# Scenario Generator: Proximity Based

## Summary

The proximity-based scenario generator creates a set of contrasting land use change maps that convert habitat in different spatial patterns. The user determines which habitat can be converted and what they are converted to, as well as type of pattern, based on proximity to the edge of a focal habitat. In this manner, an array of land-use change patterns can be generated, including pasture encroaching into forest from the forest edge, agriculture expanding from currently cropped areas, forest fragmentation, and many others. The resulting land-use maps can then be used as inputs to InVEST models, or other models for biodiversity or ecosystem services that are responsive to land use change.

## Introduction

# In order to understand the change in biodiversity and ecosystem services (BES) resulting from change in land-use, it is often helpful to start with a scenario or a set of scenarios that exhibit different types of land-use change. Because many of the relationships between landscapes and BES are spatially-explicit, a different pattern of habitat conversion for the same total area of habitat converted can lead to very different impacts on BES. This proximity-based scenario generator creates different patterns of conversion according to user inputs designating focal habitat and converted habitat, in contrast to but potentially complementing the InVEST rule-based scenario generator that creates maps of land-use change according to user-assigned probabilities that certain transitions will occur. Thus, the intent of the InVEST proximity-based scenario generator is not to forecast actual predicted patterns of expansion, but rather to develop different patterns of land use change in order to examine the relationship between land-use change and BES, and how the relationship may differ depending on land use change assumptions.

## The model

The tool can generate two scenarios at once (nearest to the edge and farthest from the edge of a focal habitat), for a conversion to particular habitat type for a given area. To convert to different habitat types, different habitat amounts, or to designate different focal habitats or converted habitats, the tool can be run multiple times in sequence.

### How it works

Three types of landcover must be defined: 1) *Focal* *landcover* is the landcover(s) that set the proximity rules from which the scenarios will be determined. The scenario generator will convert habitat from the edge or toward the edge of patches of these types of landcover. This does not mean it will convert these land-covers, only that it will measure distance to or from the edges in designating where the conversion will happen. 2) *Convertible landcover* is the landcover(s) that can be converted. These could be the same as the focal landcover(s), a subset, or completely different. 3) *Replacement landcover* is the landcover type to which the convertible landcovers will be converted. This can only be one landcover type per model run.

Two scenarios can then be run at a time: 1) *Nearest to edge* means that convertible landcover types closest to the edges of focal landcovers will be converted to the replacement landcover. 2) *Farthest from edge* means that convertible landcover types furthest from the edges of focal landcover types will be converted to the replacement landcover. If this scenario is chosen, the user can designate in how many steps the conversion should occur. This is relevant if the focal landcover is the same as the convertible land cover because the conversion of the focal landcover will create new edges and hence will affect the distance calculated from the edge of that landcover. If desired, the conversion can occur in several steps, each time converting the farthest from the edge of the focal landcover, causing a fragmentary pattern.

Below are some examples of the types of scenarios that can be generated by manipulating these basic inputs, using the land-cover in the sample data that ship with this model. This landcover is from MODIS, using the UMD classification (Friedl et al. 2011), which follows the following scheme: 1 – Evergreen needleleaf forest; 2 – Evergreen broadleaf forest; 3 – Deciduous needleleaf forest; 4 – Deciduous broadleaf forest; 5 – Mixed forest; 6 – Closed shrublands; 7 – Open shrublands; 8 – Woody savannas; 9 – Savannas; 10 – Grasslands; 12 – Croplands; 13 – Urban and built-up; 16 – Barren or sparsely vegetated.

**Expand agriculture from forest edge inwards:**

focal landcover codes: 1 2 3 4 5

convertible landcover codes: 1 2 3 4 5

replacement landcover code: 12

check "Convert From Edge"

number of steps toward conversion: 1

**Expand agriculture from forest core outwards**:

focal landcover codes: 1 2 3 4 5

convertible landcover codes: 1 2 3 4 5

replacement landcover code: 12

check "Convert Toward Edge"

number of steps toward conversion: 1

**Expand agriculture by fragmenting forest:**

focal landcover codes: 1 2 3 4 5

convertible landcover codes: 1 2 3 4 5

replacement landcover code: 12

check "Convert Toward Edge"

number of steps toward conversion: 10 (or as many steps as desired; the more steps, the more finely fragmented it will be and the longer the simulation will take)

**Expand pasture into forest nearest to existing agriculture:**

focal landcover codes: 12

convertible landcover codes: 1 2 3 4 5

replacement landcover code: 10

check "Convert From Edge"

number of steps toward conversion: 1

## Data needs

The only required input data to run the proximity-based scenario generator is a base land-use/land-cover map and user-defined land cover codes pertaining to this base map to designate how the scenarios should be computed.

1. Base land-use/cover map (required). This is the map that will be modified in the generation of the desired scenarios. All pixels in this map (that overlap with the area of interest, if included) other than the pixels that are converted will remain the same.

Name: file can be named anything (scenario\_proximity\_lulc.tif in the sample data)

Format: standard GIS raster file (e.g., ESRI GRID or IMG), with a column labeled ‘value’ that designates the LULC class code for each cell (integers only; e.g., 1 for forest, 10 for grassland, etc.)

1. AOI – Area of Interest (optional). If change is only desired in a subregion of the broader land-use/land-cover map, the user may designate this area of interest. Prior to scenario generation, the map will be clipped to the extent of this vector.

Name: file can be named anything (scenario\_proximity\_aoi.shp in the sample data)

Format: vector (polygon) file

1. Max area to convert (ha): enter the maximum numbers of hectares to be converted to agriculture. This is the maximum because due to the discretization of area of pixels, the number of pixels closest to but not exceeding this number will be converted.
2. Focal Landcover Codes: enter the LULC code(s) for the land cover types from which distance from edge should be calculated. If multiple values, they should be separated by spaces.
3. Convertible Landcover Codes: enter the LULC code(s) for the land cover types that are allowed to be converted to agriculture in the simulation. If multiple values, they should be separated by spaces.
4. Replacement Landcover Code: enter an integer that corresponds to the LULC code to which habitat will be converted. If there are multiple LULC types that are of interest for conversion, this tool should be run in sequence, choosing one type of conversion each time. A new code may be introduced if it is a novel land-use for the region or if it is desirable to track the expanded land-use as separate from historic land-use.
5. Check boxes: types of scenarios to generate
   * 1. Convert farthest from edge: land cover type(s) designated as “convertible” that are farthest from the edge of any land cover type designated as “focal” will be converted. Convertible land covers and habitat of interest land-covers may be the same, or a subset of one another, or they can be different. If they are the same, the number of steps for conversion should be specified, because the conversion of habitat within the focal land cover will create new habitat edge, resulting in a completely different pattern of conversion depending on how many steps are chosen.
     2. Convert nearest to edge: land cover type(s) designated as “convertible” that are nearest to the edge of any land cover type designated as “focal” will be converted. As for the previous scenario, convertible land covers and habitat of interest land-covers may be the same, or a subset of one another, or they can be different.
6. Number of Steps in Conversion: enter an integer for the number of steps the simulation should take to fragment the habitat of interest in the fragmentation scenario. Entering a 1 means that all of the habitat conversion will occur in the center of the patch of the habitat of interest. Entering 10 will be fragmented according to a pattern of sequentially converting the pixels furthest from the edge of that habitat, over the number of steps specified by the user.

## Running the model

The model is available as a standalone application accessible from the install directory of InVEST (under the subdirectory invest-3\_x86/invest\_scenario\_gen\_proximity.bat).

### Viewing Output from the Model

Upon successful completion of the model, a file explorer window will open to the output workspace specified in the model run. This directory contains an output folder holding files generated by this model. Those files can be viewed in any GIS tool such as ArcGIS, or QGIS. These files are described below in Section Interpreting Results.

## Interpreting Results

### Final Results

Final results are found in the *Workspace* folder within the specified for this module.

* **natcap.invest.ag\_expansion-log**: Each time the model is run, a text (.txt) file will appear in the *Output* folder. The file will list the parameter values for that run and will be named according to the service, the date and time, and the suffix.
* **nearest\_to\_edge \_<suffix>.tif:** LULC raster for the scenario of conversion nearest to the edge of the focal habitat
* **farthest\_from\_edge\_<suffix>.tif:** LULC raster for the scenario of conversion farthest from the edge of the focal habitat
* **nearest\_to\_\_edge\_ stats\_<suffix>.csv:** table listing the area (in hectares) and number of pixels for different land cover types converted for the scenario of conversion nearest to the edge of the focal habitat
* **farthest\_from\_edge\_ stats\_<suffix>.csv:** table listing the area (in hectares) and number of pixels for different land cover types converted for the scenario of conversion nearest to the edge of the focal habitat

### Intermediate Results

You may also want to examine the intermediate results. These files can help determine the reasons for the patterns in the final results. They are found in the *intermediate\_outputs* folder within the *Workspace* specified for this module.

* **{farthest\_from\_/nearest\_to}\_edge\_distance\_<suffix>.tif:** map of This raster shows the distance (in number of pixels) of each pixel to the nearest edge of the focal landcover

## Sample Script

The following script is provided to demonstrate how the scenarios described in Section “How It Works” can be composed into a single script that’s callable from the InVEST Python API.

import natcap.invest.scenario\_generator\_proximity\_based

edge\_args = {

u'aoi\_uri': u'C:/Users/Rich/Documents/svn\_repos/invest-sample-data/scenario\_proximity/scenario\_proximity\_aoi.shp',

u'area\_to\_convert': u'20000.0',

u'base\_lulc\_uri': u'C:/Users/Rich/Documents/svn\_repos/invest-sample-data/scenario\_proximity/scenario\_proximity\_lulc.tif',

u'convert\_farthest\_from\_edge': False,

u'convert\_nearest\_to\_edge': True,

u'convertible\_landcover\_codes': u'1 2 3 4 5',

u'focal\_landcover\_codes': u'1 2 3 4 5',

u'n\_fragmentation\_steps': u'1',

u'replacment\_lucode': u'12',

u'results\_suffix': 'edge',

u'workspace\_dir': u'C:\\Users\\Rich/Documents/scenario\_proximity\_workspace',

}

core\_args = {

u'aoi\_uri': u'C:/Users/Rich/Documents/svn\_repos/invest-sample-data/scenario\_proximity/scenario\_proximity\_aoi.shp',

u'area\_to\_convert': u'20000.0',

u'base\_lulc\_uri': u'C:/Users/Rich/Documents/svn\_repos/invest-sample-data/scenario\_proximity/scenario\_proximity\_lulc.tif',

u'convert\_farthest\_from\_edge': True,

u'convert\_nearest\_to\_edge': False,

u'convertible\_landcover\_codes': u'1 2 3 4 5',

u'focal\_landcover\_codes': u'1 2 3 4 5',

u'n\_fragmentation\_steps': u'1',

u'replacment\_lucode': u'12',

u'results\_suffix': 'core',

u'workspace\_dir': u'C:\\Users\\Rich/Documents/scenario\_proximity\_workspace',

}

frag\_args = {

u'aoi\_uri': u'C:/Users/Rich/Documents/svn\_repos/invest-sample-data/scenario\_proximity/scenario\_proximity\_aoi.shp',

u'area\_to\_convert': u'20000.0',

u'base\_lulc\_uri': u'C:/Users/Rich/Documents/svn\_repos/invest-sample-data/scenario\_proximity/scenario\_proximity\_lulc.tif',

u'convert\_farthest\_from\_edge': True,

u'convert\_nearest\_to\_edge': False,

u'convertible\_landcover\_codes': u'1 2 3 4 5',

u'focal\_landcover\_codes': u'1 2 3 4 5',

u'n\_fragmentation\_steps': u'10',

u'replacment\_lucode': u'12',

u'results\_suffix': 'frag',

u'workspace\_dir': u'C:\\Users\\Rich/Documents/scenario\_proximity\_workspace',

}

ag\_args = {

u'aoi\_uri': u'C:/Users/Rich/Documents/svn\_repos/invest-sample-data/scenario\_proximity/scenario\_proximity\_aoi.shp',

u'area\_to\_convert': u'20000.0',

u'base\_lulc\_uri': u'C:/Users/Rich/Documents/svn\_repos/invest-sample-data/scenario\_proximity/scenario\_proximity\_lulc.tif',

u'convert\_farthest\_from\_edge': False,

u'convert\_nearest\_to\_edge': True,

u'convertible\_landcover\_codes': u'12',

u'focal\_landcover\_codes': u'1 2 3 4 5',

u'n\_fragmentation\_steps': u'1',

u'replacment\_lucode': u'12',

u'results\_suffix': 'ag',

u'workspace\_dir': u'C:\\Users\\Rich/Documents/scenario\_proximity\_workspace',

}

if \_\_name\_\_ == '\_\_main\_\_':

natcap.invest.scenario\_generator\_proximity\_based.execute(edge\_args)

natcap.invest.scenario\_generator\_proximity\_based.execute(core\_args)

natcap.invest.scenario\_generator\_proximity\_based.execute(frag\_args)

natcap.invest.scenario\_generator\_proximity\_based.execute(ag\_args)