6.4 Water yield model

Freshwater provisioning is an ecosystem service that contributes to the welfare of society in many ways, including through the production of hydropower. Changes in the landscape that affect annual average water yield upstream of hydropower facilities can increase or decrease hydropower production capacity. This exercise illustrates how the InVEST annual water yield model can be used to assess the service of water provisioning and value hydropower production.

First, we invite you to watch the following introductory video to the InVEST Water Yield Model Introduction+to+the+InVEST+Water+Yield+Model.mp4. You can also learn more and work through an introductory-level exercise with the InVEST Water Yield model in the Natural Capital Project's MOOC: NCP101.

Upon completion of this exercise, participants should be able to:

- Run the model and visualize outputs with the tutorial data or their own data
- Explain the effect of the model calibration
- Assess the effect of an error in the precipitation input

A) Case study with provided data

The Tana River basin supplies water for irrigation and domestic use that benefits millions of Kenyans. Major water users, including rural communities, the Nairobi water utility, and a hydropower company are establishing a Water Fund that will secure the provision of key water services. In order to assess the economic benefits of conservation activities, the effect of these activities on annual water yield has been assessed. This exercise will walk you through a similar assessment.

Credit: Johannes Hunink

B) Case study with your own data (advanced/optional)

Once you have completed this exercise with the provided sample data, repeat each step with data from your own project region:

- Root restricting depth
- Precipitation
- Plant available water content
- Average annual reference evapotranspiration
- Land use land cover
- Watersheds
- Subwatersheds
- Biophysical table
- Z parameter

It is recommended to not exceed a surface area of 10'000km^2 to avoid possible problems arising from the size of your input dataset (the InVEST Water Yield model itself is not limited by the geographical extent of the study area).

Case Study Tasks

1. Assess the water yield for a baseline scenario
2. Assess the water scarcity and hydropower production
3. Calibrate the model with the Z parameter
4. Assess the water yield with some uncertainty on the precipitation inputs

Reminder: Refer to the user guide for technical terms and input data:

http://data.naturalcapitalproject.org/nightly-build/invest-users-guide/html/reservoirhydropowerproduction.html

Getting to Know the InVEST Water Yield Model (adapted from the InVEST User's Guide)

Modeling the connections between landscape changes and hydrologic processes is not simple. Sophisticated models of these connections and associated processes (such as the WEAP model) are resource-and data-intensive, in addition to requiring substantial expertise. To allow for relatively quick and simplified modeling with readily-available data, the InVEST Water Yield model maps and models the annual average water yield used for hydropower production across a landscape (as opposed to, for instance, directly addressing the effect of LULC changes on hydropower failure—a process which is closely linked to variation in water inflow on a daily to monthly timescale).

The InVEST Water Yield: Reservoir Hydropower model calculates the relative contribution of each land parcel to annual average hydropower production and the value of this contribution in terms of energy production. These calculations offer insight into how changes in land use patterns affect annual surface water yield and hydropower production. The net present value of hydropower production over the life of the reservoir also can be calculated by summing discounted annual revenues.

Step-by-step

Task 1: Water yield provisioning for the baseline scenario

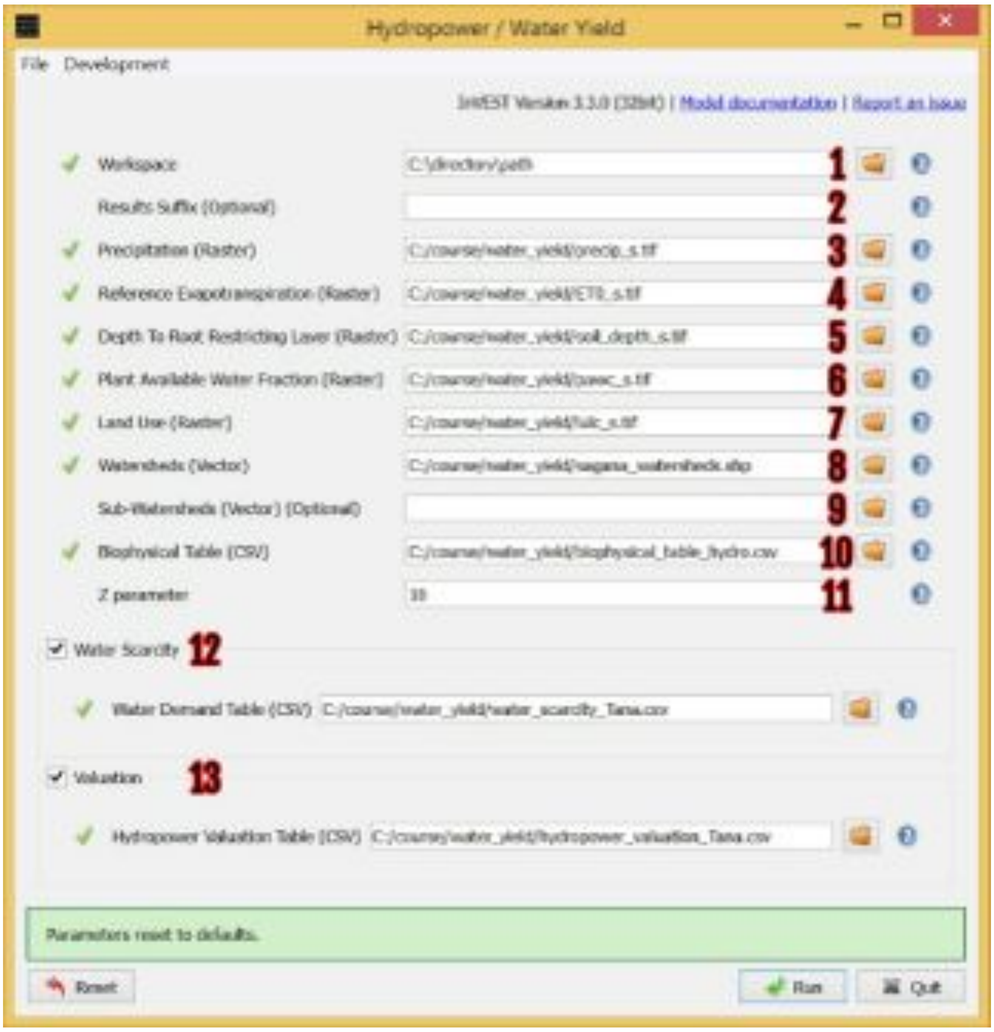
- Prepare your Biophysical Table
    - This is a table (in .csv format) of land use/land cover (LULC) classes, containing data on biophysical coefficients used in this tool. These data are attributes of each LULC class (rather than attributes of individual cells in the raster map).
    - Each column contains a different attribute of each LULC class, and must be named as follows:

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 (Item 7 in the UI).
2. LULC_desc: Descriptive name of land use/land cover class (optional)
3. LULC_veg: Contains the information on which AET equation to use (Eq. 1 or 2). Values should be 1 for vegetated land use except wetlands, and 0 for all other land uses, including wetlands, urban, water bodies, etc.
4. root_depth: The maximum root depth for vegetated land use classes, given in integer millimeters. This is often given as the depth at which 95% of a vegetation type's root biomass occurs.

5. K_c: 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).

*For more information on sources for these data, please reference the InVEST User's Guide.

- Open the InVEST Water Yield model from your Windows Start Menu (on a Mac, command+click the file <invest_wateryield.command>)



- Select your working folder (1)
    - *Tip: keep working folders clearly and simply named and organized within your file structure, to save time in selecting and adjusting inputs/outputs (e.g. C:\course\water_yield)

- Assign a Results Suffix (2) if needed (separate runs with different suffixes can be saved within the same Workspace)

- Input data for the baseline scenario (the example files below can be found in the TanaExample.zip file, downloadable here [link to data]). The first time the model is opened, the default values from the sample data included in the software download is loaded. Once the model has been run, it will default to the most recently used files when re-opened.
    - (3) Precipitation (Raster): precip_s.tif
    - (4) Reference Evapotranspiration (Raster): ETO_s.tif
    - (5) Depth To Root Restricting Layer (Raster): soil_depth_s.tif
    - (6) Plant Available Water Fraction (Raster): pawc_s.tif
    - (7) Land Use (Raster): lulc_s.tif
    - (8) Watersheds (Vector): sagana_watersheds.shp
    - (9) Sub-Watersheds (Vector) (Optional): no subwatersheds file is used in this exercise
    - (10) Biophysical Table (CSV): biophysical_table_hydro.csv

- Set the Z parameter (11) ("Seasonality factor") to a default value of 10

- Click run. The model will take several minutes to run. 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.

- Open the following two files, found in the output folder, with a GIS program:
    - watershed_results_wyield_SUFFIX.shp,
    - and wyield _SUFFIX.tif

Which subwatershed has the highest water yield?

Task 2: Water scarcity and hydropower production

For this example, it is assumed that only the urban areas are consuming water. We will add the water demand information to the model a second time in order to compare water yield and water scarcity in the study region.

- Return to or re-open the Water Yield model GUI.
- Check the "Water Scarcity" box (12), click the Open-Folder icon, and browse to the Water Demand Table in the data folder: <water_scarcity_Tana.csv>
- Check the "Valuation" box (13), click the Open-Folder icon, and browse to the Hydropower Valuation Table in the data folder: <hydropower_valuation_Tana.csv>
- *Don't forget to change your Results Suffix (2) or your results from Task 1 will be overwritten!
    - Remember, when you re-open the Water Yield model, the inputs will default to those used at the last running.
- Click Run to run the model

How do the water yield and water scarcity maps compare? What is the estimated amount of energy production?

Task 3: Model calibration

Now we will focus in on the Gura subwatershed. It is assumed that the expected total annual water yield in the Gura subwatershed is 870 mm. We want to calibrate the model by changing the Z parameter.

- Replace the Watershed layer (8) with the Gura watershed only by clicking the Open-Folder Icon and browsing to the "Task 3-4" folder in the exercise data folder: <watershed_gura.shp>
- Replace the Biophysical Table (10) with the Gura table by clicking the Open-Folder Icon and browsing to the "Task 3-4" folder in the exercise data folder: <biophysical_table_Gura.csv>
- Adjust the Z parameter value to Z=5
- *Don't forget to change the Results Suffix (e.g. "_task3") or your previous results will be overwritten!
- Click Run to run the model

How does the predicted water yield compare with the observed value? How sensitive the model was to a change in the Z parameter?

Task 4: Uncertainty in precipitation inputs

Staying in the Gura Subwatershed, we will investigate the model's sensitivity to errors in precipitation inputs. It is assumed that the precipitation inputs have a confidence interval of +/- 20%. We want to assess the effect of this error on the model outputs.

- When you return to/reopen the Water Yield model, the inputs from your previous run will automatically load.
- Change the Precipitation Raster (3) by clicking the Open-Folder icon and browsing to the precipitation layer with 20% error found in the "Task 4" folder in this exercises's data folder: <precip_error_20.tif>
- *Don't forget to change the Results Suffix (e.g. "_task4") or your previous results will be overwritten!

How sensitive the model was to an error in precipitation?