

QNSPECT Technical Guide



This document is intended for users of the QNSPECT tool. QNSPECT is an open-source version of the nonpoint source pollution and erosion comparison tool and supersedes its predecessor OpenNSPECT. It is a [QGIS plugin](#) used to investigate potential water quality impacts from climate change and development to other land uses.

This document describes:

- the various QNSPECT operations available and the parameters required to run them
- the science and algorithms behind each operation

This documentation was produced via contract with Dewberry who updated the NSPECT tool and ported it to the QGIS platform.

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Workflow

Input Data (Required)

User should possess the following data before the start of the process (or get these datasets using methods described data acquisition guide)

1. Digital Elevation Model (DEM)
2. Precipitation Raster or Constant Value
3. Land Cover Raster
4. R-Factor Raster or Constant Value
5. Soil Vector Layer (Soil must have hydrologic soil group and K-factor attribute)

Input Data (Optional)

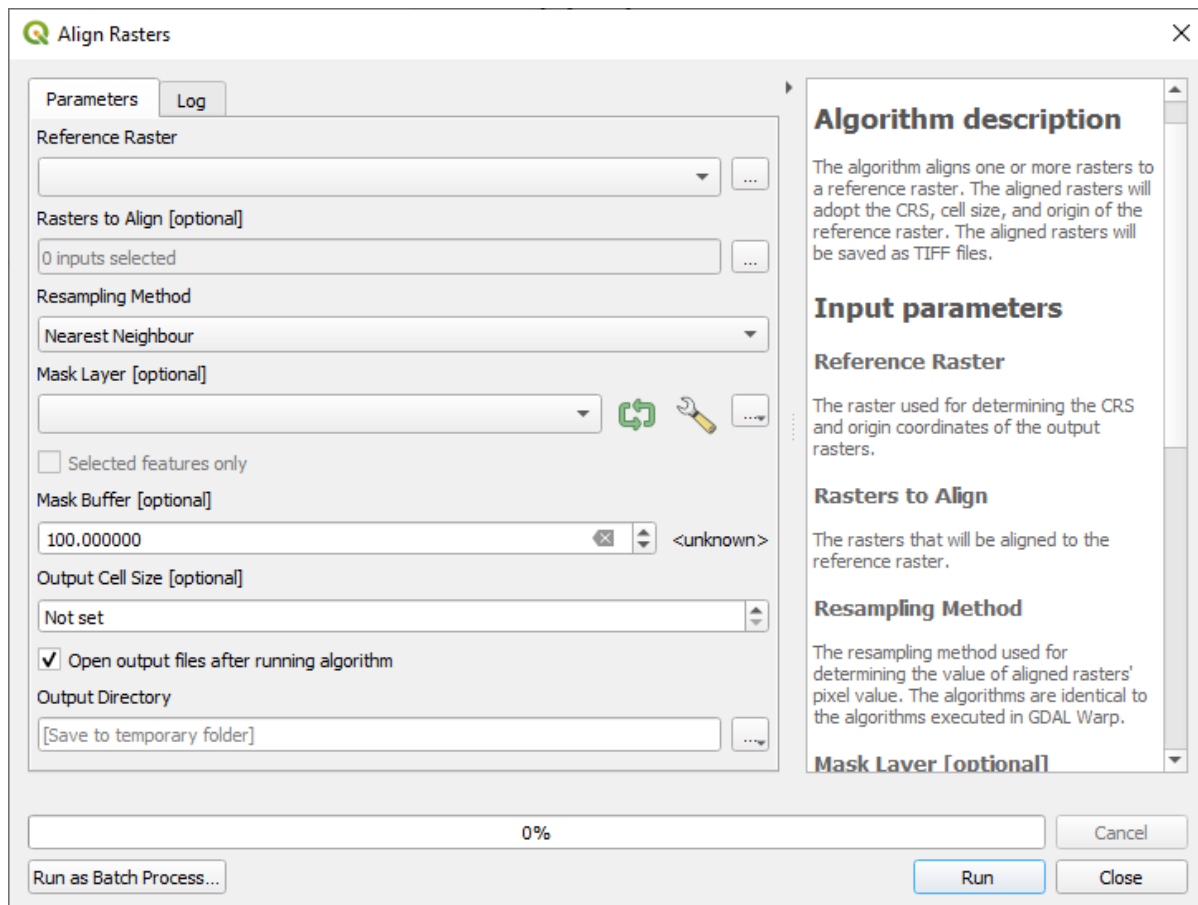
There will be two default lookup tables, one for C-CAP and one for National Land Cover Database packaged with the plugin. All coefficients will be stored in those tables. Users can use those tables or provide their own lookup tables.

Process

1. Gather Data
 - a. Collect mandatory and optional input data
2. Prepare Data

- a. Rasterize soil vector layer
 - b. Align rasters' extent and snap cells
 - c. Perform hydrology functions
3. Base Scenario Analysis
 - a. Provide input data
 - b. Perform analysis
 - c. View and verify results
4. Modify Inputs
 - a. Modify Land Cover / Lookup Table / Rain
 - b. Run Analysis for different scenarios
5. Modified Scenario Analysis
 - a. Repeat Step 3 with modified data
6. Compare Scenarios
 - a. Compare base and modified scenarios

Align Rasters



Summary

The algorithm aligns one or more rasters to a reference raster. The aligned rasters will be reprojected to the Coordinate Reference System (CRS), extent, and cell size of the reference raster. The aligned rasters will be saved as TIFF files. The tool will not run without a reference raster with a valid coordinate reference system.

This should be run at the beginning of a project on rasters that will be used for the pollution and erosion analyses. Many of the components assume the input rasters will share the same cell size and Coordinate Reference System. While some of the processes may still run without aligning them first, aligning them will increase the accuracy of the final computations.

Many of the tools require the rasters to be in a projected Coordinate Reference System. Therefore, the reference raster should have a projected Coordinate Reference System.

Input Parameters

Reference Raster

The raster used for determining the Coordinate Reference System, cell size, and origin coordinates of the output rasters. If the reference raster has non-square pixels, the aligned raster pixel sizes will be the smallest between its length and width.

Rasters to Align

The rasters that will be aligned to the reference raster.

Resampling Method

The resampling method used for determining the value of aligned rasters' pixel value. The algorithms are identical to the algorithms executed in [GDAL Warp](#).

Mask Layer [optional]

If set, all values outside of this layer will get no data value. If this is not set, the aligned rasters will be clipped to the extent of the Reference Raster.

Mask Buffer [optional]

Buffer added around the Mask Layer. If the Mask Layer is not provided, no buffer will be applied.

Output Cell Size [optional]

The raster cell size of the output rasters. If this is not set, the cell size will be the same as the reference raster.

Outputs

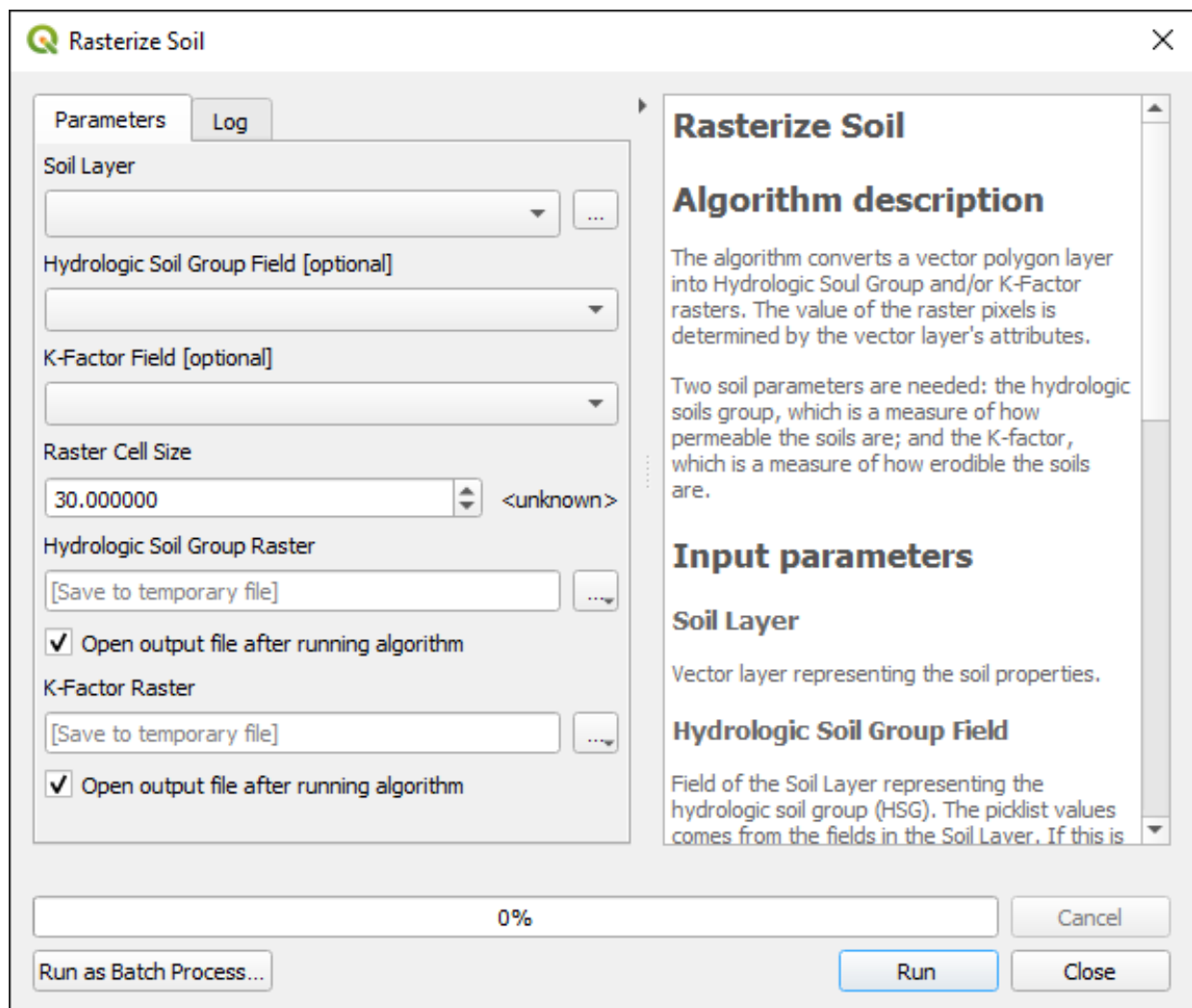
Output Directory

The output directory the aligned rasters will be saved to. The aligned rasters will have the name of their source files. If more than one raster has the same source name, numbers will be added to the end in the order they are processed.

Science and Algorithms

Resampling methods are handled through GDAL Warp operations.

Rasterize Soil



Summary

This component allows the user to convert the vector soil layer to a raster that can be provided as input to the later components. The Rasterize Soil tool takes in a soil layer with a K-factor field and a

string field containing Hydrologic Soil Groups (HSGs) and maps the HSG field to a number field using the map shown below. It then creates two rasters with the specified cell size based on the numeric field of HSG and K-factor field respectively.

The map for the classification of HSG: {'A': 1, 'B': 2, 'C': 3, 'D':4, 'A/D':5, 'B/D':6, 'C/D':7, 'W':8, Null: 9} Soil data are used to estimate sediment loads. Two soil parameters are needed: the hydrologic soils group, which is a measure of how permeable the soils are; and the K-factor, which is a measure of how erodible the soils are. This information can be obtained from the Soil Survey Geographic (SSURGO) database, an archive of county-level soil data for most of the United States, maintained by the USDA Natural Resource Conservation Service. This is an excellent first (and generally last) place to look for county-level soils data.

Input Parameters

Soil Layer

Vector layer representing the soil properties.

Hydrologic Soil Group Field

Field of the Soil Layer representing the hydrologic soil group. The picklist values come from the fields in the Soil Layer. This will default to 'hydgrpdcd' if it is present in the Soil Layer. If this is left empty, no hydrologic soil group raster will be created.

The only valid values for this field are 'A', 'B', 'C', 'D', 'A/D', 'B/D', 'C/D', 'W', and Null. Here W represents water. If the field contains any values other than these, the tool will terminate without output.

K-Factor Field

Field of the Soil Layer representing the K-Factor. The picklist values come from the fields in the Soil Layer. This will default to 'kfact' if it is present in the Soil Layer. If this is left empty, no K-Factor raster will be created.

Raster Cell Size

The cell size of the output raster(s). The units will default to the units of the Coordinate Reference System of the Soil Layer.

Outputs

Hydrologic Soil Group Raster

The output location of the Hydrologic Soil Group raster. The raster will inherit the Coordinate Reference System of the Soil Layer.

K-Factor Raster

The output location of the K-Factor raster. The raster will inherit the Coordinate Reference System of the Soil Layer.

Science and Algorithms

The hydrologic soil groups are usually an attribute in soil vector data. The hydrologic group is assigned to an area according to soil infiltration rates. These are grouped into four categories, A through D, based on decreasing infiltration (A = high infiltration, D = very slow infiltration). Occasionally, there are polygons without a value defined. This implies one of two scenarios: (1) the area covered by the polygon represents water, or (2) this area has highly disturbed soils and the actual soil type can no longer be determined (as in urbanized areas). Another potential problem is that some polygons may have a compound hydrologic group specified (e.g., A/D, C/D). The user can leave these soils as it is and specify in the analysis components how these soils should be treated in computation. A user should carefully clean the vector soil data, assign missing types if possible, before running the tool.

Areas covered by water should be recoded as hydrologic group D or W. All other polygons without values should be considered disturbed soils and should be coded as hydrologic group D or left Null, in which case they will be considered D during pollution and erosion analysis. In some cases, Appendix A of the NRCS publication *Urban Hydrology for Small Watersheds: Technical Release 55* (USDA NRCS, 1986) can be used to populate this value based on the soil series name. Another option is to assign a hydrologic group based on the defined soil texture.

Hydrologic Soil Group Definitions

Hydrologic Soil Group	Soil Texture	Soil Group Characteristics
A	Sand, loamy sand, or sandy loam	Soils having high infiltration rates, even when thoroughly wetted and consisting chiefly of deep, well- to excessively drained sands or gravels. These soils have a high rate of water transmission.
B	Silt loam or loam	Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, and moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.
C	Sandy clay loam	Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.

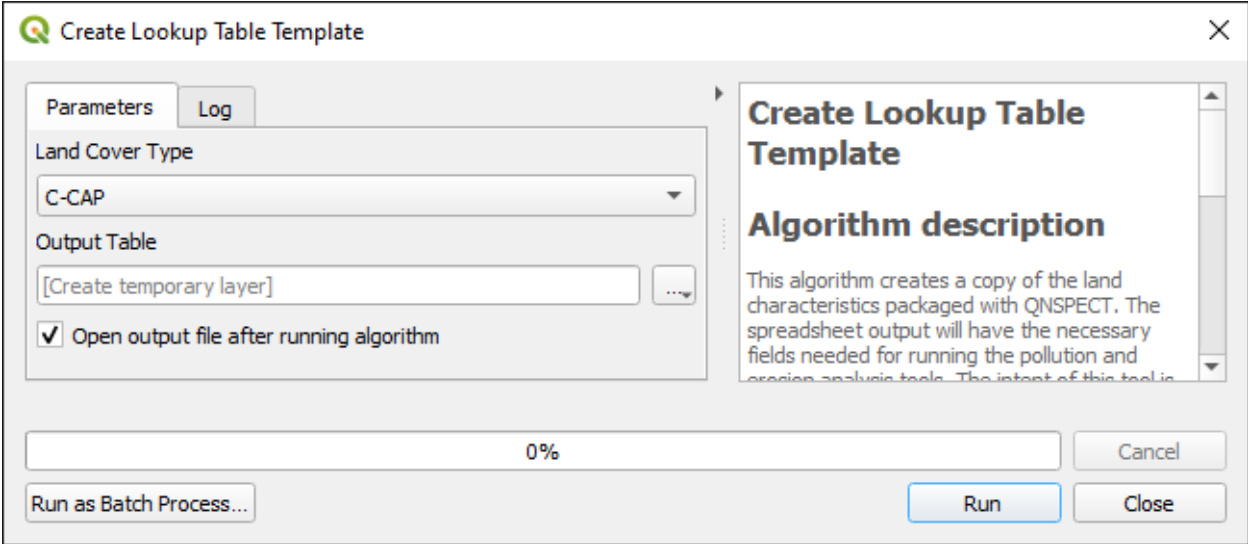
Hydrologic Soil Group	Soil Texture	Soil Group Characteristics
D	Clay loam, silty clay loam, sandy clay, silty clay, or clay	Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

Notes on Algorithm Outputs

- Created rasters will be in the Coordinate Reference System of the input layer.
- Raster Units: Byte for HSG, Float32 for K-Factor
- No data value: 255 for HSG, -9999 for K-Factor

Revised Universal Soil Loss Equation
 Urban Hydrology for Small Watersheds TR-55

Create Lookup Table Template



Summary

This algorithm creates a copy of the land characteristics packaged with QNSPECT. The spreadsheet output will have the necessary fields needed for running the pollution and erosion analysis tools. The intent of this tool is to create a copy that can be edited to include any custom land cover types and coefficients necessary for your analysis.

Input Parameters

Land Cover Type

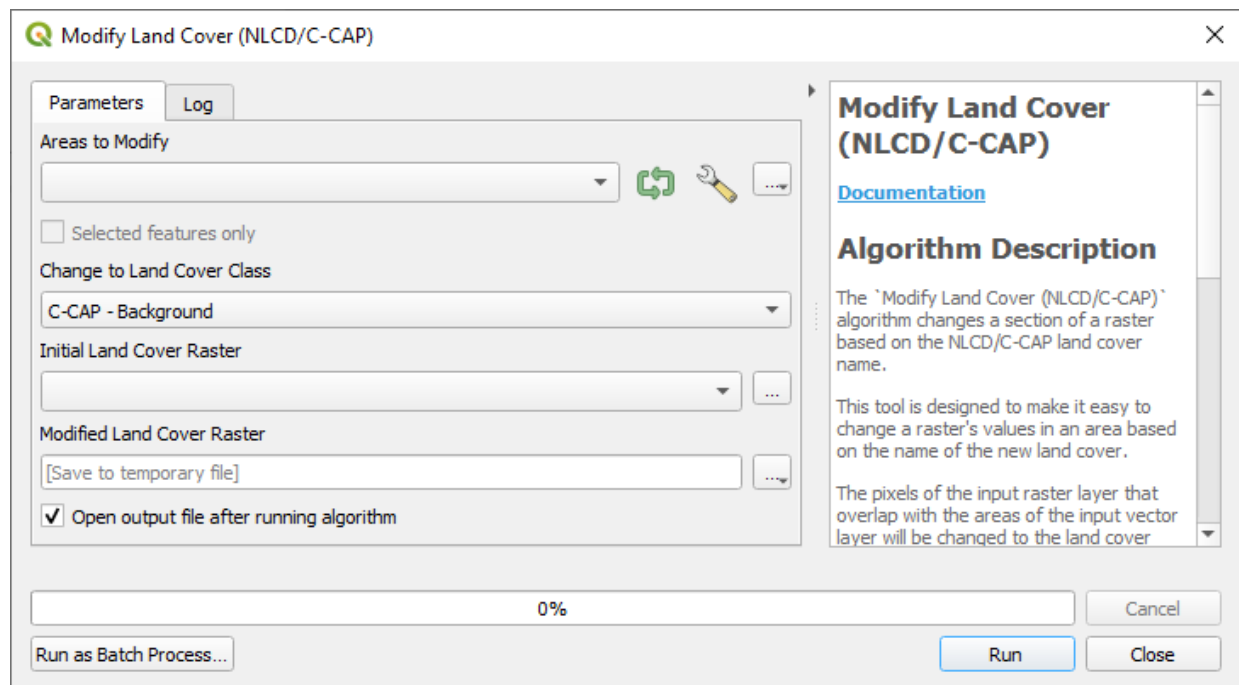
The name of the land cover characteristics.

Outputs

Output Table

A copy of the default land characteristics in a spreadsheet format (CSV, Geopackage)

Modify Land Cover (NLCD/C-CAP)



Summary

The “Modify Land Cover (NLCD/C-CAP)” algorithm changes a section of a raster based on the NLCD/C-CAP land cover name. This tool is designed to make it easy to change a raster's values in an area based on the name of the new land cover. The pixels of the input raster layer that overlap with the areas of the input vector layer will be changed to the land cover code of the name selected.

Input Parameters

Areas to Modify

Polygon vector layer that overlaps the pixels that should be changed.

Change to Land Cover Class

The land cover class to be used in the modified areas.

Initial Land Cover Raster

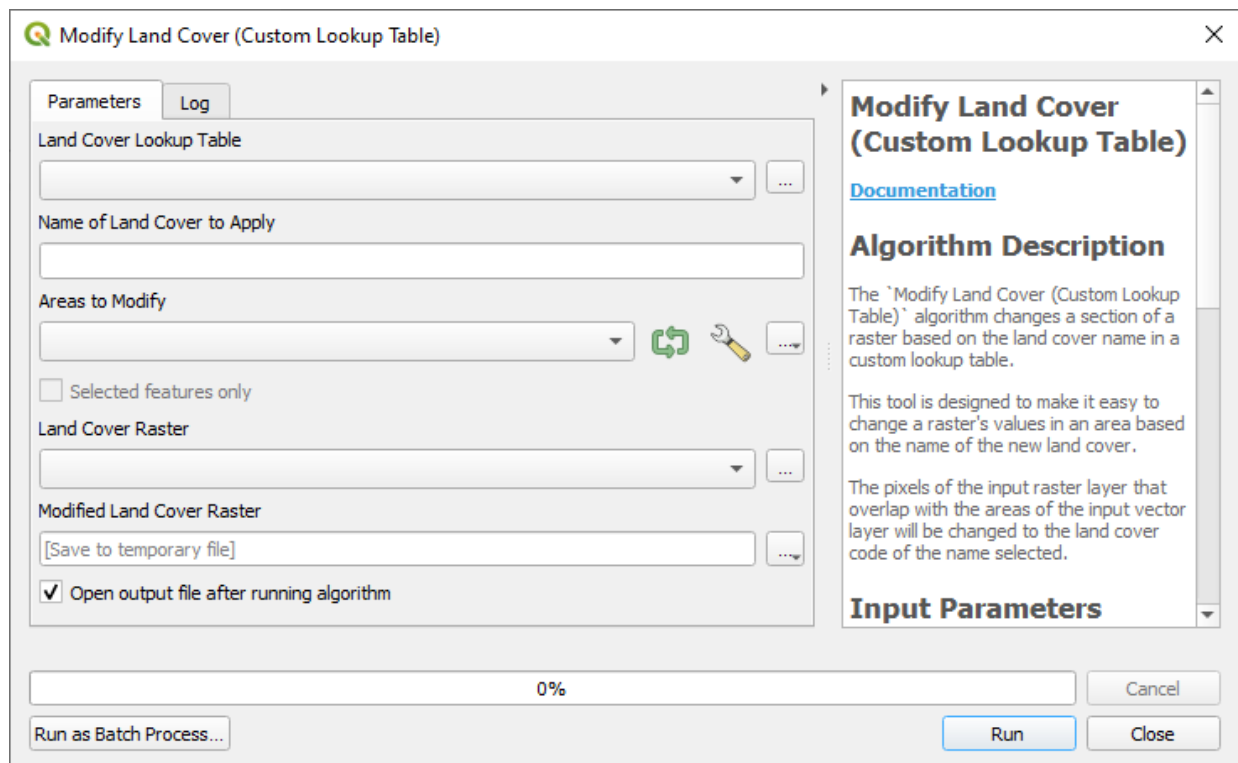
Land cover raster that needs to be modified.

Outputs

Modified Land Cover Raster

The location the modified land cover raster will be saved to.

Modify Land Cover (Custom Lookup Table)



Summary

The “Modify Land Cover (Custom Lookup Table)” algorithm changes a section of a raster based on the land cover name in a custom lookup table. This tool is designed to make it easy to change a raster's values in an area based on the name of the new land cover. The pixels of the input raster layer that overlap with the areas of the input vector layer will be changed to the land cover code of the name selected.

Input Parameters

Land Cover Lookup Table

The lookup table used to map the land cover name to a raster value. The lookup table must include the land cover name in a field called “lc_name” and a corresponding value in a field called “lc_value.”

Name of Land Cover to Apply

The name of the new land cover.

Areas to Modify

Polygon vector layer that overlaps the pixels that should be changed.

Land Cover Raster

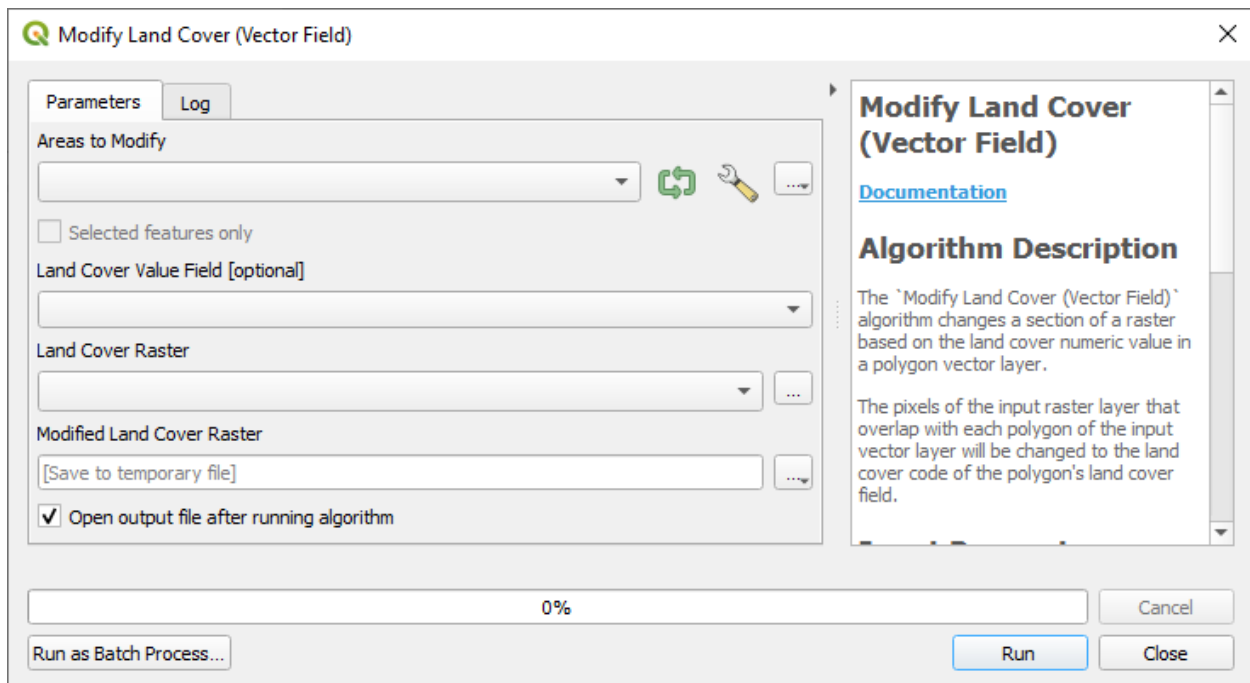
Land cover raster that needs to be modified.

Outputs

Modified Land Cover Raster

The location the modified land cover raster will be saved to.

Modify Land Cover (Vector Field)



Summary

The “Modify Land Cover (Vector Field)” algorithm changes a section of a raster based on the land cover numeric value in a polygon vector layer. The pixels of the input raster layer that overlap with each polygon of the input vector layer will be changed to the land cover code of the polygon's land cover field.

Input Parameters

Areas to Modify

Polygon vector layer that overlaps the pixels that should be changed.

Land Cover Value Field [Optional]

The field with the land cover value the raster pixels will be changed to. If this is left blank, the algorithm will try to use a field called “lc_value.”

Land Cover Raster

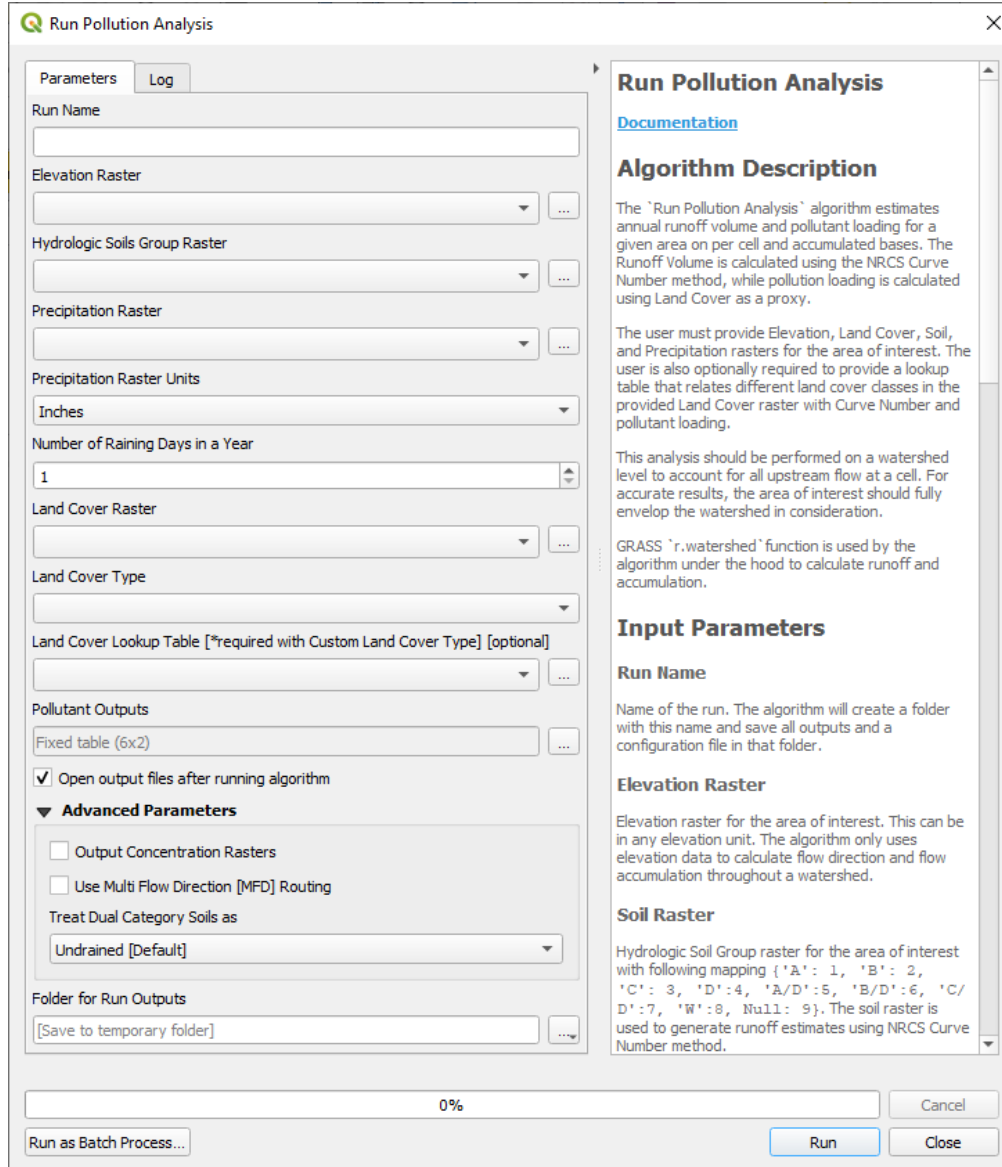
Land cover raster that needs to be modified.

Outputs

Modified Land Cover Raster

The location the modified land cover raster will be saved to.

Run Pollution Analysis



Run Pollution Analysis

Parameters Log

Run Name

Elevation Raster

Hydrologic Soils Group Raster

Precipitation Raster

Precipitation Raster Units
Inches

Number of Raining Days in a Year
1

Land Cover Raster

Land Cover Type

Land Cover Lookup Table [*required with Custom Land Cover Type] [optional]

Pollutant Outputs
Fixed table (6x2)

Open output files after running algorithm

Advanced Parameters

Output Concentration Rasters

Use Multi Flow Direction [MFD] Routing

Treat Dual Category Soils as
Undrained [Default]

Folder for Run Outputs
[Save to temporary folder]

0%

Run as Batch Process...

Run Pollution Analysis

[Documentation](#)

Algorithm Description

The "Run Pollution Analysis" algorithm estimates annual runoff volume and pollutant loading for a given area on a per cell and accumulated bases. The Runoff Volume is calculated using the NRCS Curve Number method, while pollution loading is calculated using Land Cover as a proxy.

The user must provide Elevation, Land Cover, Soil, and Precipitation rasters for the area of interest. The user is also optionally required to provide a lookup table that relates different land cover classes in the provided Land Cover raster with Curve Number and pollutant loading.

This analysis should be performed on a watershed level to account for all upstream flow at a cell. For accurate results, the area of interest should fully envelop the watershed in consideration.

GRASS "r.watershed" function is used by the algorithm under the hood to calculate runoff and accumulation.

Input Parameters

Run Name

Name of the run. The algorithm will create a folder with this name and save all outputs and a configuration file in that folder.

Elevation Raster

Elevation raster for the area of interest. This can be in any elevation unit. The algorithm only uses elevation data to calculate flow direction and flow accumulation throughout a watershed.

Soil Raster

Hydrologic Soil Group raster for the area of interest with following mapping {'A': 1, 'B': 2, 'C': 3, 'D': 4, 'A/D': 5, 'B/D': 6, 'C/D': 7, 'W': 8, Null: 9}. The soil raster is used to generate runoff estimates using NRCS Curve Number method.

Cancel

Run Close

Summary

The "Run Pollution Analysis" algorithm estimates annual runoff volume and pollutant loading for a given area on a per cell and accumulated basis. The Runoff Volume is calculated using the NRCS Curve Number method, while pollution loading is calculated using Land Cover as a proxy.

The user must provide Elevation, Land Cover, Soil, and Precipitation rasters for the area of interest. The user is also optionally required to provide a lookup table that relates different land cover classes in the provided Land Cover raster with Curve Number and pollutant loading.

Many of the grids driving “Run Pollution Analysis” functionality are derived from the DEM (Elevation Raster), and for this reason, it is perhaps the most important of these data sets. QNSPECT automatically sets the raster analysis environment to the parameters of the DEM file. QNSPECTS expects all input rasters to have the same cell size, spatial reference, and extent. Otherwise, the cells of input and output grids may or may not overlay properly. Therefore, it is suggested that the [Align Rasters](#) tool is first used to align all input rasters.

This analysis should be performed on a watershed level to account for all upstream flow at a cell. For accurate results, the area of interest should fully envelop the watershed in consideration. It is also important to note that the QNSPECT analysis is based on an annual period.

GRASS r.watershed function is used by the algorithm under the hood to calculate runoff and accumulation.

Input Parameters

Run Name

Name of the run. The algorithm will create a folder with this name and save all outputs and a configuration file in that folder.

Elevation Raster

Elevation raster for the area of interest. This can be in any elevation unit. The algorithm only uses elevation data to calculate flow direction and flow accumulation throughout a watershed.

Hydrologic Soils Group Raster

Hydrologic Soil Group raster for the area of interest with following mapping {'A': 1, 'B': 2, 'C': 3, 'D':4, 'A/D':5, 'B/D':6, 'C/D':7, 'W':8, Null: 9}. The soil raster is used to generate runoff estimates using NRCS Curve Number method.

Precipitation Raster

Annual precipitation amounts in inches or millimeters for the area of interest. The precipitation values are used to calculate access runoff.

Precipitation Raster Units

Units of the precipitation raster, inches or millimeters.

Number of Rainy Days in a Year

This field indicates the average number of days rain occurs in one year in the area of interest. A “rainy day” is a day on which there was enough rain to produce runoff. The higher number of rainy days reduces access runoff volume by increasing retention.

Land Cover Raster

Land Cover/Classification raster for the area of interest. The algorithm uses Land Cover Raster and Lookup Table to determine each cell's runoff and pollution potential.

Land Cover Type

Type of Land Cover raster. If the Land Cover raster is not of type C-CAP or NCLD, select custom for this field and supply a lookup table in the Land Cover Lookup Table field.

Land Cover Lookup Table [optional]

Lookup table to relate each land cover class with Curve Number and pollutant load. The user can skip providing a lookup table if the land cover type is not custom; the algorithm will utilize the default lookup table for the land cover type selected in the previous option.

To create a custom lookup table, develop a table using this format. The table must contain all land cover classes available in the land cover raster and all pollutants that have Output = Y in the Desired Outputs parameter.

Pollutant Outputs

In addition to the runoff, the algorithm will output the following rasters for each pollutant added here with the Output column as Y.

1. Local (per cell) pollutant load [mg]
2. Accumulated (all upstream cell) pollutant load [kg]
3. Concentration (accumulated pollutant mass divided by accumulated runoff volume) [mg/L].
The concentration raster will only be outputted if the Output Concentration Raster option is checked in Advanced Parameters

The user can add more pollutants here as long as the lookup coefficients for each pollutant are supplied in the land cover lookup table.

To exclude an output from the analysis, write N in the Output column. You must click Ok after editing to save your changes.

Advanced Parameters

Output Concentration Raster

The concentration raster will only be outputted if the Output Concentration Raster option is checked in Advanced Parameters. Default is unchecked.

Use Multi Flow Direction [MFD] Routing

By default, the Single Flow Direction [SFD] option is used for flow routing. Multi Flow Direction [MFD] routing will be utilized for the whole analysis if this option is checked. The algorithm passes these flags to GRASS r.watershed function, which is the computational engine for runoff direction and accumulation calculations.

Treat Dual Category Soils

Certain areas can have dual soil types (A/D, B/D, or C/D). These areas possess characteristics of Hydrologic Soil Group D during undrained conditions and characteristics of Hydrologic Soil Group A/B/C for drained conditions.

In this parameter, the user can specify if these areas should be treated as drained, undrained, or average of both conditions. If the average option is selected, the algorithm will use the average of drained and undrained Curve Number for runoff estimations.

Outputs

Folder for Run Outputs

The algorithm outputs and configuration file will be saved in this directory in a separate folder.

Science and Algorithms

The Science and Algorithms section is aimed at more advanced users and explains the underlying science and mathematical equations that drive the tool's processing and functionality.

Stormwater runoff and nonpoint source pollution are problematic for several reasons. Reduced capacities for infiltration and storage associated with impervious surfaces lead to larger and more rapid discharges to receiving waters. Downstream flooding, changes in stream morphology (straightening, downcutting), and erosion are a few of the problems that can result from too much water leaving a site too quickly. Stormwater runoff from developed areas also tends to carry higher pollutant loads than runoff from undisturbed sites. Nutrients such as phosphorus and nitrogen, suspended solids or sediments, hydrocarbons such as oil and grease, and metals (zinc, copper, lead) are all commonly found in stormwater runoff from developed sites (Schueler 2000).

The Run Pollution Analysis is a flexible tool that addresses several issues of concern to water quality specialists and coastal managers. Tool capabilities include

- Estimating runoff volume
- Estimating pollutant loads and concentrations

Pollutant concentrations are estimated using coefficients that represent the contribution of each land cover class to the overall pollutant load. The analysis is based on an annual basis.

The entire runoff and pollutant routing process is based on flow direction and flow accumulation grids derived from the DEM. Although it is possible to use higher resolution DEMs with QNSPECT, these data sets will result in increased processing times.

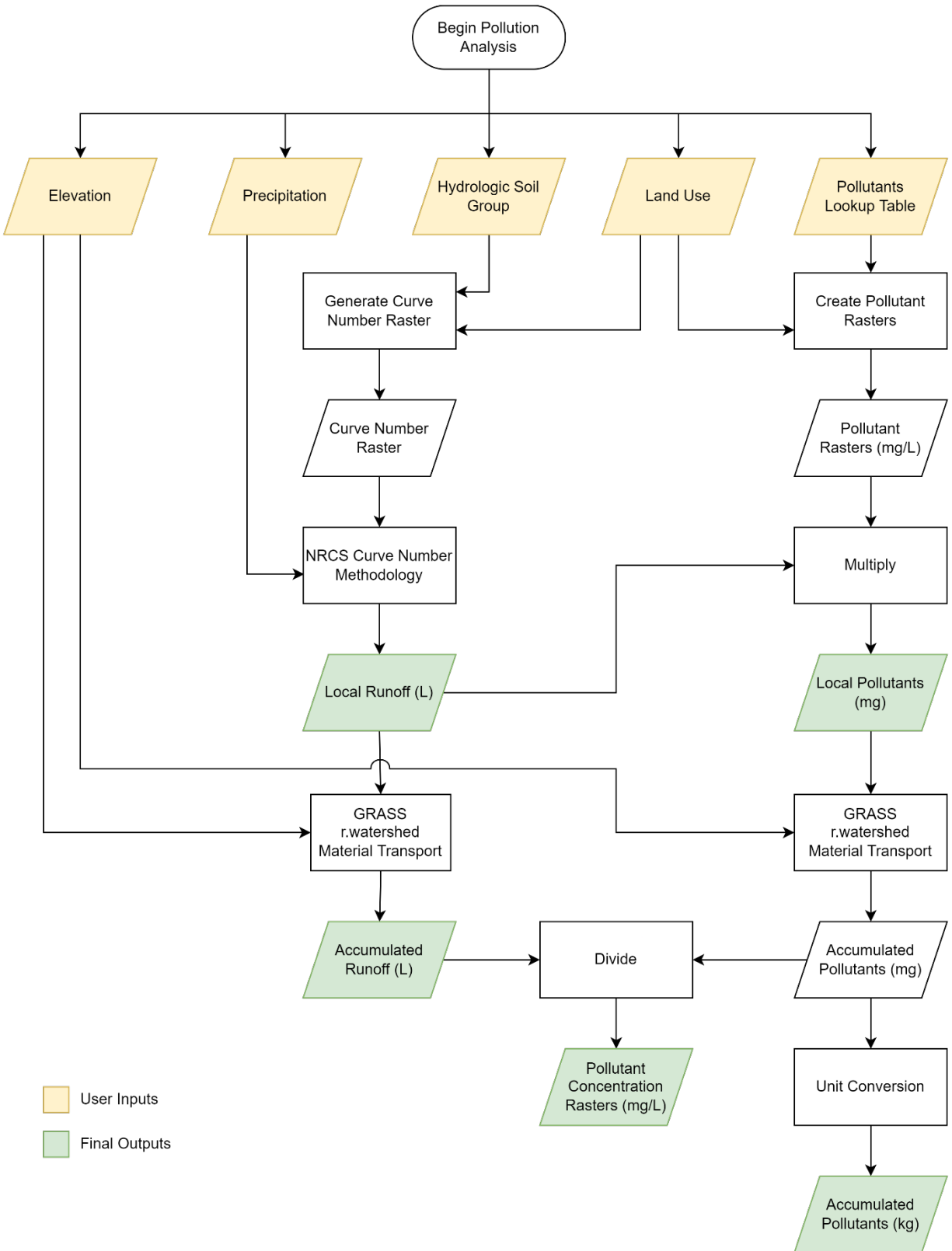
Overall Workflow

A typical Pollution Analysis begins with the generation of Curve Number (CN) Raster using provided land cover and HSG soil rasters. The CN Raster is then used to calculate annual runoff volume on a per cell basis using SCS Curve-Number method. GRASS's r.watershed is then used to route local volume to accumulated runoff.

In the second step of the process for each desired pollutant, a pollutant load raster is generated using land cover classes and the lookup table. The product of pollutant load and local runoff provides the local pollutant raster. Just like runoff accumulation, pollutants are also accumulated using GRASS's r.watershed.

In the final step of the process, accumulated pollutant rasters are divided by accumulated runoff to get pollutant concentration.

The following flowchart outlines the procedural workflow for "Run Pollution Analysis."



Curve Number Generation

Runoff curve numbers represent the infiltration capacity of the soil and range from 0 to 100, with 0 being no runoff and 100 indicating no infiltration. Curve numbers play an important role in QNSPECT's runoff depth estimation calculations.

QNSPECT includes default curve-number values for use with C-CAP and NLCD land cover datasets. Table 1 shows C-CAP land cover classifications and the corresponding curve-number values for each of the four hydrologic soil types. QNSPECT also allows the user to copy these values using Create a Lookup Table Template, modify these default values or specify entirely new values. The user can also use these tables to create a new table for a completely different land cover type. Refer to *Urban Hydrology for Small Watersheds: Technical Release 55 (USDA NRCS, 1986)* for more information on determining appropriate curve numbers for other land cover classes.

Inputs for this process:

1. Land Cover
2. Hydrologic Soil Group

In the first step of this process, the soil raster is prepared according to the user's selection on how to treat dual soil categories.

For example, if undrained soils are selected for dual category soils (A/D, B/D, C/D), all soil cells for these categories are converted to type D integer value. On the other hand, if dual soils are considered drained, all soil cells for these categories are converted to type A/B/C values, respectively. If the average option is selected, two different soil rasters and corresponding Curve Number rasters will be created for each drained and undrained type. Then the final Curve Number will be the average of both Curve Number rasters.

At this point, all Null and water type soil cells will be assigned soil category D integer value. The second step of the process involves assigning a CN value from the lookup table for each distinct combination of land cover type and soil group, and this will give us the final CN raster.

Runoff Estimation [NRCS Curve-Number Method]

QNSPECT uses the method presented in the Natural Resources Conservation Service's *Urban Hydrology for Small Watersheds: Technical Release 55 (USDA NRCS, 1986)* as the basis for its runoff estimates.

Inputs for this process:

1. Precipitation
2. Number of Rainy Days in a Year
3. Curve Number (CN)

Following is the step by step procedure of calculation runoff for each cell.

Step 1: Convert precipitation (P) to inches

If not already in inches, QNSPECT will convert precipitation (P) to inches. This is because the Technical Release 55 (TR-55) (USDA NRCS, 1986) equation for estimating runoff assumes precipitation inputs are in inches.

Step 2: Calculate Maximum Potential Retention (S) (inches)

Retention represents the ability of the soil to absorb or retain moisture. Precipitation absorbed or retained by the soil does not contribute to runoff. QNSPECT calculates retention at each grid cell as shown below:

$$\text{Retention} = S = (1000 / \text{Curve Number}) - 10$$

Units associated with the abstraction grid are inches.

Step 3: Calculate cell area (sq feet)

Calculate the raster cell area in square feet.

Step 4: Calculate runoff depth (Q_D) (inches)

Runoff depth for each cell is estimated based on the following equation, which accounts for the average number of days it rains per year. The estimated abstraction and retention are multiplied by the number of rain days, thus reducing estimated runoff.

$$\text{Runoff depth} = \frac{(\text{Rainfall} \times (\text{Abstraction} \times \text{RainDays}))^2}{[(\text{Rainfall} \times (\text{Abstraction} \times \text{RainDays})) + (\text{Retention} \times \text{RainDays})]}$$

or $Q_D = (P - I_a)^2 / [(P - I_a) + (S * \text{number of rainy days})]$

Abstraction (I_a) refers to the losses that occur before runoff begins. This can include water stored by surface depressions and water intercepted by vegetation, evaporation, and infiltration.

$$\text{Abstraction} = (0.2 \times \text{Retention})$$

or $I_a = 0.2 * S * \text{number of rainy days}$

Note:

If the initial abstraction at a given cell is greater than the rainfall at that cell, QNSPECT sets runoff depth to zero. This prevents the reintroduction of artificial sinks to runoff analysis.

$$[\text{If } (P - I_a) \leq 0, \text{ then } Q = 0]$$

Step 6: Convert depth to volume (Liters) by multiplying with cell area

The next step in the runoff estimation process is to convert the runoff depth grid to runoff volume. Because the TR-55 runoff equation yields the depth (inches) of excess water that runs off the landscape for a given total rainfall depth, this grid must be multiplied by the cell area in order to produce a true runoff volume grid. The cell area is simply the length times the width of the cell. For example, a grid with 30 x 30 feet cells would have a cell area of 900 square feet.

The final raster produced by the above steps is called “Local Runoff,” and it will be in Liters.

Accumulated Runoff:

Once the per cell (local) runoff is calculated Grass’s r.watershed method is used to route per cell runoff across the Elevation Raster to get total flow passing through each cell per year. This raster is called "Accumulated Runoff". Each cell in the accumulated runoff grid represents the total amount of water that passes through that cell, including contributions from upstream cells.

For more on this please refer to the GRASS r.watershed documentation. Following are the important things to note from GRASS's r.watershed documentation:

- “The elevation map need not be sink-filled because the module uses a least-cost algorithm.”
- “r.watershed uses an A^T least-cost search algorithm designed to minimize the impact of DEM data errors.”
- “r.watershed offers two methods to calculate surface flow: single flow direction (SFD, D8) and multiple flow direction (MFD). With MFD, water flow is distributed to all neighboring cells with lower elevation, using slope towards neighboring cells as a weighing factor for proportional distribution. The AT least-cost path is always included. As a result, depressions and obstacles are traversed with a graceful flow convergence before the overflow.”

*NCRCS is the new name of the former name of SCS – Soil Conservation Service

Pollutant Loading Estimation

Nonpoint source pollution has proven to be a difficult problem to address because of its complex nature. It is not always clear exactly where the most significant pollution sources are located, and it is even more difficult to monitor and enforce relatively small contributions from many widely dispersed sources.

The effects of nonpoint source pollution range from eutrophication and algal blooms to closed beaches and shellfish beds, and can cause human health impacts through the food chain (Arnold and Gibbons, 1996).

QNSPECT estimates pollutant loading by using land cover as a proxy. This is accomplished by applying pollutant contribution coefficients (similar to event mean concentrations) to land cover classes.

QNSPECT allows users to examine both local and accumulated contributions to pollutant loads. “Local” refers to pollution generated by a single cell. “Accumulated” include local but also incorporate pollutants flowing into the current cell from upstream cells according to the flow direction grid from GRASS's r.watershed.

Following is the step by step procedure of calculating pollutant loads.

Step 1: Calculate pollutant per land cover (mg/L)

A pollutant source raster is created from either the default pollutant coefficients or a user provided set of pollutant coefficients from the lookup table. The pollutant coefficient value represents an average pollutant generation (milligrams/liter) for a given land cover classification.

Step 2: Generate Local Pollutant Load (mg)

The pollutant concentration grid is multiplied by the Local Runoff Volume raster to get a new raster that indicates the mass of the pollutant produced by each individual cell. This grid does not take into account upstream contributions.

Step 3: Generate Accumulated Pollutant load (mg)

The pollutant mass grid is accumulated using the flow direction grid, this is done in exactly the same way as Runoff Accumulation using GRASS's r.watershed algorithm. This yields an accumulated pollutant mass grid in which the value of each cell represents the total mass of pollutant that passes through that cell, including contributions from upstream cells.

Step 4: Convert Accumulated Pollutant load to kg

Multiply the previous steps output to 1,000,000 to get the results in kg. This will be the final “Accumulated Pollutant” raster.

Step 5: Get Pollutant Concentration (mg/L)

The final output i.e. pollutant concentration grid is derived by dividing the accumulated pollutant mass grid from step 3 by the accumulated runoff grid. The pollutant concentration grids can be used as water quality assessment parameters.

Run Erosion Analysis

Run Erosion Analysis

Parameters Log

Run Name

Elevation Raster

R-Factor Raster

Hydrologic Soils Group Raster

K-Factor Raster

Land Cover Raster

Land Cover Type

Land Cover Lookup Table [optional]

Open output files after running algorithm

Advanced Parameters

Treat Dual Category Soils as

Undrained [Default]

Folder for Run Outputs

[Save to temporary folder]

0%

Run as Batch Process... Run Close

Cancel Close

is calculated using RUSLE and Sediment Delivery Ratio models (see the QNSPECT Technical documentation for details).

The user must provide Elevation, Land Cover, Hydrologic Soil Group, K-Factor, and R-Factor rasters for the area of interest. The user is also optionally required to provide a lookup table that relates different land cover classes in the provided Land Cover raster with Curve Number and C-Factor values.

Input Parameters

Run Name

Name of the run. The algorithm will create a folder with this name and save all outputs and a configuration file in that folder.

Elevation Raster

Elevation raster for the area of interest. The CRS can be in any units, but the **elevation must be in meters**. The algorithm uses elevation data to calculate ratios, flow direction, and flow accumulation throughout a watershed.

Hydrologic Soils Group Raster

Hydrologic Soil Group raster for the area of interest with following mapping {'A': 1, 'B': 2, 'C': 3, 'D': 4, 'A/D': 5, 'B/D': 6, 'C/D': 7, 'W': 8, Null: 9}. The soil raster is used to

Summary

The “Run Erosion Analysis” algorithm estimates annual erosion volume for a given area on a per cell and accumulated basis. The volume is calculated using RUSLE and Sediment Delivery Ratio models (see the Science and Algorithms section for details).

The user must provide Elevation, Land Cover, Hydrographic Soil Group, K-Factor, and R-Factor rasters for the area of interest. The user is also optionally required to provide a lookup table that relates different land cover classes in the provided Land Cover raster with Curve Number and C-Factor values.

This analysis should be performed on a watershed level to account for all upstream flow at a cell. For accurate results, the area of interest should fully envelop the watershed in consideration.

GRASS r.watershed function is used by the algorithm under the hood to calculate the LS-Factor and accumulation.

Input Parameters

Run Name

Name of the run. The algorithm will create a folder with this name and save all outputs and a configuration file in that folder.

Elevation Raster

Elevation raster for the area of interest. The Coordinate Reference System can be in any units, but the elevation must be in meters. The algorithm uses elevation data to calculate ratios, flow direction, and flow accumulation throughout a watershed.

Hydrographic Soils Group Raster

Hydrologic Soil Group raster for the area of interest with following mapping {'A': 1, 'B': 2, 'C': 3, 'D':4, 'A/D':5, 'B/D':6, 'C/D':7, 'W':8, Null: 9}. The soil raster is used to generate runoff estimates using NRCS Curve Number method.

K-factor Raster

Soil erodibility raster for the area of interest. The K-factor is a component of the RUSLE equation.

Land Cover Raster

Land Cover/Classification raster for the area of interest. The algorithm uses Land Cover Raster and Lookup Table to determine each cell's erosion potential.

Land Cover Type

Type of Land Cover raster. If the Land Cover raster is not of type C-CAP or NCLD, select custom for this field and supply a lookup table in the Land Cover Lookup Table field.

Land Cover Lookup Table [optional]

Lookup table to relate each land cover class with Curve Number and C-Factor. The user can skip providing a lookup table if the land cover type is not custom; the algorithm will utilize the default lookup table for the land cover type selected in the previous option.

To create a custom lookup table, use the “Create Lookup Table Template” tool. The table must contain all land cover classes available in the land cover raster.

Advanced Parameters

Treat Dual Category Soils

Certain areas can have dual soil types (A/D, B/D, or C/D). These areas possess characteristics of Hydrologic Soil Group D during undrained conditions and characteristics of Hydrologic Soil Group A/B/C for drained conditions.

In this parameter, the user can specify if these areas should be treated as drained, undrained, or average of both conditions. If the average option is selected, the algorithm will use the average of drained and undrained Curve Number for Sediment Delivery Ratio calculations.

Outputs

Folder for Run Outputs

The algorithm outputs and configuration file will be saved in this directory in a separate folder.

Science and Algorithms

This component uses the Revised Universal Soil Loss Equation and Sediment Delivery Ratio models for predicting the predicted erosion of an area.

RUSLE

The Revised Universal Soil Loss Equation (RUSLE) is a model for predicting average annual soil loss from raindrops and runoff. The equation is as follows:

$$A = R * K * LS * C * P$$

Where:

A = average annual soil loss

R = rainfall/runoff erosivity factor ((feet * tonfeet * inch) / (acre * hour * year))

K = soil erodibility factor ((ton * acre * hour) / (acres * tonfeet * feet * inch))

LS = slope length and steepness factor

C = cover management factor

P = supporting practices factor

R-Factor Raster: A quantified effect of raindrop impact and the amount and rate of runoff from that rain. R-factor maps for other regions can typically be found in the NRCS Electronic Field Office Technical Guide or by contacting the local NRCS office. R-Factor rasters may also be downloaded in the "Data Requirements" section of NOAA's QNSPECT web page (<https://coast.noaa.gov/digitalcoast/tools/qnspect.html>).

K-Factor Raster: The soil erodibility factor. This can be derived from the SSURGO data set. It is one of the outputs from the "Rasterize Soils" component in QNSPECT. Areas without a K-factor value will be assumed to be urban areas and given a value of 0.3.

LS-Factor Raster: Erosion is influenced by both the slope length and steepness. For the RUSLE equation, these two factors are usually evaluated together. QNSPECT uses the LS-Factor raster generated by GRASS' watershed component

C-Factor Raster: The erosivity factor based on land cover.

P-Factor Raster: The supporting practices factor is not included in this version of QNSPECT. The product of the RUSLE equation will be in (tons / acre). QNSPECT will convert this into (tons / square meter).

Sediment Delivery Ratio

RUSLE produces an estimate of gross erosion but does not indicate how much eroded soil is transported by streams. The Sediment Delivery Ratio is used to calculate the total sediment yield. The Sediment Delivery Ratio represents the efficiency of the watershed to move particulates (Williams 1977).

$$SDR = 1.366 * 10^{-11} * DA^{-0.0998} * ZL^{0.3629} * CN^{5.444}$$

Where:

DA = drainage area (km²)

ZL = relief-length ratio (m/km)

CN = SCS curve number

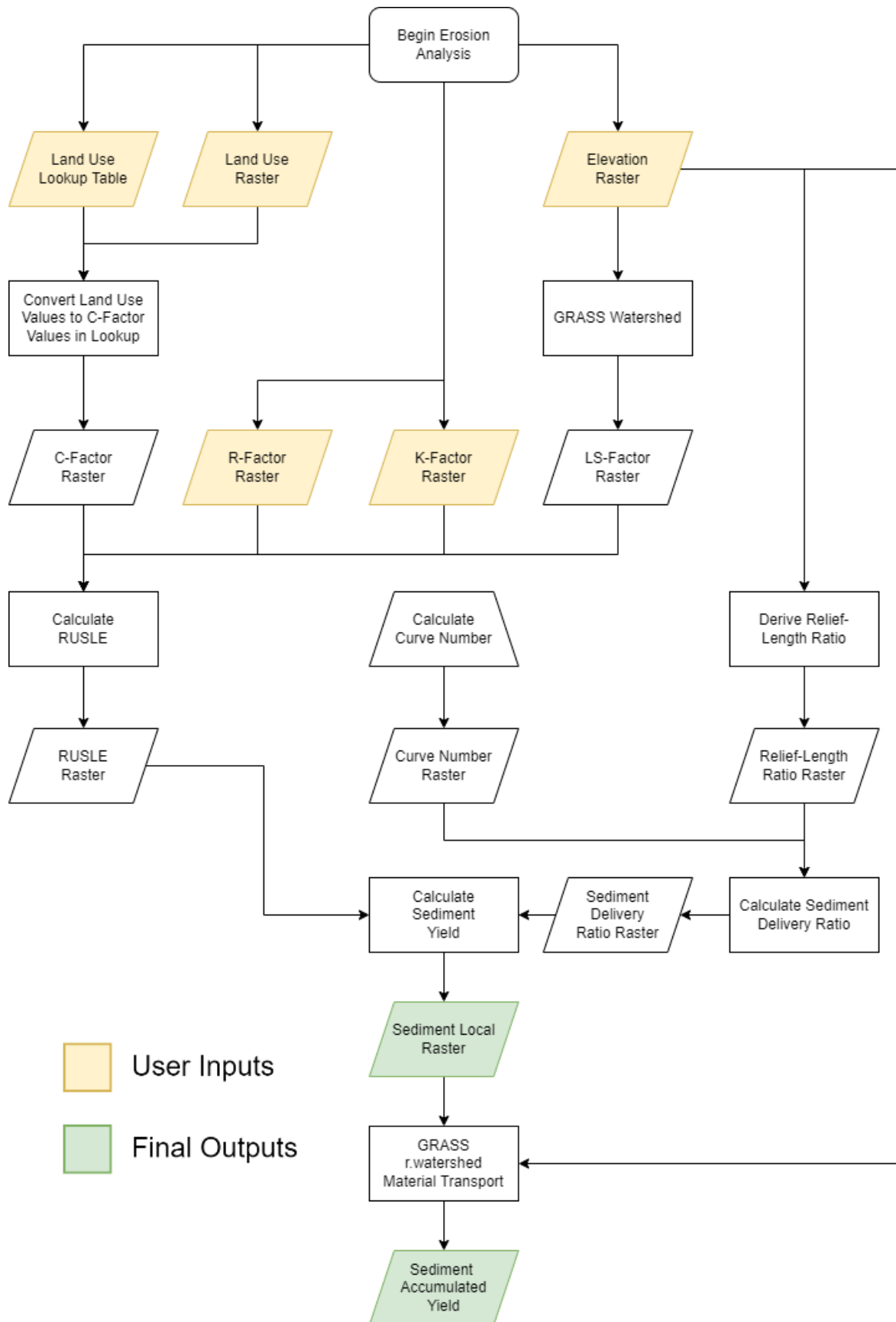
Drainage Area (DA): The sediment delivery ratio is applied at the cell level rather than at the watershed or catchment level. The drainage area parameter represents the area of each individual raster cell.

Relief-Length Ratio (ZL): The ratio between the vertical and horizontal distance between a cell and the cell downslope from it. The horizontal distance can be assumed to be the cell size. The vertical distance can be calculated by finding the slope of the cell, then multiplying the tangent of the slope by the cell size. The ratio is the division of the vertical distance and horizontal distance in (m/m). This is divided by 1,000 to convert it to (m/km).

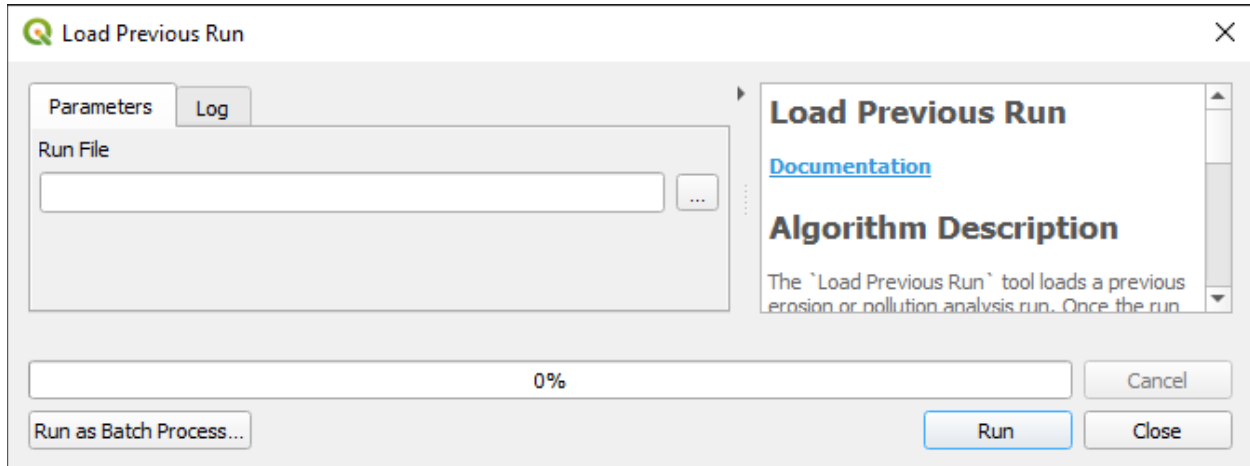
Curve number (CN): The runoff curve number raster is derived from the land cover grid and SSURGO shapefile. See the Pollution Analysis section above for how this is calculated.

Annual Sediment Yield

Multiplying the Sediment Delivery Ratio raster by the RUSLE raster will produce a true annual sediment yield grid. The product is multiplied by 907.18474 to convert from tons to kilograms.



Load Previous Run



Summary

The “Load Previous Run” component uses a JSON file from a previous analysis run to load the “Run Pollution Analysis” or “Run Erosion Analysis” tool. This can be helpful when running multiple scenarios with only one or two parameters changed between them.

After running, the appropriate analysis component will load with the parameters of the previous scenario automatically populated.

Input Parameters

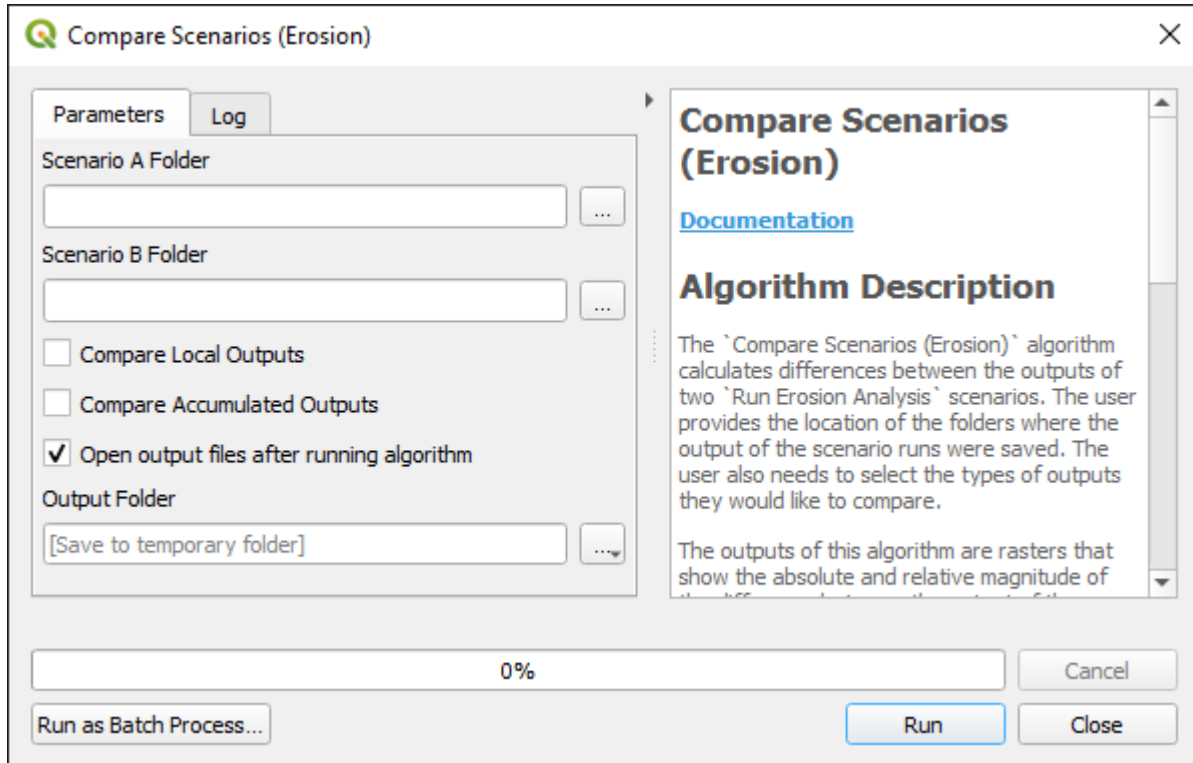
Run File

JSON file created by the “Run Pollution Analysis” or “Run Erosion Analysis” algorithms. The file must have the extension “.pol.json” for pollution analysis and “.ero.json” for erosion analysis.

Outputs

No outputs will be created from this component.

Compare Scenarios (Erosion)



Summary

The “Compare Scenarios (Erosion)” algorithm creates a raster with the differences between “Run Erosion Analysis” results. The user provides the folders where the outputs were saved and which analysis types they would like the comparison to run on.

The results of this analysis are rasters that show the locations of change between the two runs. This can be used to see the effects of changing land cover types after construction.

Input Parameters

Scenario A Folder

Folder location of the results of the first analysis.

Scenario B Folder

Folder location of the results of the second analysis.

Compare Local Outputs

Select to run the comparison on the local effects rasters.

Compare Accumulated Outputs

Select to run on the comparison on the accumulated effects rasters.

Open output files after running algorithm

Select to open the results of the comparison after the analysis has concluded.

Outputs

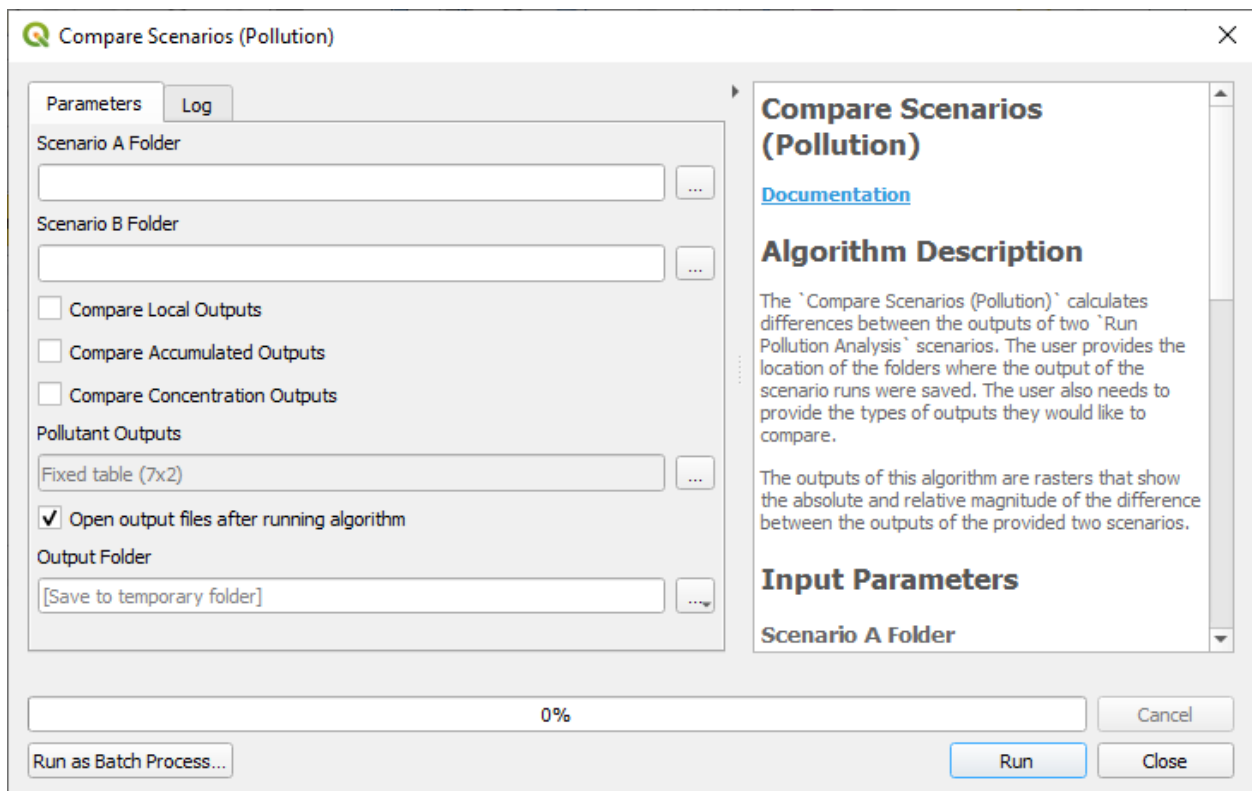
Output Folder

The folder the results of the comparison will be saved to.

Science and Algorithms

Two comparison methods are used. The first is a direct comparison which subtracts the values in the raster(s) of Scenario B from the raster(s) in Scenario A (formula: $A - B$). The second is a percent comparison which is a function of the percent change between A and B (formula: $100 * ((A-B) / B)$).

Compare Scenarios (Pollution)



Summary

The “Compare Scenarios (Pollution)” algorithm creates a raster with the differences between “Run Pollution Analysis” results. The user provides the folders where the outputs were saved and which analysis types they would like the comparison to run on.

The results of this analysis are rasters that show the locations of change between the two runs. This can be used to see the effects of changing land cover types after construction.

Input Parameters

Scenario A Folder

Folder location of the results of the first analysis.

Scenario B Folder

Folder location of the results of the second analysis.

Compare Local Outputs

Select to run the comparison on the local effects rasters.

Compare Accumulated Outputs

Select to run on the comparison on the accumulated effects rasters.

Compare Concentration Outputs

Select to run on the comparison on the concentration effects rasters.

Open output files after running algorithm

Select to open the results of the comparison after the analysis has concluded.

Pollutant Outputs

The comparison will be run on runoff and pollutants with a “Y” in the Output column. If “Everything” is selected, the comparison will be run on all pollutants that are shared between the scenarios.

The user can add more pollutants to the table. To exclude an output from the analysis, enter “N” in the Output column. You must click OK after editing to save your changes.

Open output files after running algorithm

Select to open the results of the comparison after the analysis has concluded.

Outputs

Output Folder

The folder the results of the comparison will be saved to.

Science and Algorithms

Two comparison methods are used. The first is a direct comparison which subtracts the values in the raster(s) of Scenario B from the raster(s) in Scenario A (formula: $A - B$). The second is a percent comparison which is a function of the percent change between A and B (formula: $100 * ((A-B) / B)$).

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