


Common borders. Common solutions.

**SciNetNatHaz Project Progress Meeting - 23-26 Oct 2014, Burgas, Bulgaria**

**SciNetNatHaz Project Progress Meeting - 7-9 May 2015, Thessaloniki, Hellas**



# Using Morphometric models and Open Source Software to locate Flood prone areas

## A guide to pilot Implementation

Konstantinos Papatheodorou

Helena Tzanou

TEI of Kentriki Makedonia, LB

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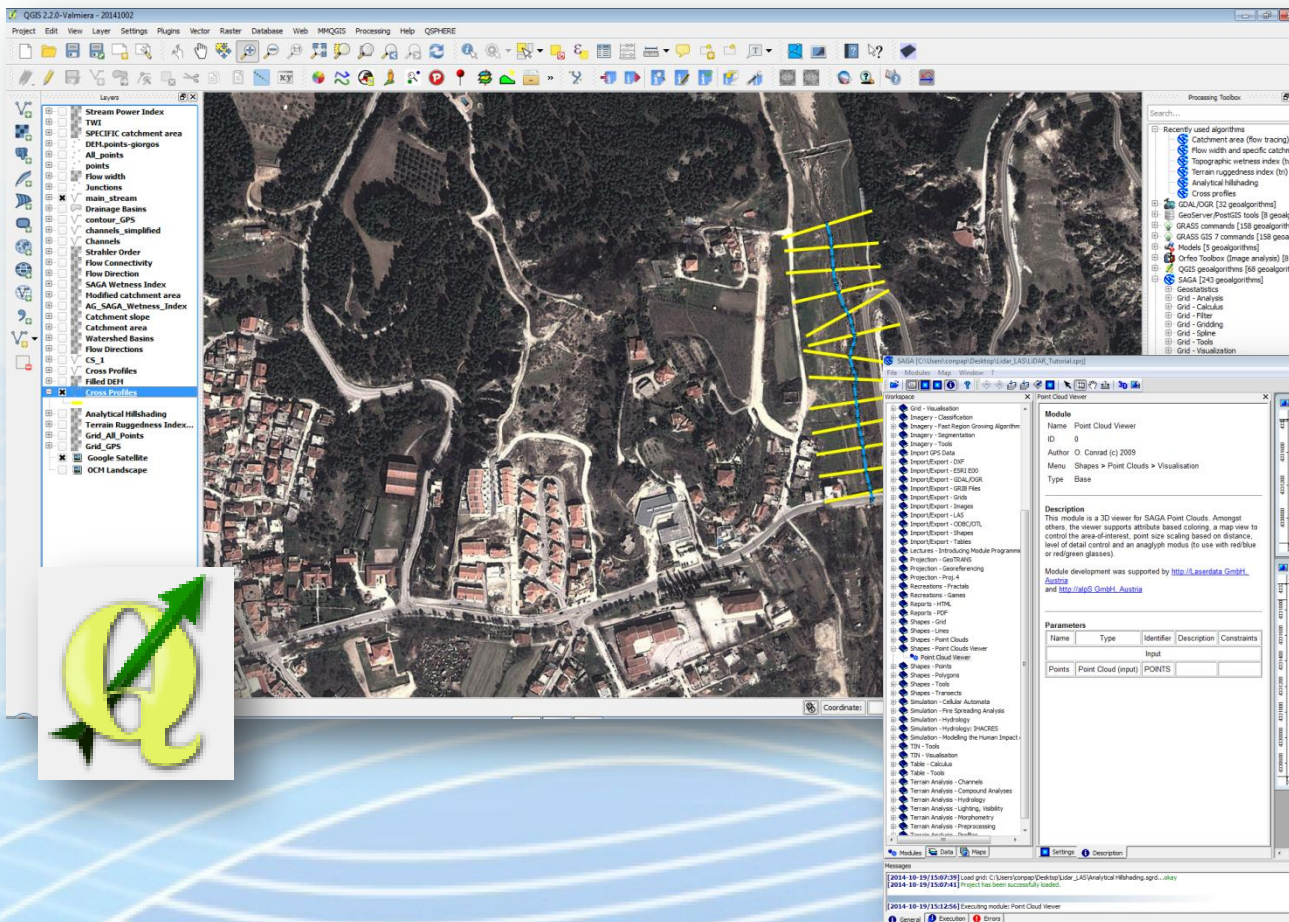
# Contents

- Data Requirements
- Procedures
- Outputs
- Evaluation



Common borders. Common solutions.

# The Tools



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## Data: Morphology

- Topographic Maps, scale 1:50.000
- Elevation Points
- Land Use maps (Corine 2000 / 2006)
- Road and Railroad Network





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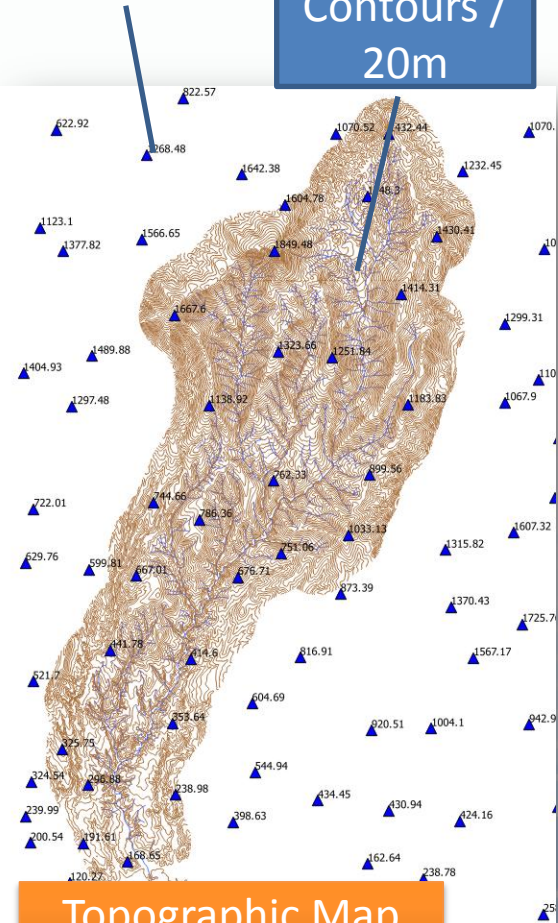


Common borders. Common solutions.

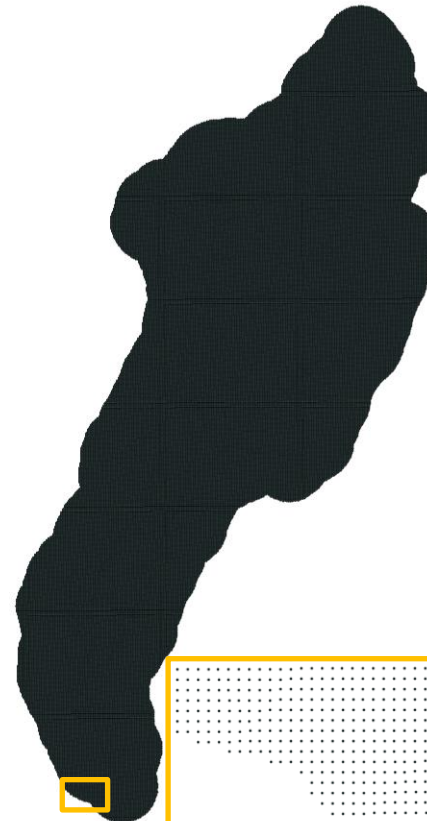
# Data: Morphology

Elevation  
Points

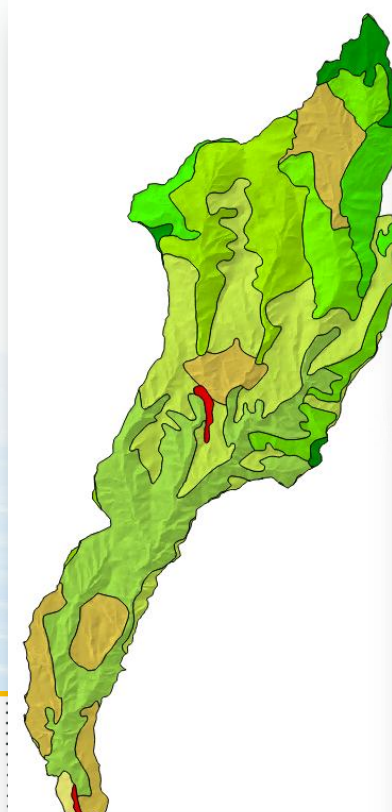
Contours /  
20m



Topographic Map  
1:50.000

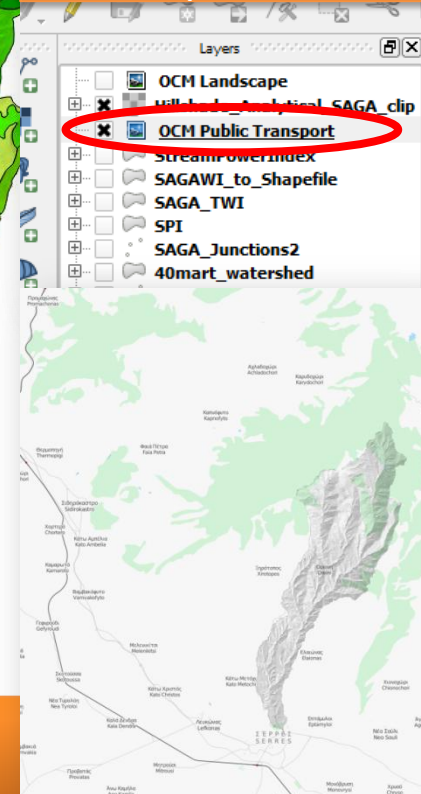


Lattice points /25m



CORINE  
Land Use map

OpenStreet Maps  
Public  
Transportation

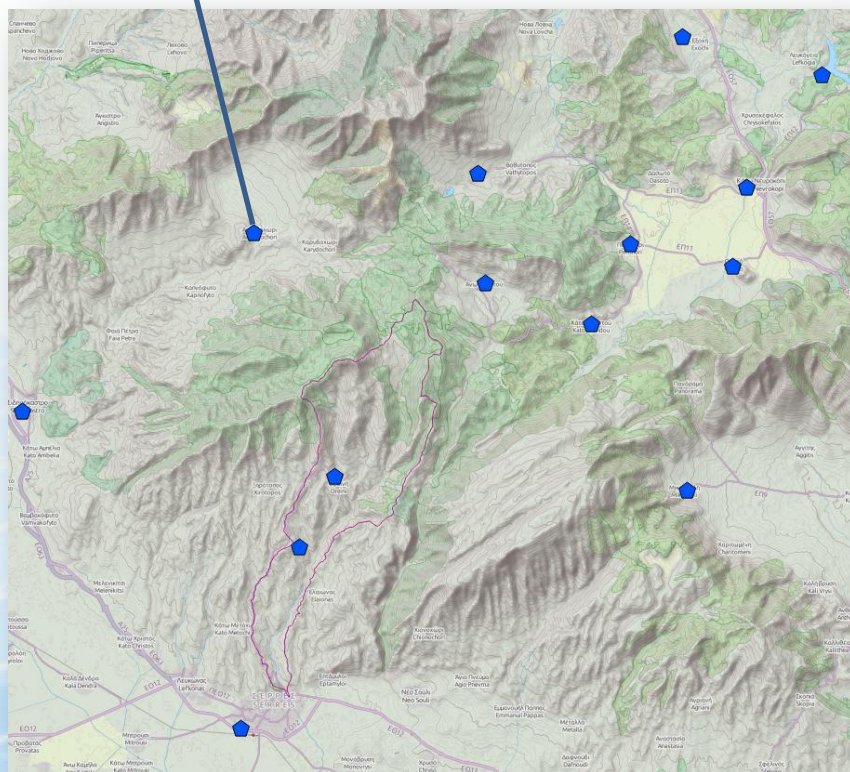


Common borders. Common solutions.

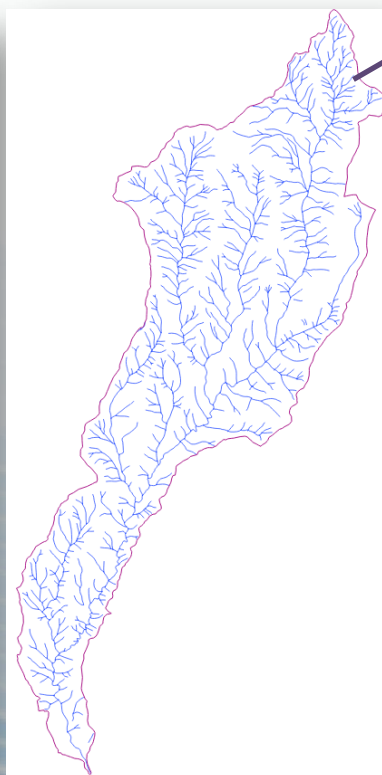
Meteorological  
Stations

# Data: Rainfall & Hydrology

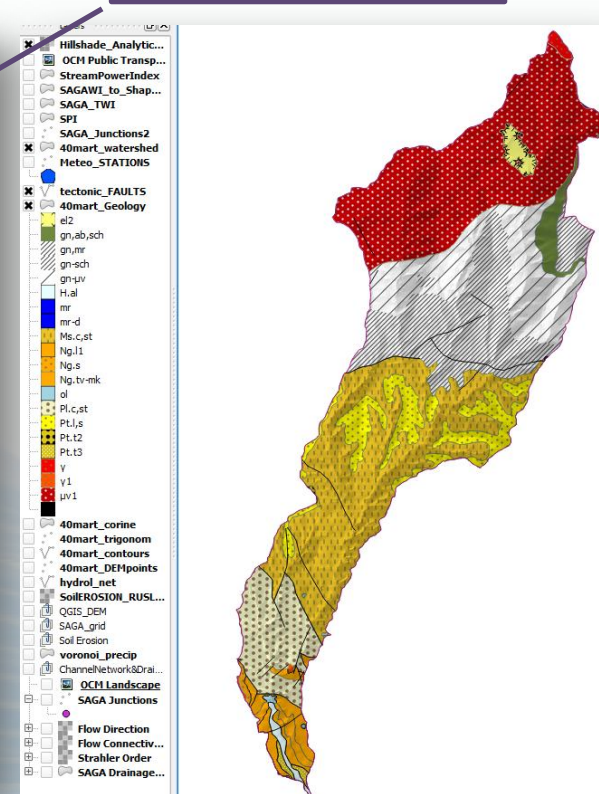
Watershed



Meteo – Stations on an OpenStreet Map  
Landscape layer



Hydrology Network  
(digitized from topo maps)

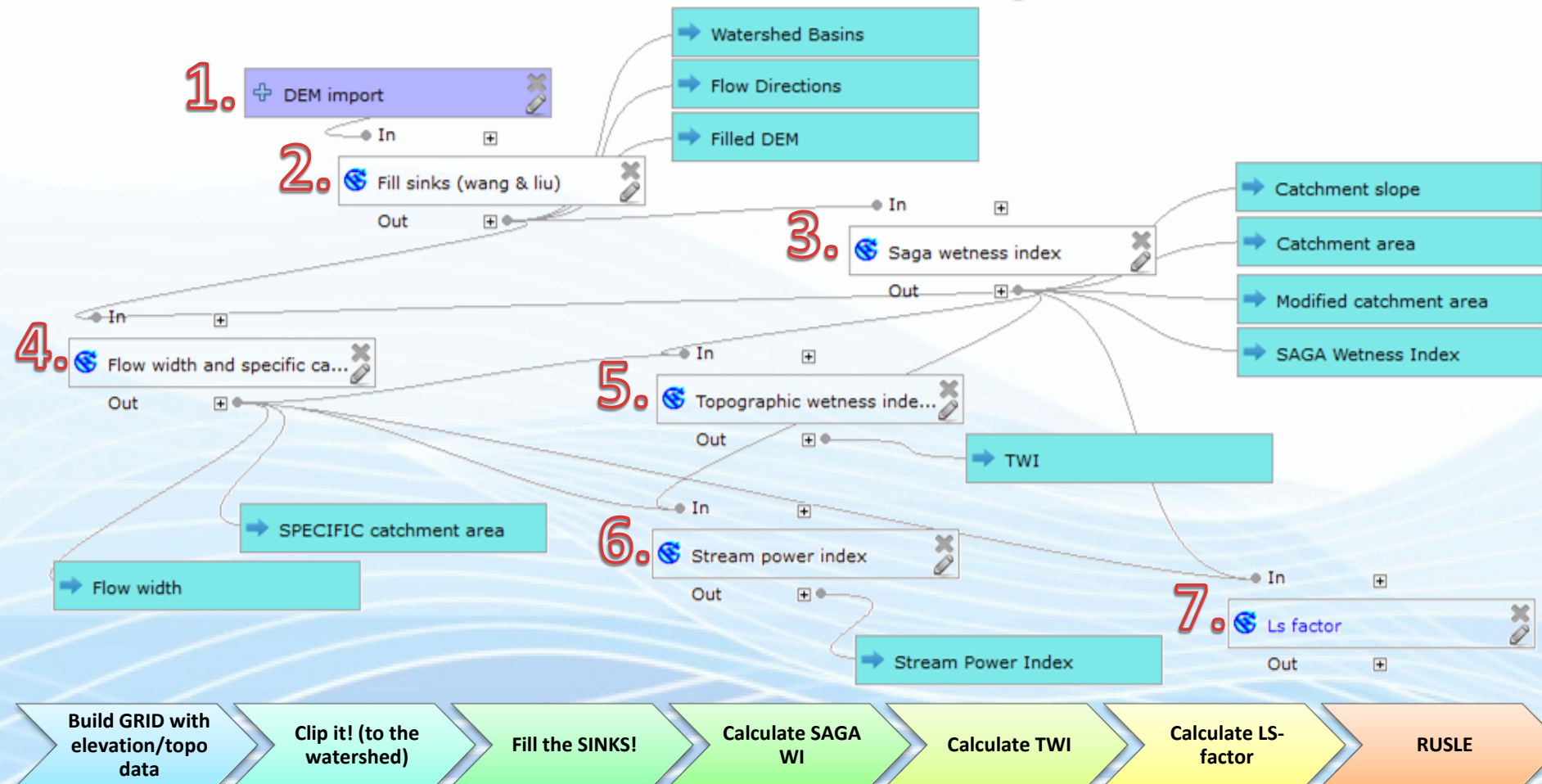


Geologic map



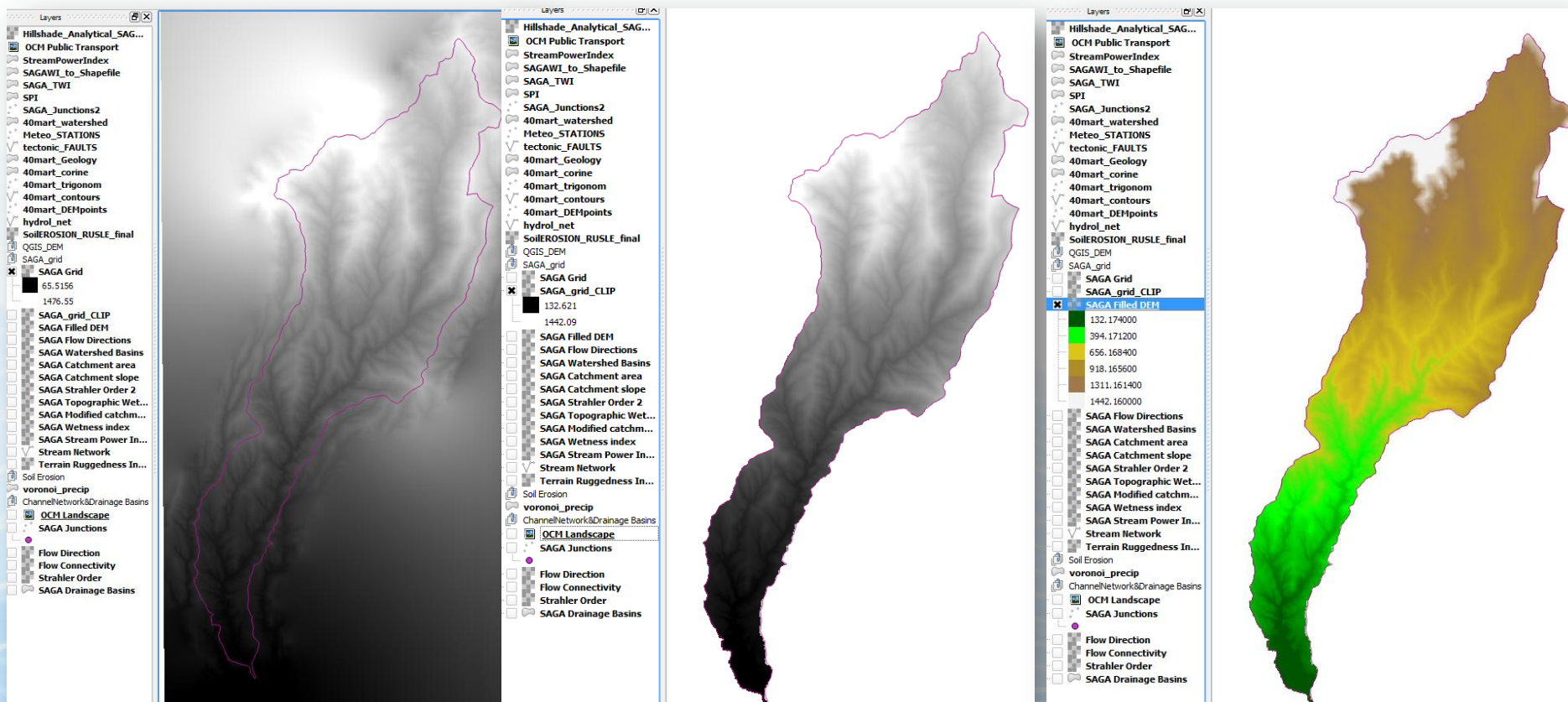
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# Procedural steps



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# GRID Related Processes



Build GRID with elevation/topo  
data

Clip it! (to the watershed)

Fill the SINKS!



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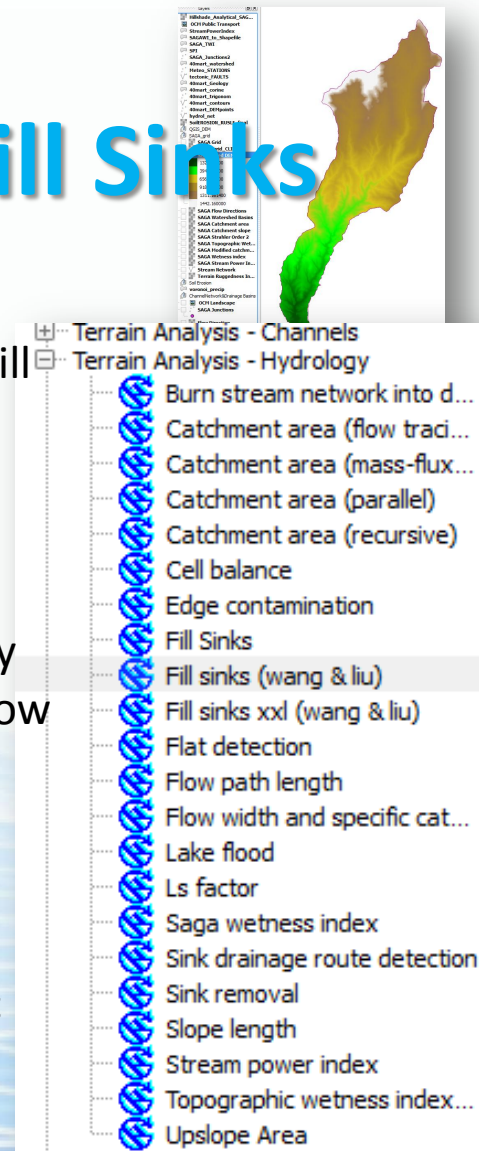
# GRID Related Processes – Fill Sinks

## Description

This module uses an algorithm (Wang & Liu, 2006) to identify and fill surface depressions in digital elevation models. The method was enhanced to allow the creation of hydrologic sound elevation models, i.e. not only to fill the depression(s) but also to preserve a downward slope along the flow path. This is accomplished by preserving a minimum slope gradient between cells. This is the fully featured version of the module creating a depressionless DEM, a flow path grid and a grid with watershed basins.

## References

Wang, L. & H. Liu (2006): An efficient method for identifying and filling surface depressions in digital elevation models for hydrologic analysis and modeling. International Journal of Geographical Information Science, Vol. 20, No. 2: 193-213.



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## SAGA Wetness Index

SAGA Wetness Index

REFERENCES

### Module

Name SAGA Wetness Index  
ID 15  
Author (c) 2001 by J.Boehner, O.Conrad  
Menu Terrain Analysis > Hydrology > Topographic Indices  
Type Grid

### Description

The 'SAGA Wetness Index' is, as the name says, similar to the 'Topographic Wetness Index' (TWI), but it is based on a modified catchment area calculation ('Modified Catchment Area'), which does not think of the flow as very thin film. As result it predicts for cells situated in valley floors with a small vertical distance to a channel a more realistic, higher potential soil moisture compared to the standard TWI calculation.

### References

- Boehner, J., Koethe, R. Conrad, O., Gross, J., Ringeler, A., Selige, T. (2002): Soil Regionalisation by Means of Terrain Analysis and Process Parameterisation. In: Micheli, E., Nachtergaele, F., Montanarella, L. [Ed.]: Soil Classification 2001. European Soil Bureau, Research Report No. 7, EUR 20398 EN, Luxembourg. pp.213-222.

### Parameters

Name	Type	Identifier	Description	Constraints
Input				
Elevation	Grid (input)	DEM		
Output				
Catchment area	Grid (output)	C		
Catchment slope	Grid (output)	GN		
Modified catchment area	Grid (output)	CS		
Wetness index	Grid (output)	SB		
Options				
t	Floating point	T		Minimum: 0.000000

SAGA GIS



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# SAGA Wetness Index

Processing Toolbox

SAGA wetness index

Parameters Log Help

Elevation  
SAGA Filled DEM [EPSG:2100]

t  
10

Catchment area  
[Save to temporary file]

☒ Open output file after running algorithm

Catchment slope  
[Save to temporary file]

☒ Open output file after running algorithm

Modified catchment area  
[Save to temporary file]

☒ Open output file after running algorithm

Wetness index  
[Save to temporary file]

☒ Open output file after running algorithm

0%

Run Close Cancel

Input FILLED DEM

The rest are created automatically

Outputs

- Hillshade\_Analytical\_S...
  - Wetness index
    - 6.99976
    - 16.5441
  - Modified catchment area
    - 224.687
    - 3.01162e+06
  - Catchment slope
    - 0
    - 0.474734
  - Catchment area
    - 224.687
    - 311789
  - OCM Public Transport

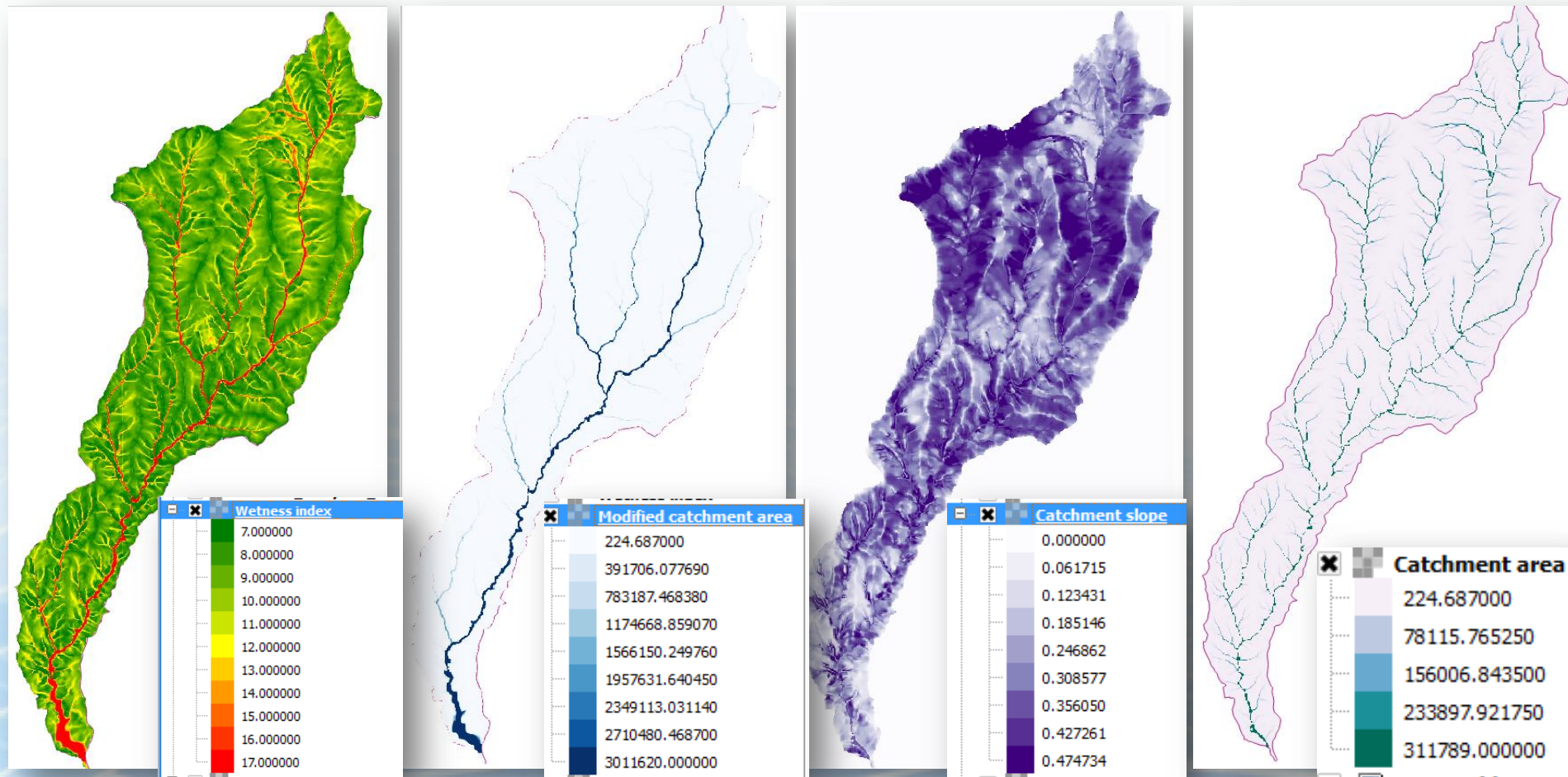


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# SAGA Wetness Index - Outputs





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# Flow Width & Specific Catchment Area

## REFERENCES

Flow Width and Specific Catchment Area

**Module**

Name Flow Width and Specific Catchment Area

ID 19

Author O. Conrad (c) 2009

Menu Terrain Analysis > Hydrology > Catchment Area

Type Grid

**Description**

Flow width and specific catchment area (SCA) calculation.

**References:**

Gruber, S., Peckham, S. (2008): Land-Surface Parameters and Objects in Hydrology. In: Hengl, T. and Reuter, H.I. [Eds.]: Geomorphometry: Concepts, Software, Applications. Developments in Soil Science, Elsevier, 33:293-308.

Quinn, P.F., Beven, K.J., Chevallier, P., Planchon, O. (1991): The prediction of hillslope flow paths for distributed hydrological modelling using digital terrain models. Hydrological Processes, 5:59-79

**Parameters**

Name	Type	Identifier	Description	Constraints
<b>Input</b>				
Elevation	Grid (input)	DEM		
Total Catchment Area (TCA) (*)	Grid (optional input)	TCA		
<b>Output</b>				
Flow Width	Grid (output)	WIDTH		
Specific Catchment Area (SCA) (*)	Grid (optional output)	SCA		
<b>Options</b>				
Method	Choice	METHOD		Available Choices: [0] Deterministic 8 [1] Multiple Flow Direction (Quinn et al. 1991) [2] Aspect

(\*) optional

Flow width and specific catchment area

Parameters Log Help

Elevation  
SAGA Filled DEM [EPSG:2100]

Total Catchment Area (TCA)  
[Not selected]

Method  
[0] Deterministic 8

Flow Width  
[Save to temporary file]

☒ Open output file after running algorithm

Specific Catchment Area (SCA)  
[Save to temporary file]

☒ Open output file after running algorithm

0%

Run Close Cancel

Terrain Analysis - Channels

☒ Terrain Analysis - Hydrology

- Burn stream network in...
- Catchment area (flow t...
- Catchment area (mass...
- Catchment area (parall...
- Catchment area (recur...
- Cell balance
- Edge contamination
- Fill Sinks
- Fill sinks (wang & liu)
- Fill sinks xxl (wang & liu)
- Flat detection
- Flow path length
- Flow width and specific...
- Lake model
- Ls factor

SAGA GIS

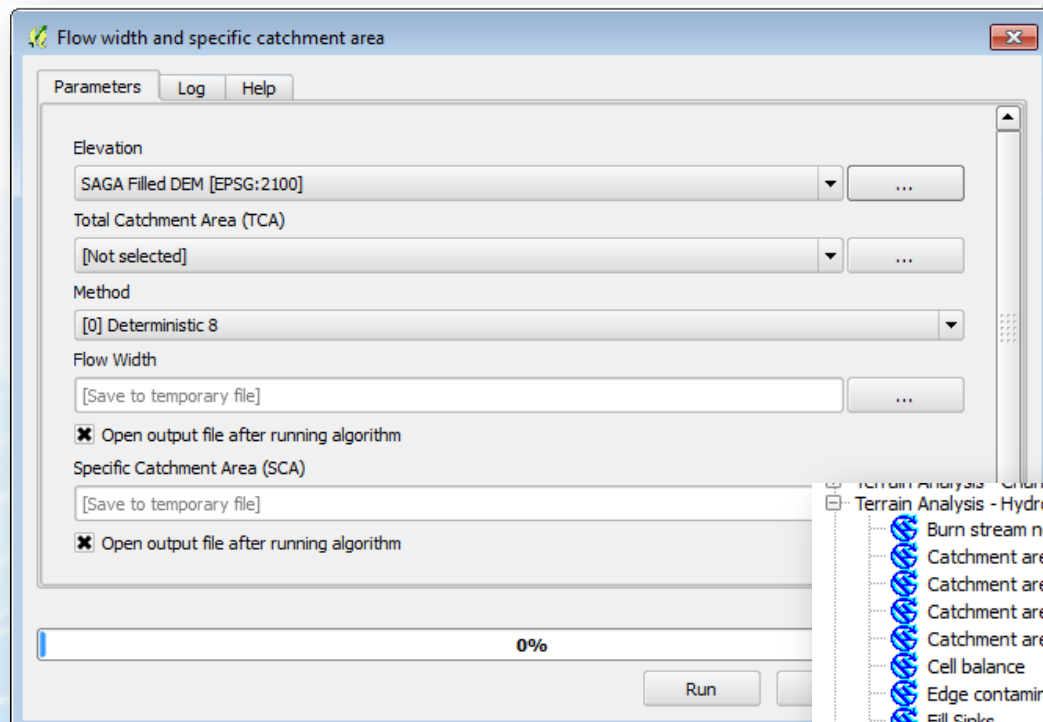


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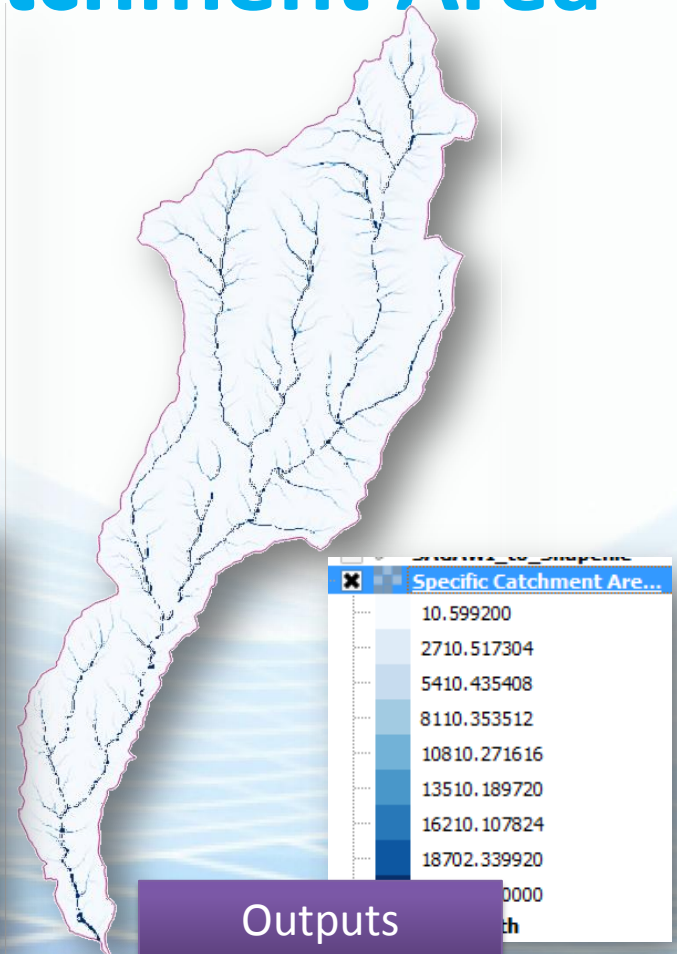
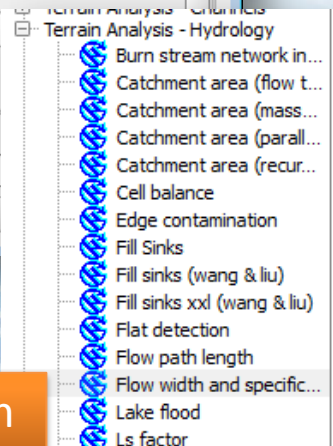


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# Flow Width & Specific Catchment Area



Menu/Location



Outputs





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# Topographic Wetness Index

Topographic Wetness Index (TWI)

## Module

Name Topographic Wetness Index (TWI)  
ID 20  
Author O.Conrad (c) 2003  
Menu Terrain Analysis > Hydrology > Topographic Indices  
Type Grid

## Description

Calculation of the slope and specific catchment area (SCA) based Topographic Wetness Index (TWI)

## References:

Beven, K.J., Kirkby, M.J. (1979):

A physically-based variable contributing area model of basin hydrology/  
Hydrology Science Bulletin 24(1), p.43-69

Boehner, J., Selige, T. (2006):

Spatial Prediction of Soil Attributes Using Terrain Analysis and Climate Regionalisation'

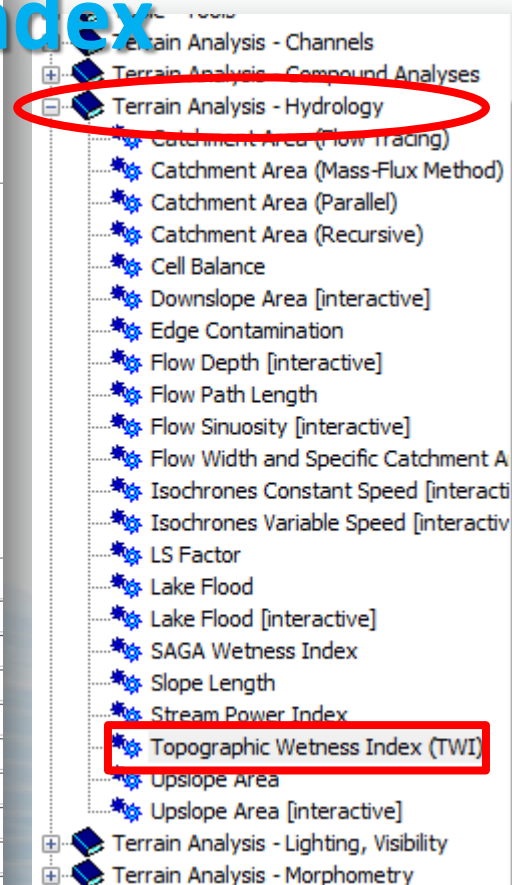
In: Boehner, J., McCloy, K.R., Strobl, J.: 'SAGA - Analysis and Modelling Applications', Goettinger Geographische Abhandlungen, Vol.115, p.13-27

Moore, I.D., Grayson, R.B., Ladson, A.R. (1991):

'Digital terrain modelling: a review of hydrological, geomorphological, and biological applications'  
Hydrological Processes, Vol.5, No.1

## Parameters

Name	Type	Identifier	Description	Constraints
Input				
Slope	Grid (input)	SLOPE		
Catchment Area	Grid (input)	AREA		
Transmissivity (*)	Grid (optional input)	TRANS		
Output				
Topographic Wetness Index	Grid (output)	TWI		
Options				
Area Conversion	Choice	CONV		Available Choices: [0] no conversion (areas already given as specific catchment area) [1] 1 / cell size (pseudo specific catchment area)
Method (TWI)	Choice	METHOD		Available Choices: [0] Standard [1] TOPMODEL



SAGA GIS

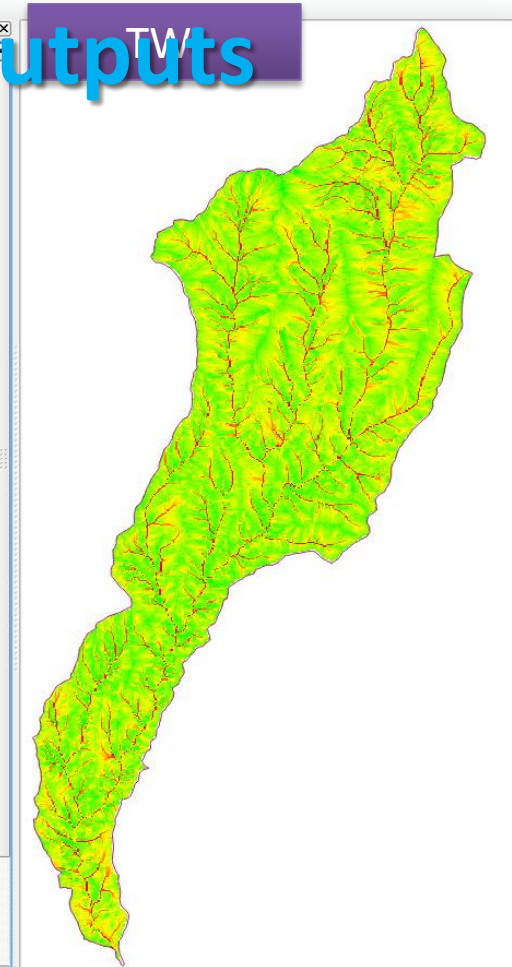
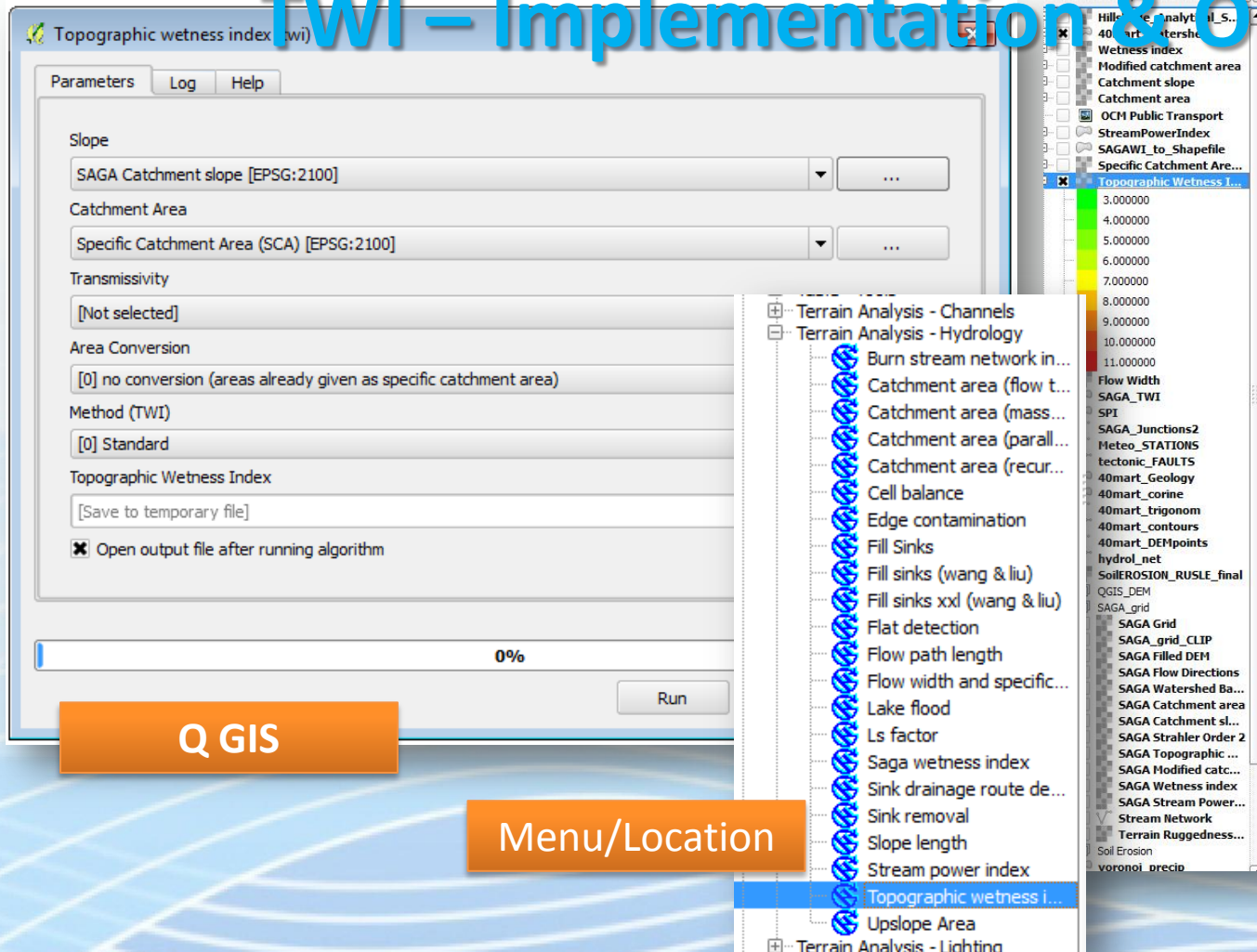


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# TWI – Implementation & Outputs







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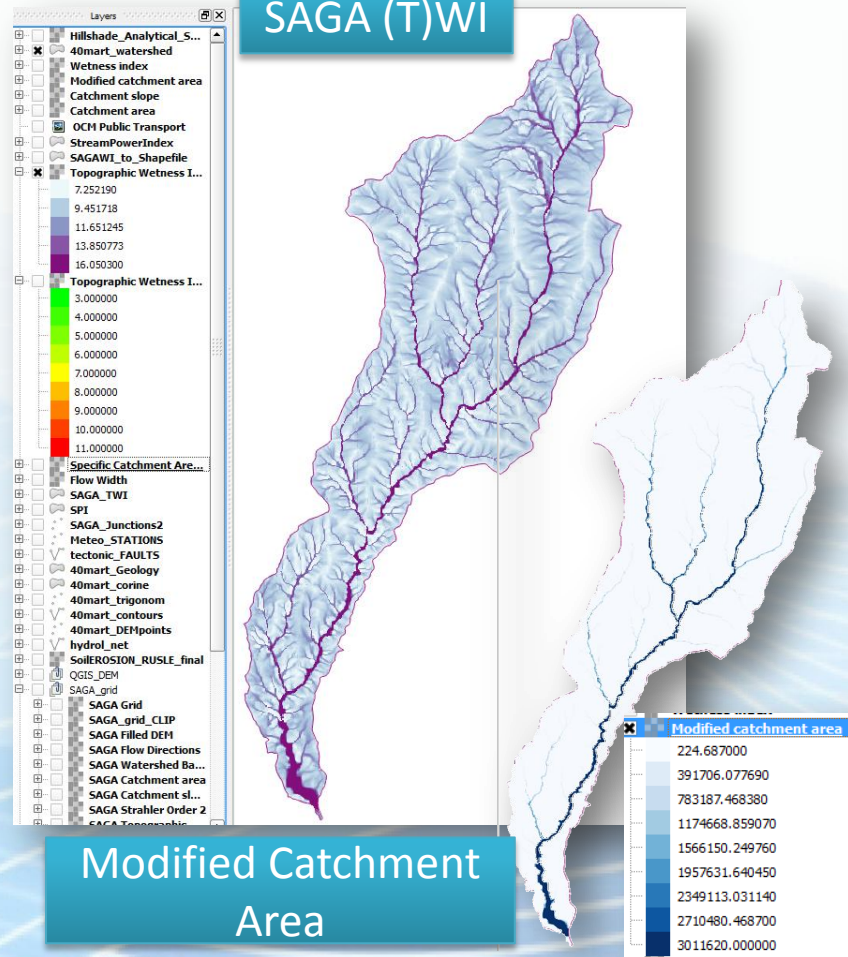


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## TWI vs SAGA WI

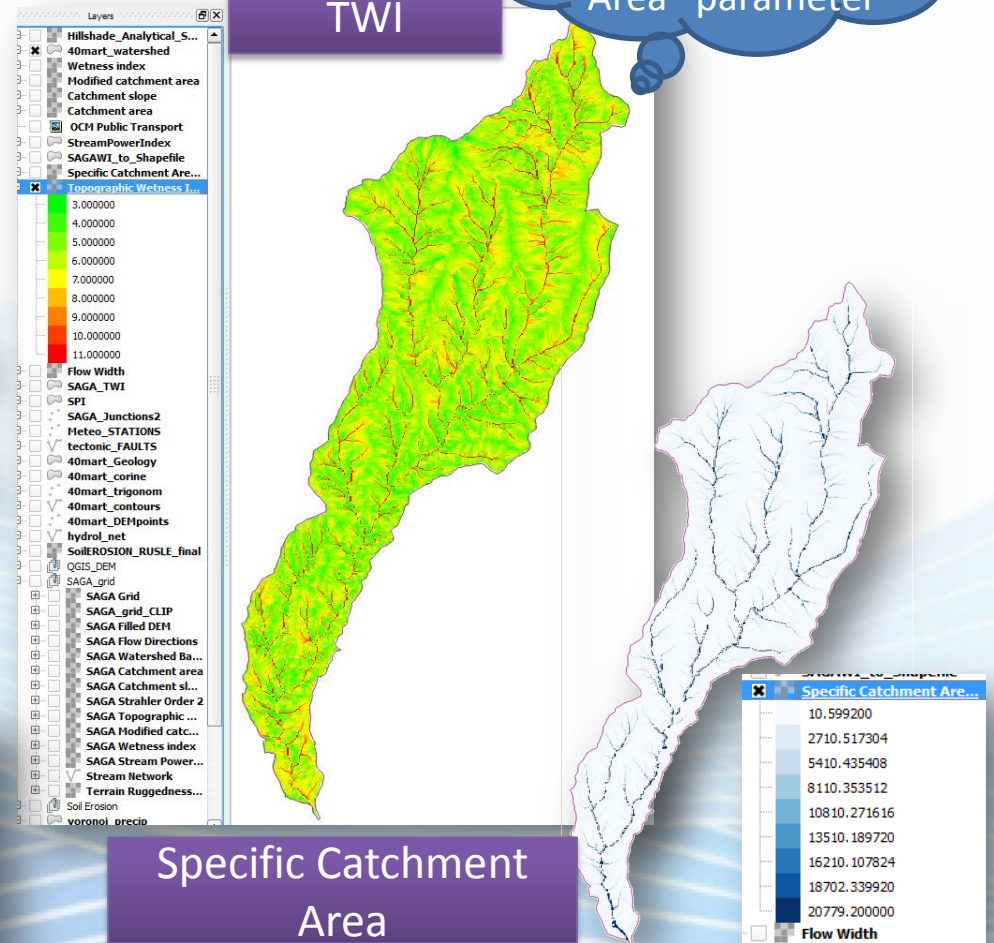
Differences due  
to the  
“Catchment  
Area” parameter

SAGA (T)WI



Modified Catchment  
Area

TWI



Specific Catchment  
Area



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## TWI vs SAGA WI

SAGA (T)WI



TWI



This is what has actually happen in Serres,  
eight years ago

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# RUSLE – LS factor

Workspace

- Reports - HTML
- Reports - PDF
- Shapes - Grid
- Shapes - Lines
- Shapes - Point Clouds
- Shapes - Point Clouds Viewer
- Shapes - Points
- Shapes - Polygons
- Shapes - Tools
- Shapes - Transects
- Simulation - Cellular Automata
- Simulation - Fire Spreading Analysis
- Simulation - Hydrology
- Simulation - Hydrology: IHACRES
- Simulation - Modelling the Human Impact
- TIN - Tools
- TIN - Visualisation
- Table - Calculus
- Table - Tools
- Terrain Analysis - Channels
- Terrain Analysis - Compound Analyses
- Terrain Analysis - Hydrology
  - Catchment Area (Flow Tracing)
  - Catchment Area (Mass-Flux Method)
  - Catchment Area (Parallel)
  - Catchment Area (Recursive)
  - Cell Balance
  - Downslope Area [Interactive]
  - Edge Contamination
  - Flow Depth [Interactive]
  - Flow Path Length
  - Flow Sinuosity [Interactive]
  - Flow Width and Specific Catchment A
  - Isochrones Constant Speed [Interacti
  - Isochrones Variable Speed [Interactiv
  - LS Factor**
  - Lake Flood
  - Lake Flood [Interactive]
  - SAGA Wetness Index
  - Slope Length
  - Stream Power Index
  - Topographic Wetness Index (TWI)
  - Upslope Area
  - Upslope Area [Interactive]
- Terrain Analysis - Lighting, Visibility
- Terrain Analysis - Morphometry
- Terrain Analysis - Preprocessing
- Terrain Analysis - Profiles

LS Factor

**Description**  
Calculation of slope length (LS) factor as used by the Universal Soil Loss Equation (USLE), based on slope and specific catchment area (SCA, as substitute for slope length).  
References:

Boehner, J., Selige, T. (2006):  
Spatial Prediction of Soil Attributes Using Terrain Analysis and Climate Regionalisation'  
In: Boehner, J., McCloy, K.R., Strobl, J.: 'SAGA – Analysis and Modelling Applications', Goettinger Geographische Abhandlungen, Vol.115, p.13-27

Desmet & Govers (1996):  
'A GIS Procedure for Automatically Calculating the USLE LS Factor on Topographically Complex Landscape Units'  
Journal of Soil and Water Conservation, 51(5):427-433

Kinnell, P.I.A. (2005):  
'Alternative Approaches for Determining the USLE-M Slope Length Factor for Grid Cells.'  
<http://soil.scijournals.org/cgi/content/full/69/3/674>

Moore, I.D., Grayson, R.B., Ladson, A.R. (1991):  
'Digital terrain modelling: a review of hydrological, geomorphological, and biological applications'  
Hydrological Processes, Vol.5, No.1

Wischmeier, W.H., Smith, D.D. (1978):  
'Predicting rainfall erosion losses – A guide to conservation planning'  
Agriculture Handbook No. 537: US Department of Agriculture, Washington DC.

**Parameters**

Name	Type	Identifier	Description	Constraints
Input				
Slope	Grid (input)	SLOPE		
Catchment Area	Grid (input)	AREA		
Output				
LS Factor	Grid (output)	LS		
Options				
Area to Length Conversion	Choice	CONV	Derivation of slope lengths from catchment areas. These are rough approximations! Applies not to Desmet & Govers' method.	Available Choices: [0] no conversion (areas already given as specific catchment area) [1] 1 / cell size (specific catchment area) [2] square root (catchment length)
Method (I S)	Choice	METHOD		Available Choices:

SAGA GIS



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# RUSLE – LS factor

Workspace

- Reports - HTML
- Reports - PDF
- Shapes - Grid
- Shapes - Lines
- Shapes - Point Clouds
- Shapes - Point Clouds Viewer
- Shapes - Points
- Shapes - Polygons
- Shapes - Tools
- Shapes - Transects
- Simulation - Cellular Automata
- Simulation - Fire Spreading Analysis
- Simulation - Hydrology
- Simulation - Hydrology: IHACRES
- Simulation - Modelling the Human Impact
- TIN - Tools
- TIN - Visualisation
- Table - Calculus
- Table - Tools
- Terrain Analysis - Channels
- Terrain Analysis - Compound Analyses
- Terrain Analysis - Hydrology
  - Catchment Area (Flow Tracing)
  - Catchment Area (Mass-Flux Method)
  - Catchment Area (Parallel)
  - Catchment Area (Recursive)
  - Cell Balance
  - Downslope Area [Interactive]
  - Edge Contamination
  - Flow Depth [Interactive]
  - Flow Path Length
  - Flow Sinuosity [Interactive]
  - Flow Width and Specific Catchment A
  - Isochrones Constant Speed [Interacti
  - Isochrones Variable Speed [Interactiv
  - LS Factor**
  - Lake Flood
  - Lake Flood [Interactive]
  - SAGA Wetness Index
  - Slope Length
  - Stream Power Index
  - Topographic Wetness Index (TWI)
  - Upslope Area
  - Upslope Area [Interactive]
- Terrain Analysis - Lighting, Visibility
- Terrain Analysis - Morphometry
- Terrain Analysis - Preprocessing
- Terrain Analysis - Profiles

LS Factor

**Description**  
Calculation of slope length (LS) factor as used by the Universal Soil Loss Equation (USLE), based on slope and specific catchment area (SCA, as substitute for slope length).  
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In: Boehner, J., McCloy, K.R., Strobl, J.: 'SAGA – Analysis and Modelling Applications', Goettinger Geographische Abhandlungen, Vol.115, p.13-27

Desmet & Govers (1996):  
'A GIS Procedure for Automatically Calculating the USLE LS Factor on Topographically Complex Landscape Units'  
Journal of Soil and Water Conservation, 51(5):427-433

Kinnell, P.I.A. (2005):  
'Alternative Approaches for Determining the USLE-M Slope Length Factor for Grid Cells.'  
<http://soil.scijournals.org/cgi/content/full/69/3/674>

Moore, I.D., Grayson, R.B., Ladson, A.R. (1991):  
'Digital terrain modelling: a review of hydrological, geomorphological, and biological applications'  
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Wischmeier, W.H., Smith, D.D. (1978):  
'Predicting rainfall erosion losses – A guide to conservation planning'  
Agriculture Handbook No. 537: US Department of Agriculture, Washington DC.

**Parameters**

Name	Type	Identifier	Description	Constraints
Input				
Slope	Grid (input)	SLOPE		
Catchment Area	Grid (input)	AREA		
Output				
LS Factor	Grid (output)	LS		
Options				
Area to Length Conversion	Choice	CONV	Derivation of slope lengths from catchment areas. These are rough approximations! Applies not to Desmet & Govers' method.	Available Choices: [0] no conversion (areas already given as specific catchment area) [1] 1 / cell size (specific catchment area) [2] square root (catchment length)
Method (I S)	Choice	METHOD		Available Choices:

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## RUSLE – LS factor

- Table - Tools
- Terrain Analysis - Channels
- Terrain Analysis - Hydrology
  - Burn stream network in...
  - Catchment area (flow t...
  - Catchment area (mass...
  - Catchment area (parall...
  - Catchment area (recur...
  - Cell balance
  - Edge contamination
  - Fill Sinks
  - Fill sinks (wang & liu)
  - Fill sinks xxi (wang & liu)
  - Flat detection
  - Flow path length
  - Flow width and specific...
  - Lake flood
  - LS factor
  - Saga wetness index
  - Sink drainage route de...
  - Sink removal
  - Slope length
  - Stream power index
  - Topographic wetness i...
  - Upslope Area
- Terrain Analysis - Lighting
- Terrain Analysis - Morphometry
- Terrain Analysis - Profiles

**LS factor**

Parameters Log Help

Slope  
SAGA\_Slope [EPSG:2100]

Catchment Area  
Specific Catchment Area (SCA) [EPSG:2100]

Area to Length Conversion  
[0] no conversion (areas already given as specific catchment area)

Method (LS)  
[0] Moore et al. 1991

Rill/Interrill Erosivity  
0.000000

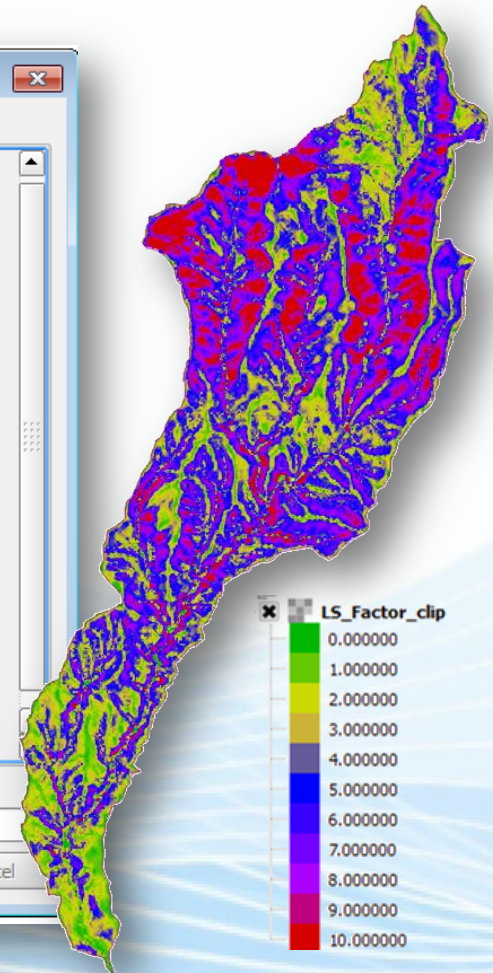
Stability  
[0] stable

LS Factor  
[Save to temporary file]

☒ Open output file after running algorithm

0%

Run Close Cancel

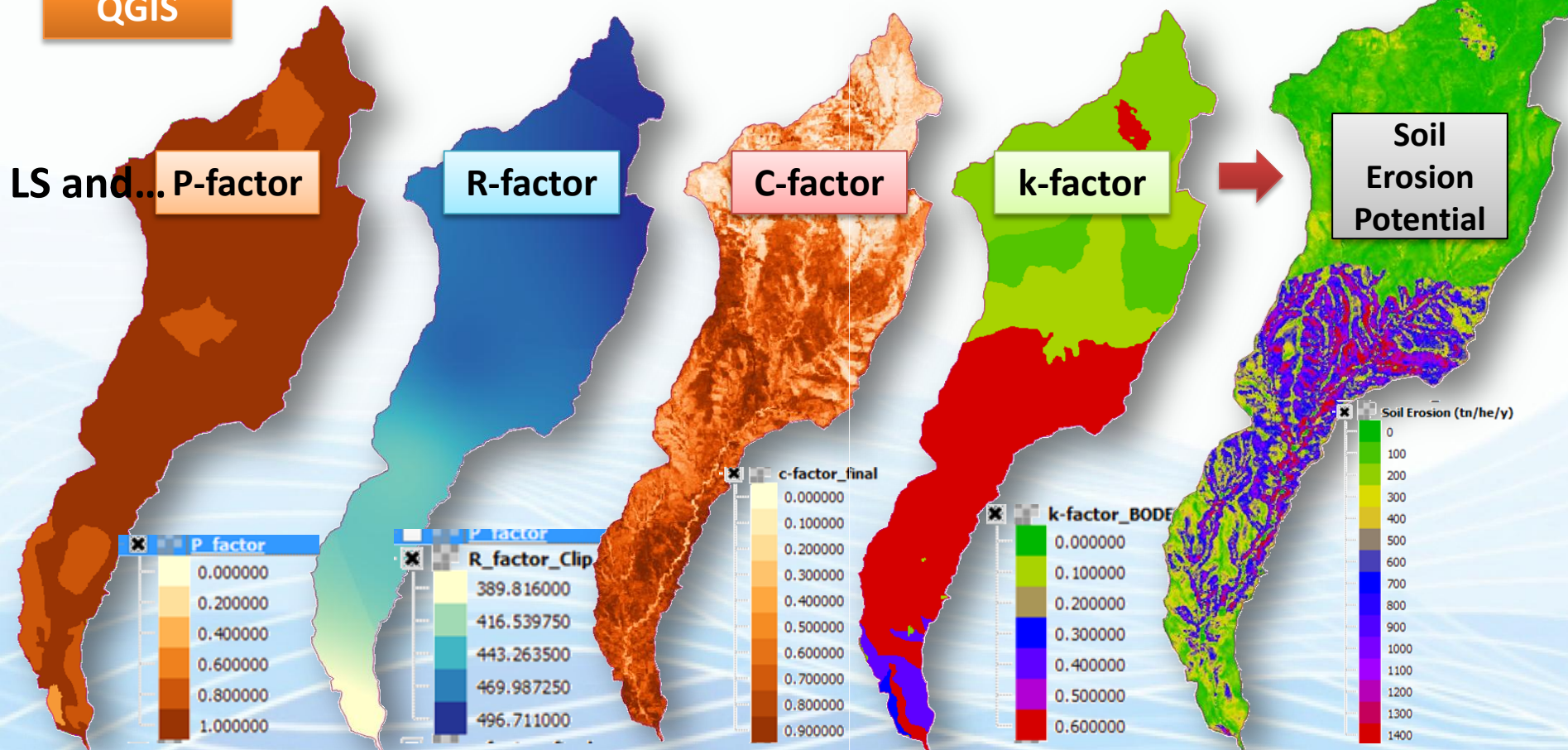


QGIS

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# RUSLE – Soil Erosion Potential...

QGIS



...to support decisions regarding RETENTION measures





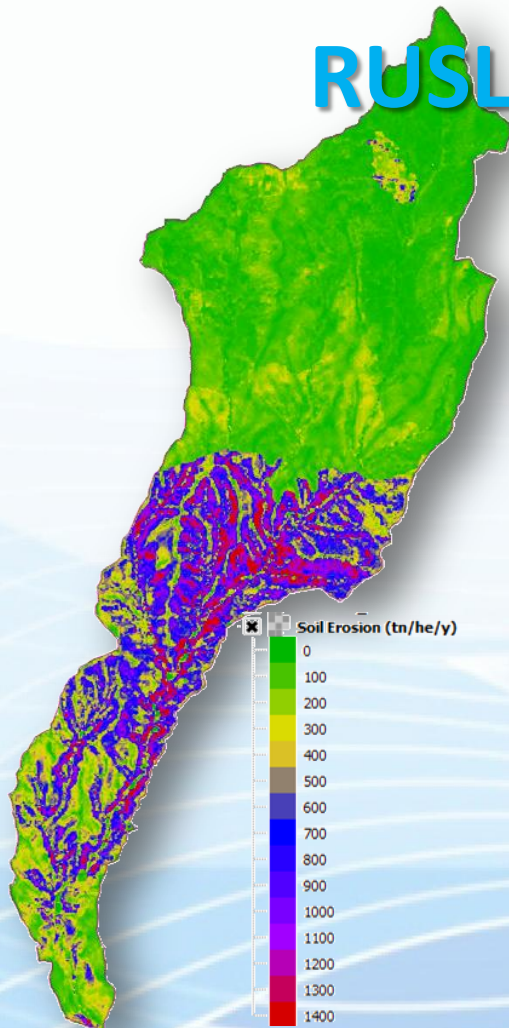
Project funded by the  
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## RUSLE – Soil Erosion Potential...

...Can be used to plan **Sediment Retention structures (assess location) upstream** in order to effectively **control sediment transport** towards the flood prone area.



Soil Erosion Potential



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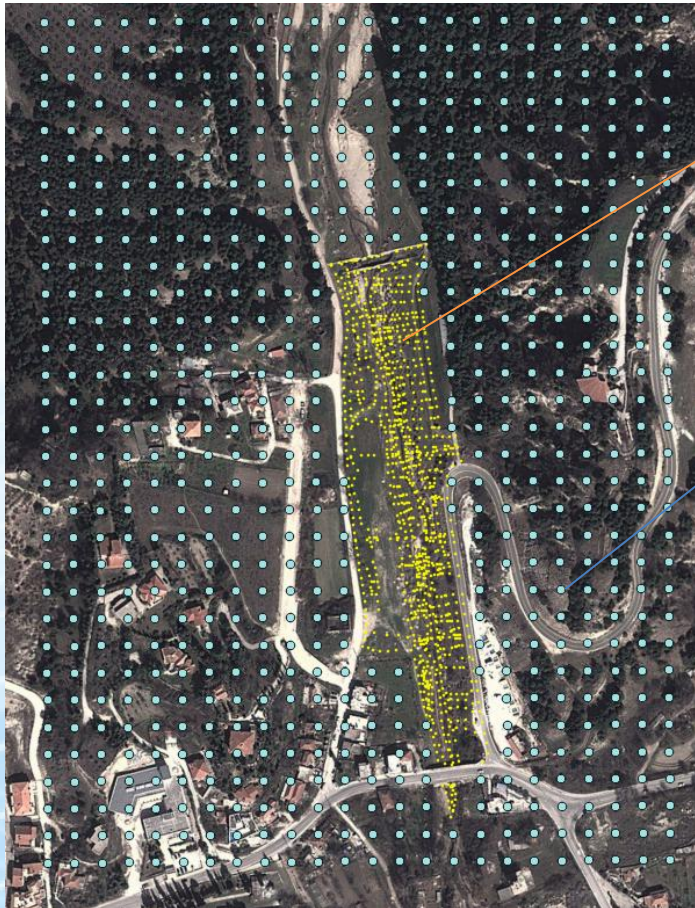
# From Regional to Local Scale





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# Detailed Topographic Data



Measured in situ with GPS  
(differential GPS & RTK)

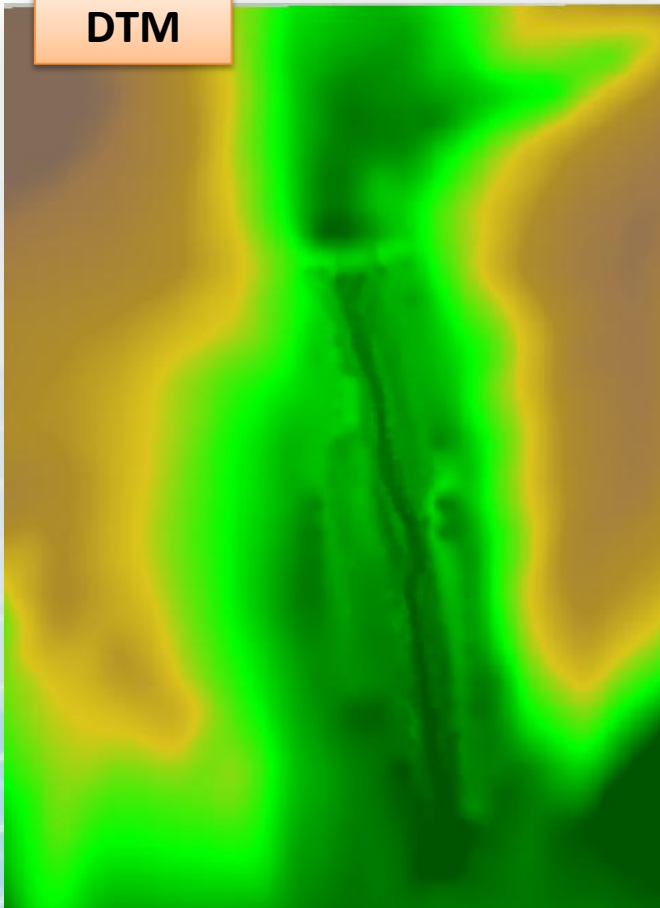
Lattice /25m  
or Produced by topographic maps  
1:2.000 - 1 : 5.000



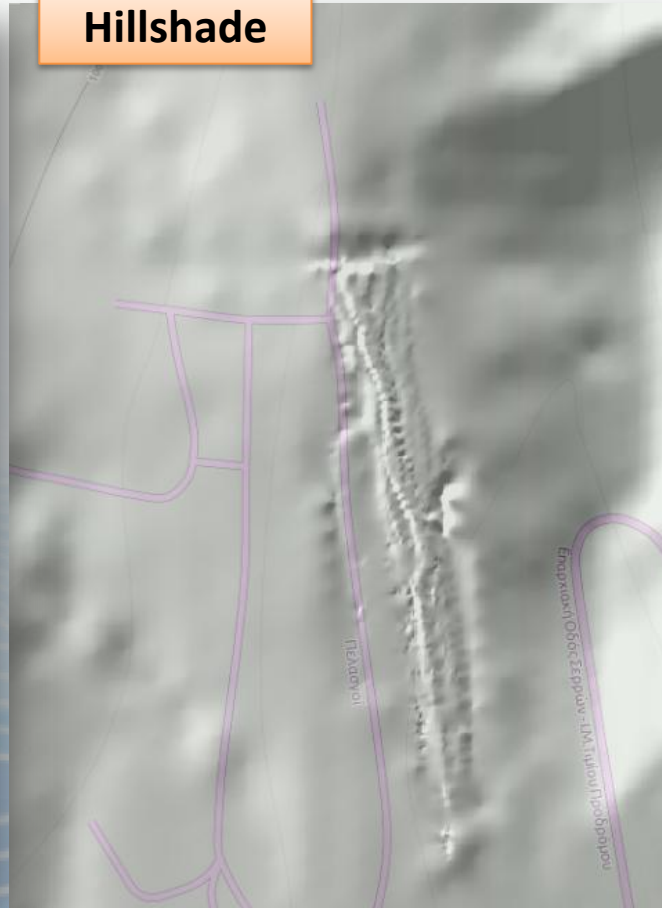
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# DTM & Products – additional parameters

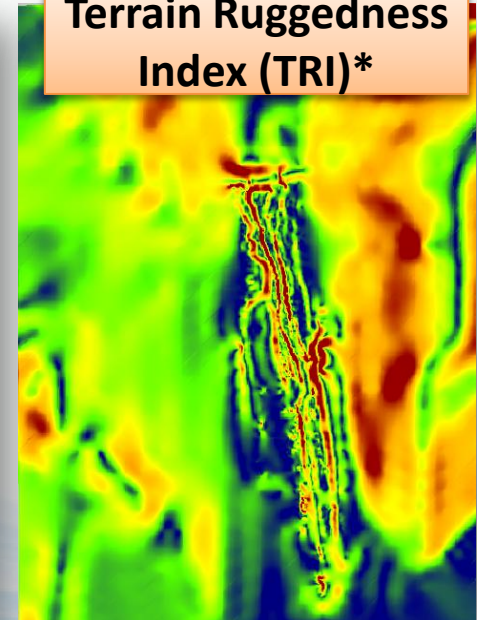
DTM



Hillshade



Terrain Ruggedness  
Index (TRI)\*



\*Riley, S.J., De Gloria,  
S.D., Elliot, R. (1999)

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# Cross Sections

## Requirements

1. DTM
2. STREAM (digitized towards downstream)

QGIS

The screenshot shows the 'Cross profiles' dialog box in QGIS. The background is a map with a blue stream line. The dialog box has several fields and a checkbox, each with an orange callout box pointing to it:

- DEM**: Points to the 'Grid\_All\_Points [EPSG:2100]' dropdown.
- Stream**: Points to the 'main\_stream [EPSG:2100]' dropdown.
- Distance between profiles**: Points to the 'Profile Distance' field, which contains '25.000000'.
- Profile Length**: Points to the 'Profile Length' field, which contains '50.000000'.
- Points per Profile**: Points to the 'Profile Samples' field, which contains '10|000000'.
- File Name of Cross Sections**: Points to the 'Cross Profiles' section, specifically to the 'Open output file after running algorithm' checkbox.

At the bottom of the dialog box, there is a progress bar showing '0%' and buttons for 'Run', 'Close', and 'Cancel'.

- Processing Toolbox [5 geospatial...
- Processing Toolbox (Image analysis) [8...
- QGIS geospatial algorithms [68 geospatial...
- SAGA [243 geospatial algorithms]
- Geostatistics
- Grid - Analysis
- Grid - Calculus
- Grid - Filter
- Grid - Gridding
- Grid - Spline
- Grid - Tools
- Grid - Visualization
- Imagery - Classification
- Imagery - RGA
- Imagery - Segmentation
- Imagery - Tools
- Kriging
- Recreations
- Shapes - Grid
- Shapes - Lines
- Shapes - Points
- Shapes - Polygons
- Shapes - Tools
- Shapes - Transect
- Simulation - Fire Spreading
- Simulation - Hydrology
- Table - Calculus
- Table - Tools
- Terrain Analysis - Channels
- Terrain Analysis - Hydrology
- Terrain Analysis - Lighting
- Terrain Analysis - Morphometry
- Cross profiles**
- Profile from points table
- Profiles from lines
- Vigra
- Scripts [14 geospatial algorithms]
- Tools for LIDAR data [42 geospatial algorithms]



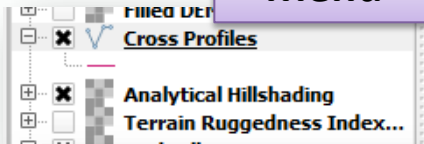
Project funded by the  
EUROPEAN UNION



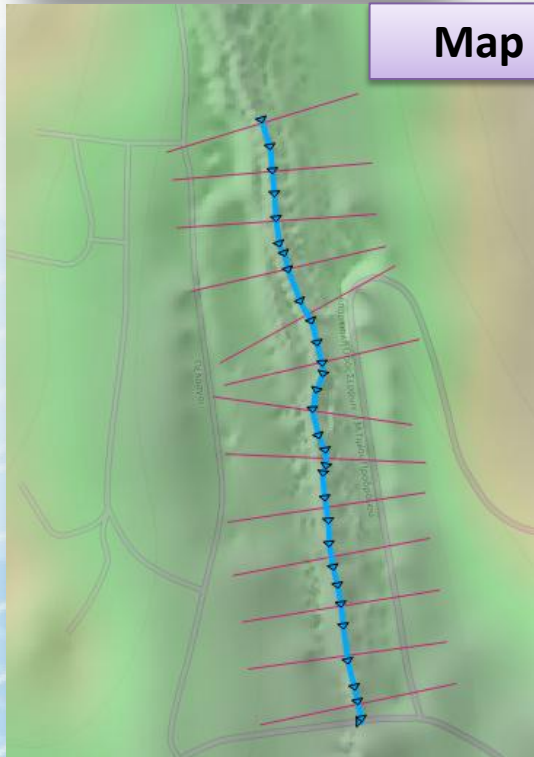
Common borders. Common solutions.

# Cross Sections

Menu



Map



Attribute Table (elevation per point)

table - Cross Profiles :: Features total: 13, filtered: 13, selected: 0

	LINE	PART	X000	X001	X002	X003	X004	X005	X006	
1	0	0	81.31216345	81.01318737	80.77740383	81.94197267	77.05189802	76.69844410	77.05443992	76
2	0	0	80.36807859	80.53721828	81.22395998	81.06987561	77.57384116	76.87042625	76.97116680	76
3	0	0	80.09556574	79.41675102	77.92777418	79.48167429	75.89942276	74.94321184	76.79975725	7
4	0	0	76.66154973	77.76394551	79.05340228	78.59009320	76.49035852	74.47164445	76.77079476	76
5	0	0	77.80336311	77.37470877	78.16067886	75.46817292	76.80625927	74.02599430	80.54654084	76
6	0	0	77.34242100	76.73347127	76.66835280	74.92638915	74.61941307	74.38077634	80.26241746	7
7	0	0	77.80927850	76.68323782	76.14639791	76.07710368	75.01390560	74.42291312	75.13211237	76
8	0	0	77.23749681	75.90792673	75.72605607	76.68124969	73.87090896	74.31871114	75.77795388	76
9	0	0	76.55099047	76.18423905	75.55665144	75.24518147	74.32255786	73.49378710	74.02076655	7
10	0	0	73.85383254	73.31347786	73.62798108	74.90021990	73.46479715	72.95154047	73.71524203	76
11	0	0	74.68907417	74.15059204	74.05358555	74.13774337	73.45784859	73.19855870	73.83427092	76
12	0	0	75.14858686	74.18871763	72.67972298	72.79477218	72.78129420	72.28222858	74.62984865	76
13	0	0	74.83953867	74.12967483	72.99763645	72.37374664	72.17354573	72.12532994	75.62717616	76



Common borders. Common solutions.

# Cross Sections to ...HEC-RAS

Attribute Table (elevation per point)

Attribute table - Cross Profiles :: Features total: 13, filtered: 13, selected: 0

	ID	LINE	PART	X000	X001	X002	X003	X004	X005	X006	
0	1	0	0	81.31216345	81.01318737	80.77740383	81.94197267	77.05189802	76.69844410	77.05443992	76
1	2	0	0	80.36807859	80.53721828	81.22395998	81.06987561	77.57384116	76.87042625	76.97116680	76
2	3	0	0	80.09556574	79.41675102	77.92777418	79.48167429	75.89942276	74.94321184	76.79975725	76
3	4	0	0	76.66154973	77.76394551	79.05340228	78.59009320	76.49035852	74.47164445	76.77079476	76
4	5	0	0	77.80336311	77.37470877	78.16067886	75.46817292	76.80625927	74.02599430	80.54654084	75
5	6	0	0	77.34242100	76.73347127	76.66835280	74.92638915	74.61941307	74.38077634	80.26241746	76
6	7	0	0	77.80927850	76.68323782	76.14639791	76.07710368	75.01390560	74.42291312	75.13211237	76
7	8	0	0	77.23749681	75.90792673	75.72605607	76.68124969	73.87090896	74.31871114	75.77795388	76
8	9	0	0	76.55099047	76.18423905	75.55665144	75.24518147	74.32255786	73.49378710	74.02076655	76
9	10	0	0	73.85383254	73.31347786	73.62798108	74.90021990	73.46479715	72.95154047	73.71524203	76
10	11	0	0	74.68907417	74.15059204	74.05358555	74.13774337	73.45784859	73.19855870	73.83427092	76
11	12	0	0	75.14858686	74.18871763	72.67972298	72.79477218	72.78129420	72.28222858	74.62984865	75
12	13	0	0	74.83953867	74.12967483	72.99763645	72.37374664	72.17354573	72.12532994	75.62717616	75

Show All Features

...

and we copy those data and paste them into HEC-RAS cross section creation module

Common borders. Common solutions.

SciNetNatHaz Project Progress Meeting - 23-26 Oct 2014, Burgas, Bulgaria

**Thank**  
Using Hydrodynamic models  
and Open Source Software to  
locate Flood prone areas  
**you!**



Konstantinos Papatheodorou  
Helena Tzanou

TEI of Kentriki Makedonia, LP/ENPI  
Beneficiary