is a polygon shapefile. If no input is provided, MAFE-T defaults to using the project footprint's hydrological subzone (or subzones, if the project crosses more than one). MAFE-T tracks which potential offset parcels are located within the area of influence so that they can be prioritized for selection in the offset portfolio.

6. **Use custom ecosystems map, servicesheds, search areas or municipalities (all optional):** Select boxes to override default data and then set the location of the custom data.

    a. **Custom natural ecosystems map**

    A polygon shapefile of natural ecosystems. The amount and type of biodiversity offset needed is calculated based on the overlap between natural ecosystems and the project footprint, and potential offset patches are also selected from natural ecosystems provided here.

    Format: Each row should be a polygon or multi-polygon of a particular ecosystem type. Each column contains information about the ecosystem, and two columns must be named as follows:
    1. *ecosystem:* string value with the name of the ecosystem type
    2. *mit_ratio*: the numeric compensation factor/mitigation ratio for that ecosystem

    b. **Custom servicesheds**

    A polygon shapefile of the servicesheds for hydrological services, which are the watersheds upstream of drinking water intake points. Impacts for hydrological services will be summed by serviceshed.

    Format: Each row should be a polygon or multi-polygon of the serviceshed for a particular population center. Each column contains information about the serviceshed, and two columns must be named as follows:
    1. *pop_center*: string value with the name of the population center or beneficiary group linked to the serviceshed
    2. *pop_size*: the number of people within the population center or beneficiary group

    c. **Custom search areas**

    A polygon shapefile. Within Colombia, this represents hydrological zones and subzones, as specified by the offset manual. Potential offset patches are restricted to the same hydrozone as the project footprint**,** and the results report indicates which

offset patches are located within the same hydrosubzone as the project footprint so that they can be prioritized.

> *Format*: Each row should be a hydrosubzone. The column contains the name of the hydrozone to which each hydrosubzone belongs, and must be formatted as follows:
> 1. *zone*: string value with the name of the hydrozone to which the hydrozone belongs

    d. **Custom municipalities**

A polygon shapefile. Each individual polygon should represent a municipality's borders. The results report indicates which offset patches are located within the same municipality as the project footprint so that they can be prioritized.

7. Input **threat map (optional)**

A raster file whose values should indicate the level of threat from anthropogenic influences at a particular point. Threat is considered an indicator of patch quality for biodiversity. If included, offset patches will be restricted to those with average threat values less than or equal to that of ecosystem patches intersecting the impact site (project footprint). This ensures that offset patches are of equal or greater quality to the impacted patches.

8. Input **species richness map (optional)**

A raster file whose values indicate the level of species richness at a particular site. Species richness is considered an indicator of patch quality for biodiversity. If included, offset patches will be restricted to those with average species richness values greater than or equal to that of ecosystem patches intersecting the impact site (project footprint). This ensures that offset patches are contain an equal or greater amount of species richness relative to the impacted patches

9. Input **avoidance areas (optional)**

A polygon shapefile indicating designated areas where development impacts should be avoided. In Colombia, these are also termed "areas of exclusion." This might include protected areas, RAMSAR wetland sites or other areas where development impacts are discouraged or prevented by law. If the project footprint intersects with an avoidance area, the tool will issue a warning. Such projects are unlikely to be allowed or may face additional mitigation requirements beyond those calculated by the tool due to their special conditions.

10. Input **conservation portfolio (optional)**

A polygon shapefile indicating priority areas for locating offsets. This map could be based on landscape-level conservation planning exercises, policy or other source of prioritization. If included, the results will indicate which potential offset patches fall within the conservation portfolio so that they can be preferentially selected for the offset portfolio.

11. Input **previously granted impacts (optional)**

A polygon shapefile of project footprints of impact sites that have been granted but are not yet represented as developed land in the land use/land cover map. If included, portions of natural vegetation patches that intersect previously granted impacts will be removed from potential offset patches so that they cannot be counted towards offsets.

12. Input **previously selected offsets (optional)**

A polygon shapefile of areas that cannot be selected as offsets because they have already designated as offsets for other projects. . Vegetation patches within this shapefile will be excluded from potential offset sites in the results. Other sites that are not at risk of degradation and so whose protection would not provide additional benefits beyond baseline conditions (e.g., protected areas), or areas that are otherwise not feasible as offsets for political, social, economic or other reasons can also be included here

13. Choose to **calculate impacts/offsets to carbon, nitrogen and/or sediment (all three recommended)**. Select the boxes for services that should be included in the results. The default static data for Colombia includes data for all three services.

14. Input **custom carbon, nutrient, sediment or other ecosystem service static maps (optional)** by selecting a folder containing the static maps for each desired service. For carbon, nutrient or sediment static maps to be included, the associated check box described above must also be selected.

    a. **Custom carbon, nutrient and sediment static maps** are sets of raster maps used by the tool to estimate the impacts of development or benefits of protection. These maps can be created using MAFE-T's static map generators. **See section for detailed information on creating custom static maps.**

    b. **Custom ecosystem service static map**: To include an additional ecosystem service beyond the three default services, the user can develop their own set of static maps and select the folder containing them here. The **type of custom service** field indicates what kind of serviceshed should be applied when tracking impacts: either the total change in service ("global" option, as applies to carbon storage) or the change in service per upstream watershed ("hydrological" option, as applies to sediment and nutrient retention for drinking water quality).

        Format: A folder containing the following three rasters ==(plus associated percent to stream rasters for each, if "hydrological option" is selected)==:
        1. *custom_bare_static_map.tif*: A raster indicating the impact on the given service for each pixel of conversion to bare ground. Negative values indicate a loss in service provision.
        2. *custom_paved_static_map.tif*: A raster indicating the impact on the given service for each pixel of conversion to paved ground. Negative values indicate a loss in service provision.

3. *custom_protection_static_map.tif*: A raster indicating the impact on the given service for each pixel of avoided loss of natural vegetation (protection). Positive values indicate a gain in service provision.

15. Click "Run" to begin analysis.

Interpreting results and selecting an offset portfolio

After successfully running MAFE-T, the results can be found in the selected workspace in a folder named after the hydrozone containing the impact site. For impact sites that span multiple hydrozones, a separate folder will appear for each hydrozone.

Located within each results folder is an interactive report (hydrozonename_report.html) for exploring the results. The report is organized into three sections: 1. The estimated impacts to ecosystems and ecosystem services from the project; 2. An interactive table of the potential offset patches and their mitigation value, from which an offset portfolio can be selected; and 3. The estimated net benefits to ecosystems and ecosystem services based on the combined project impacts and selected offsets.

The report contains the following information for analyzing impacts, evaluating potential offset patches and selecting an offset portfolio:

1. **Summary of impacts to ecosystems and ecosystem services**
    a. Impact type
        Indicates the impact type that was selected for analysis, either "Paved/Road" or "Bare ground/Mine"
    b. Total impacts to ecosystem services
        Estimate of the biophysical impact of the project on carbon storage, sediment retention, nitrogen retention and, if data is provided, any additional ecosystem service. Note that a negative value indicates a loss of service provision, and therefore a negative impact. These estimates are based on the static impacts maps. (See "Static maps: default maps and & generating custom maps" details) To see where people are affected by these changes, scroll down to the "Ecosystem service benefits" table in the third section ("Net benefits to ecosystems and ecosystem services"), where impacts are listed by serviceshed.
    c. Total impacts to terrestrial ecosystems:
        Estimate of the impacts of the project on ecosystems, summarized by ecosystem type.
    d. Details of impacts to terrestrial ecosystems:
        Information on each ecosystem patch affected by the project, including ecosystem type, the area affected, patch quality (Landscape Context Index, and richness and threat level, if optional inputs are included), the specified mitigation ratio and total required offset area (impacted area x mitigation ratio).

2. **Offset patches and mitigation potential**
    MAFE-T provides a set of ecosystem patches that can potentially meet offset needs based on Colombia's offset policy. MAFE-T returns those offset patches that are located within the same hydrographic zone and of the same impacted vegetation type(s) as the project footprint. It also returns only those patches that meet the minimum patch size,

Landscape Context Index, and, if optional input data is provided, threat and species richness levels, based on the impacted patches. Note that in cases when multiple patches of the same ecosystem type are impacted, some possible offset patches may be valid as offsets for only part, and not all, of the impacts to a given ecosystem type (see "Tool limitations" for more details).

The set of potential offset patches is presented in an interactive table, with key attributes (amount of offset provided, size of patch, distance from impact site, etc.) associated with each patch.

Patches can be added to or removed from the offset portfolio clicking the checkbox in the second column. Clicking on a column heading allows you to sort the table by that column's attribute. This can be used to identify potential offset patches that may be especially preferable. Note that positive ecosystem service values indicate the potential offset parcel increases service provision and provides. To see the total contribution that the selected set of parcels makes to offsetting ecosystem and ecosystem service impacts, scroll down to the third section of the report ("Net benefits to ecosystems and ecosystem services").

If more sophisticated sorting or optimization is desired, the file offset_parcels.csv located in the results folder can be opened in excel or another program. A shapefile of all potential offsets parcels (selected_offsets.shp) can be accessed by clicking the link at the top of the table and is also found in the results folder.

3. **Net benefits to ecosystems and ecosystem services**
   The tables in this section show the net effects of the project and selected offsets. The totals shown will change as offset patches are selected or deselected to reflect the net effects of a given offset portfolio. The color of the cells in the net benefits/net service column change color to indicate either a net loss (red) or net gain (green) of services as different combinations of offset patches are selected. An offset portfolio that mitigates impacts to ecosystems and to the ecosystem services accounted for in this tool will display only green cells in the results.
   a. Benefits to terrestrial ecosystems:
        This table shows the amount of offsets selected for each ecosystem type and whether the net benefits are adequate to meet the required offset area based on the area impacted and the specified compensation factor/mitigation ratio.
   b. Ecosystem service benefits
        The first table sums the net effects of the project impact and selected offsets by serviceshed for water-related services (sediment, nitrogen, and, if included, a hydrological-type custom service). Population centers that are not affected by either the impact or the offset portfolio are not shown. The net benefits columns for sediment and nitrogen indicate whether ecosystem service losses have been mitigated for each population center. The column totals at the bottom of the table for the final columns ("net sediment * population" and net nitrogen * population) indicate whether, across the whole population, more people receive ecosystem service

benefits from offsets than were lost from development. When these totals are positive (green) but some totals for net benefits per serviceshed remain negative (red), this indicates that mitigation has transferred ecosystem services away from some populations and towards others, creating winners and losers.

The second table sums the net impacts to carbon. In this case, because the carbon serviceshed is global, only the total change in carbon storage is reported. If a global-type custom ecosystem service was included, it will appear here as well.

In addition to the interactive report, each results folder contains the following files:

- **impacted_municipalities.shp** Shapefile of the municipalities that intersect with the project footprint**.**
- **impacted_parcels.csv** Table of information on patches of natural vegetation impacted by the project.
- **impacted_subzones.shp** Shapefile of hydrosubzones that intersect with the project footprint
- **impacted_zone.shp** Shapefile of the impacted hydrozone.
- **offset_sites.shp** Shapefile of all parcels of natural vegetation in the zone, excluding the parts of parcels to be impacted.
- **offset_parcels.csv** Table of information on the potential offset sites included in selected_offsets.shp
- **offset_benefits_to_servicesheds.csv** Table of detailed benefits to servicesheds from selected_offsets.shp
- **parcels_in_zone.shp** Shapefile of all parcels of natural vegetation from which potential offset sites were selected.
- **selected_offsets.shp** Shapefile of potential offset sites from parcels_in_zone.shp that meet biodiversity requirements.
- **servicesheds.shp** Shapefile of all servicesheds that intersect the hydrozone.
- **servicesheds_with_offset_parcels.shp** Shapefile of all servicesheds that intersect the selected offset parcels.

Static maps: default maps and & generating custom maps

To rapidly evaluate the impacts of development activities and the benefits of different mitigation options, MAFE-T relies on a set of pre-calculated static maps rather than directly running InVEST models every time the tool is used. These static maps are still based on the InVEST sediment, nutrient and carbon models. To generate static maps, each InVEST model is run for the entire country of Colombia under current landscape conditions and under three simulated land use/land cover scenarios (conversion to bare ground, conversion to paved ground, and total loss of natural vegetation). Intermediate and final outputs from the InVEST models are combined to produce a set of maps indicating the impacts of converting areas to paved or bare ground, or of protecting areas to avoid loss of natural vegetation on sediment and nutrient export and carbon storage services. By overlaying the footprint of an area being considered for development or as an offset onto these maps, a good estimate

of the change in service can be calculated quickly, avoiding the need for a repeated and potentially lengthy series of InVEST model runs. <mark>Mention quality/correlation indicators from final maps when available.</mark>

If the default static map data for Colombia was downloaded and installed along with MAFE-T (see "Downloading and installing MAFE-T"), then the pre-calculated static maps for all of Colombia are used by default when running the tool. If more recent or higher quality data is available for the area of interest, the user can generate new static maps for that particular area using static map generator helper tools included with MAFE-T. The user can then override the default static maps when running MAFE-T for sediment retention, nitrogen retention and/or carbon storage services. In addition, the user has the option to generate their own set of static maps for another service and include this service in MAFE-T analyses.

Ecosystem service models and data needs:

MAFE-T's static maps are based on the InVEST nutrient, sediment and carbon models and require the same inputs as the InVEST models. See the InVEST User's Guide for information on data requirements and format: http://www.naturalcapitalproject.org/download.html. The inputs on which the default static maps are based are downloaded along with the tool and can be located within the program folder (Program Files > MAFE-T > data > colombia_tool_data) or downloaded here: http://ncp-dev.stanford.edu/~dataportal/nightly-build/adept/data/ from the file tool_data.zip. It is therefore possible to generate new static maps by updating only some of the inputs and retaining the remaining default data for the other model inputs.

Generating static maps for estimating impacts and offset values for carbon, sediment and nutrient services:

The static map generator helper tools are downloaded along with MAFE-T and can be run from the Start Menu.

The sediment, nutrient and carbon static map generators implement three steps:

First, the helper tools run the InVEST sediment, nutrient or carbon model across four scenarios: current land use/land cover (LULC), complete conversion of the landscape to bare ground, complete conversion of the landscape to paved ground, and total loss of natural vegetation. The helper tool will automatically generate the bare and paved scenarios using the matching LULC code provided by the user. For the total loss of natural vegetation scenario, the user must provide the LULC raster map representing the LULC types expected if natural vegetation was removed. This loss of natural vegetation scenario can include multiple LULC types, representing, for example, conversion of plantations, pasture, croplands or urban development in different locations. All LULC types specified in the loss of vegetation scenario must also appear with associated parameters in the biophysical table. These can be added to the default table if not already included.

Second, relevant InVEST model outputs are used to create sets of static maps for estimating the impacts of development (either conversion to bare ground or to paved ground) and for estimating the benefits of offsets (though avoided loss of natural vegetation by protection). The technical details and equations used in the InVEST models to generate these outputs can be found in the InVEST User's

Guide: http://www.naturalcapitalproject.org/download.html. Briefly, for carbon sequestration, the helper tool calculates the difference in pixel-level carbon storage. For sediment and nutrient retention, the helper tools calculate pixel-level differences in sediment or nutrient export and adjust by the amount of the export likely to actually reach the stream based on the sediment or nutrient delivery ratio from the current LULC scenario.

Thirdly and finally, the helper tools optionally run simulations to compare the static map-based estimates of changes in service provision against estimates obtained directly from the InVEST model. For each run of the simulation, the helper tool generates a random impact site polygon. The random impact site is used to generate a LULC scenario for InVEST in which just the impact site is converted to either bare or paved ground, or to the alternate LULC type in the loss of natural vegetation scenario provided. The helper tool then runs InVEST for the current and random impact site scenarios and calculates the change in service provision, as well as the static map-based estimate based on the static maps generated in the second step. The results of these simulations are provided as an output, allowing the user to evaluate the quality of the static map estimates as compared to expected changes in service provision modeled directly with InVEST. Note that the more simulations requested per watershed, the greater the computational time and disk space required to complete the simulations. Multiple simulations across all watersheds within the country of Colombia can take days to complete. For smaller areas of interest containing fewer watersheds, simulations will be must faster.

Note that the default model parameters for the InVEST models and static maps have not been calibrated for Colombia, as there was insufficient data available for this. Therefore, we recommend that outputs are interpreted as indicative of relative change rather than in terms of absolute biophysical amounts. If data for calibration is available for the areas of interest, the models can be calibrated in InVEST and then the calibrated parameters can be used in the helper tools to generate new static maps. If more precise estimates are needed than the static maps provide, MAFE-T can also service as a first-pass screening of the most promising offset parcels. The offset portfolio can be re-run in InVEST or with other ecosystem service models to provide an improved estimate of the changes expected with varying offset portfolios.

Generating static maps for custom ecosystem services:

While custom static maps can be created independently and input directly into the main MAFE-T tool, a custom ecosystem service helper tool is also included. Both approaches can be used to create static maps for services beyond carbon, sediment or nitrogen, or to use models other than InVEST to estimate impacts to carbon, sediment or nitrogen services. In either case, negative static maps values should indicate a loss of service and positive values should indicate service gain.

The helper tool requires as inputs maps of pixel-level service provision under the same four scenarios as used to generate the standard carbon, sediment and nitrogen static maps: current LULC conditions (base), complete conversion of the landscape to bare ground, complete conversion of the landscape to paved ground, and total loss of natural vegetation. The static map helper tool then calculates the difference between the current (base) level of service provision and the other three scenarios to generate the three static maps needed for estimating development impacts and offset benefits in MAFE-T. The static map outs are saved to a folder in the user-specified workspace, when can then be provided as a custom ecosystem service input to MAFE-T.

Information on Colombia default data

MAFE-T comes pre-loaded with national-level data for Colombia to minimize the time required for users to acquire and pre-process data. If a user has more up-to-date or higher resolution data, the default data can be overridden. Default data and the data used to generate the default static maps are downloaded when MAFE-T is installed and can be located here: Program Files > MAFE-T > data > colombia_tool_dataThese data include:

National ecosystems map
> A map of the ecosystems of Colombia. The information on primary vegetation is used to calculate project impacts and to determine potential offset sites (see below). The map is also used to create the land use/land cover raster ecosystems.tif, which is the basis for the InVEST carbon, sediment and nitrogen models.
> *Source:* IDEAM, IAvH, IGAC, IIAP, INVEMAR, SINCHI. 2007. Mapa de Ecosistemas Continentales, Costeros y Marinos de Colombia. Escala 1:500.000 Bogotá: Instituto de Hidrología, Meteorología y Estudios Ambientales (IDEAM), Instituto de Investigaciones de Recursos Biológicos Alexander von Humboldt (IAvH), Instituto Geográfico Agustín Codazzi (IGAC), Instituto de Investigaciones Ambientales del Pacífico John von Neumann (IIAP), Instituto de Investigaciones Marinas y Costeras José Benito Vives De Andréis (INVEMAR) e Instituto Amazónico de Investigaciones Científicas (SINCHI).

Map of natural vegetation and associated compensation factor – ecosys_dis_nat_comp_fac.shp
> A shapefile created by combining natural ecosystems from the above national ecosystems map with information on biogeographic districts (see source below) and Colombia's specified compensation factors. This map is used both to calculate impacts to natural ecosystems and to locate potential offset sites.
> *Source:* Corzo,G. y G. Andrade, 2010 Diversidad Biogeográfica en los ecosistemas terrestres. Parques nacionales naturales. Propuesta de ajuste del modelo ecorregional para Colombia en preparación, el cual se adoptó por el documento CONPES 3580 de 2010

Hydrographic zones and subzones – Hydrographic_subzones.shp
> A shapefile of Colombia's hydrographic zone and subzones. Offset parcels must be located within the same hydrographic zone as the impact site, and are preferred to be within the same hydrographic subzone, as per Colombia's national offset policy.
> *Source:* Ideam, 2010. Estudio Nacional del Agua 2010. Instituto de Hidrología, Meteorología y Estudios Ambientales. Bogotá D.C.

Municipalities – Municipalities.shp
> A shapefile of Colombia's municipalities. Offset parcels are preferred to be within the same municipality as the impact site, as per Colombia's national offset policy.
> *Source:* IGAC. 2007. Mapa de Municipios de Colombia, Escala 1:100.000 Bogotá: Instituto Geográfico Agustín Codazzi.

IGAC. 2007. Cartografía base de Colombia, Escala 1:100.000 Bogotá: Instituto Geográfico Agustín Codazzi.

Servicesheds

Servicesheds for hydrological services are calculated as upstream watersheds based on the DEM and population center file using population centers >20,000 people.

Inputs used to generate static maps:
Digital elevation model (DEM) – DEM.tif

A 90 m resolution raster used to determine the flow paths of water carrying sediments and nutrients to streams.

Source: Jarvis, A., H.I. Reuter, A. Nelson, E. Guevara, 2008, Hole-filled SRTM for the globe Version 4, available from the CGIAR-CSI SRTM 90m Database (http://srtm.csi.cgiar.org).

Rivers and water bodies – Single_rivers.shp

A shapefile of the national stream network. The flow accumulation threshold in the InVEST sediment and nutrient models should be set to produce a modeled stream network approximating the observed stream network. With the above DEM, a flow accumulation threshold of 100 produced good correspondence overall at the national level between the modeled stream network and this stream network. For analyses focused on smaller regions within Colombia, a different threshold may produce better results.

Source: IGAC. 2007. Cartografía base de Colombia, Escala 1:100.000 Bogotá: Instituto Geográfico Agustín Codazzi.

Carbon pools – Carbon_pools_Colombia.csv

Information on carbon storage by land use/land cover type in this table is combined with a land use/land cover map to estimate carbon storage.

Source: Peralvo, M., Coello, X. (2008) Implementación de modelos de funciones hidrológicas para Ecuador y Colombia. Report. Seearth Consulting Group.

Biophysical table for sediment and nutrient models – Biophysial_Colombia.csv

Peralvo, M., Coello, X. (2008) Implementación de modelos de funciones hidrológicas para Ecuador y Colombia. Report. Seearth Consulting Group.

Rainfall erosivity map – Erosivity.shp

Hijmans, R.J., S.E. Cameron, J.L. Parra, P.G. Jones and A. Jarvis, 2005. Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25: 1965-1978. TOOK PRECIPITATION FROM THIS REFERENCE. TO CONVERT IT TO EROSIVITY, WE FOLLOWED THE EMPIRICAL FORMULA IN THIS PAPER: Pérez J, Mesa O. 2002. Estimación del Factor de Erosividad de la Lluvia en Colombia Colombia: Simposio Latinoamericano de Control de Erosión.

Soil erodibility map

IGAC. 2003. Mapa de Suelos de Colombia, Escala 1:500.000 Bogotá: Instituto Geográfico Agustín Codazzi. (THIS FOR THE SOILS MAP). The table that derives erodability from soil texture comes from http://www.omafra.gov.on.ca/english/engineer/facts/12-051.pdf. Page 3

Precipitation

Hijmans, R.J., S.E. Cameron, J.L. Parra, P.G. Jones and A. Jarvis, 2005. Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25: 1965-1978.

Reference evapotranspiration

METHOD FROM Droogers P, Allen R. 2002. Estimating reference evapotranspiration under inaccurate data conditions. Irrigation and Drainage Systems 16:33-45. USING DATA FROM Hijmans, R.J., S.E. Cameron, J.L. Parra, P.G. Jones and A. Jarvis, 2005. Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25: 1965-1978.

Soil depth

IGAC. 2003. Mapa de Suelos de Colombia, Escala 1:500.000 Bogotá: Instituto Geográfico Agustín Codazzi.

Converted vegetation – converted_veg_deforest.tif

Base map: IDEAM, IAvH, IGAC, IIAP, INVEMAR, SINCHI. 2007. Mapa de Ecosistemas Continentales, Costeros y Marinos de Colombia. Escala 1:500.000 Bogotá: Instituto de Hidrología, Meteorología y Estudios Ambientales (IDEAM), Instituto de Investigaciones de Recursos Biológicos Alexander von Humboldt (IAvH), Instituto Geográfico Agustín Codazzi (IGAC), Instituto de Investigaciones Ambientales del Pacífico John von Neumann (IIAP), Instituto de Investigaciones Marinas y Costeras José Benito Vives De Andréis (INVEMAR) e Instituto Amazónico de Investigaciones Científicas (SINCHI) **modified according to TNC expert judgement**

Glossary/key terms

Landscape Context Index (LCI): The Landscape Context Index, as defined in Colombia's Offsets Manual, represents the level of connectivity of a natural ecosystem patch to other patches. It is calculated as the fraction of natural ecosystem within a 500 m buffer strip around a particular patch.

Serviceshed: In general, a serviceshed is the area providing a specific ecosystem service to particular beneficiary. By tracking the impacts of planned development and offset activities within servicesheds, MAFE-T is able to trace the consequences of changes in the environment to the changes in benefits people receive. Servicesheds can operate over vastly different scales, depending on the nature of the service. Carbon sequestration and its contribution to climate regulation benefits all humans on the planet, and so its serviceshed is global. In contrast, the serviceshed for drinking water purification, including the sediment and nitrogen retention services included in MAFE-T, is watershed upstream from a particular population center's water intake point. For more

information on the serviceshed approach, see
http://www.naturalcapitalproject.org/decisions/servicesheds.html.

Tool limitations

MAFE-T is intended to facilitate the selection of offset portfolios that mitigate impacts to ecosystems and ecosystem services in Colombia. However, it may not be able to address all mitigation-related questions that arise and may not be applicable in all situations. When deciding whether to use MAFE-T, it is important to be aware of the tool's limitations, including:

- MAFE-T only accounts for impacts due to changes in land use/land cover within the project footprint and does not account for any indirect impacts, such as land use change around a road spurred by road development). More sophisticated analyses are needed to estimate indirect effects. This can be done by linking land use change modeling with other tools for estimating change in ecosystem services, such as InVEST.
- MAFE-T does not account for significant changes to an area's hydrology, such as may occur when a landscape is significantly altered by mining.
- Servicesheds in MAFE-T are currently limited to either hydrological servicesheds or global servicesheds (such as for carbon). If there are other services you would like to include, please let us know on Natural Capital Project User Forum (http://ncp-yamato.stanford.edu/natcapforums/), and we can help figure out if there's the possibility of including that service and its servicesheds.
- Due to processing limitation, default hydrological servicesheds are currently only provided for population centers >20,000 people. In future releases, we plan to include hydrological servicesheds for population centers of all sizes.
- If using default vegetation maps, MAFE-T will only account for impacts to and suggest offsets for the loss biodiversity from primary vegetation. Secondary vegetation is currently not included because different offsetting rules apply. Mitigation for impacts to secondary vegetation may be required of projects in Colombia, and must be calculated separately at this point in time.
- Currently, MAFE-T shows whether the selected offset portfolio meets the required amount of offset (total hectares per ecosystem type and biophysical amount of service), but MAFE-T does not test whether selected offset portfolio meets all mitigation requirements (e.g., LCI, minimum patch size, threat level and richness). The tool only screens out patches below the minimum threshold for all patches. In cases where multiple patches are impacted, potential offset patches provided in the results may be acceptable offsets for only some of the impacted patches. When a project impacts multiple ecosystem patches, it is important to independently check that the final offset portfolio meets requirements for each impacted patch.

Tips and troubleshooting

- The tool requires that all data and inputs to be in the same project. To match the default data, any inputs must have the following projection:
    MAGNA_Colombia_Bogota
    WKID: 3116

Authority: EPSG
Projection: Transverse_Mercator
False_Easting: 1000000.0
False_Northing: 1000000.0
Central_Meridian: -74.07750791666666
Scale_Factor: 1.0
Latitude_Of_Origin: 4.596200416666666
Linear Unit: Meter (1.0)