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SciNetNatHaz Project Workshop - March 13-14, 2014, Istanbul, Turkey

# Flash Flood Disaster Prevention using Morphometric models and Open Source Software


## A pilot Implementation

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# Contents

- A Brief Overview of the flash flood problem
- Some comments on Selection of Methodologies
- Implementation (Methodologies used to locate flood prone areas)
- Results

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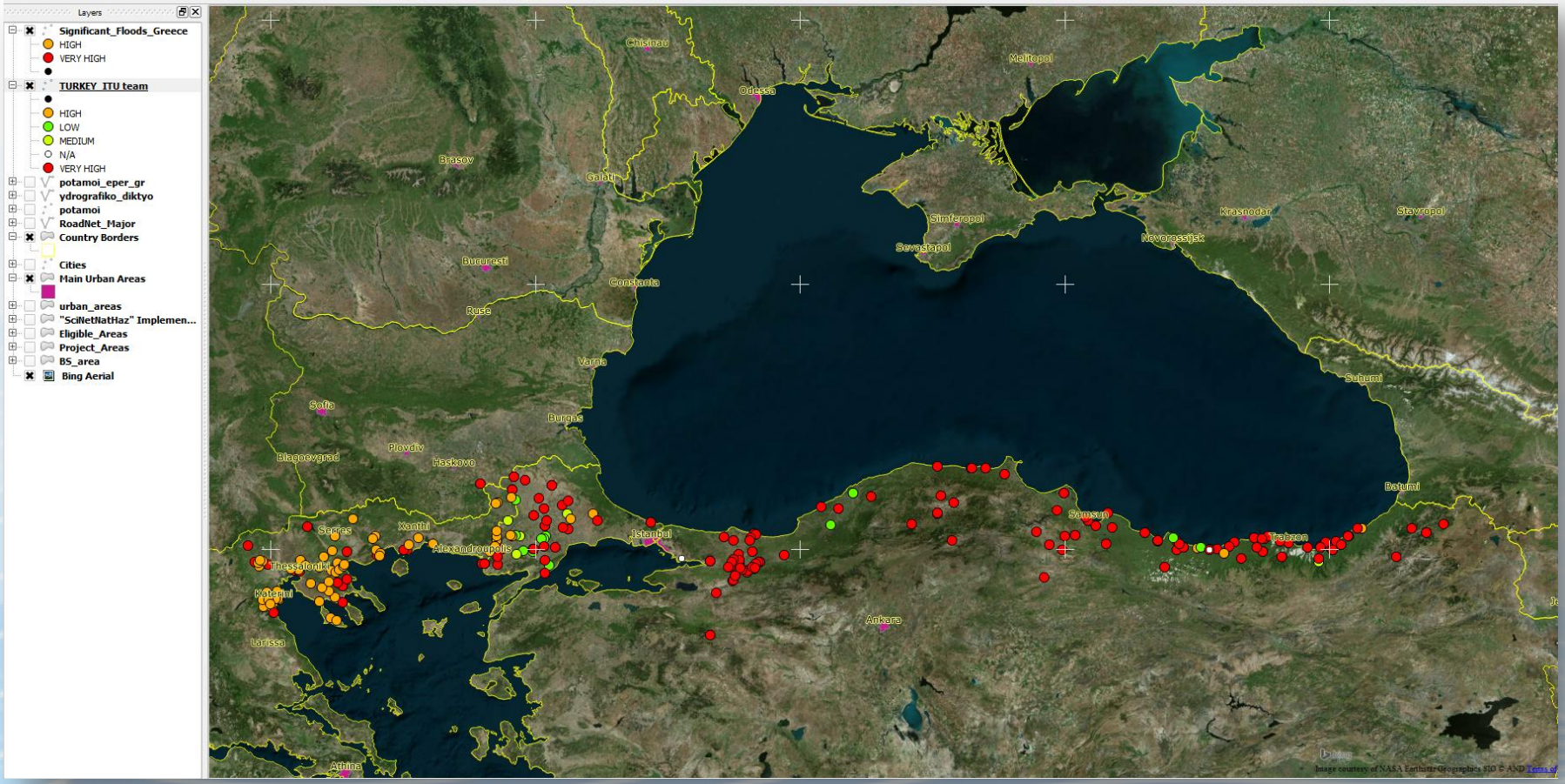
# The problem of flash floods



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# Implementation of the "Flood" Directive- Timetable

| Issue | Deadline | Reference |
|---|---|---|
| Entry into force | 26.11.2007 | OJ L 288, 6.11.2007 Art 18 |
| Transposition | 26.11.2009 | Art 17 |
| Reporting format Preliminary Flood Risk Assessment | 22.12.2009 | Art 11 |
| Administrative arrangements to be in place and to be notified to the Commission | 26.5.2010 | Art 3 |
| Cut-off date transitional measure (availability of existing tools) | 22.12.2010 | Art 13 |
| Preliminary flood risk assessment | 22.12.2011 | Art 4 & 5 |

*http://ec.europa.eu/environment/water/flood_risk/implem.htm*

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| Issue | Deadline | Reference |
|---|---|---|
| Public participation process starts (publication of mechanism and timetable for consultation) | 22.12.2012 * | Art 9.3 & 10 |
| Flood hazard and risk maps | 22.12.2013 ** | Art 6 |
| Flood risk management plans | 22.12.2015 *** | Art 7 |
| 2nd Preliminary Flood Risk Assessment, specific requirement on climate change<br>Commission's first implementation report due. | 22.12.2018 | Art 14.1 & 4 |
| 2nd Flood hazard and risk maps | 22.12.2019 | Art 14.2 |
| End of 1st flood risk management cycle<br>2nd Flood Risk Management Plans, specific requirement on climate change.<br>3rd Water Framework Directive River Basin Management Plans. | 22.12.2021 | Art 14.3 & 4 |

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# A bit of consideration

## Disaster Prevention

**Applied Research**
(implementation) on a LOCAL scale

**Risk Assessment**

**Hazard Identification**

"Local" means "site specific"… means the use of Hydraulic Models to assess flood specific parameters …means …."preventive" measures can be proposed

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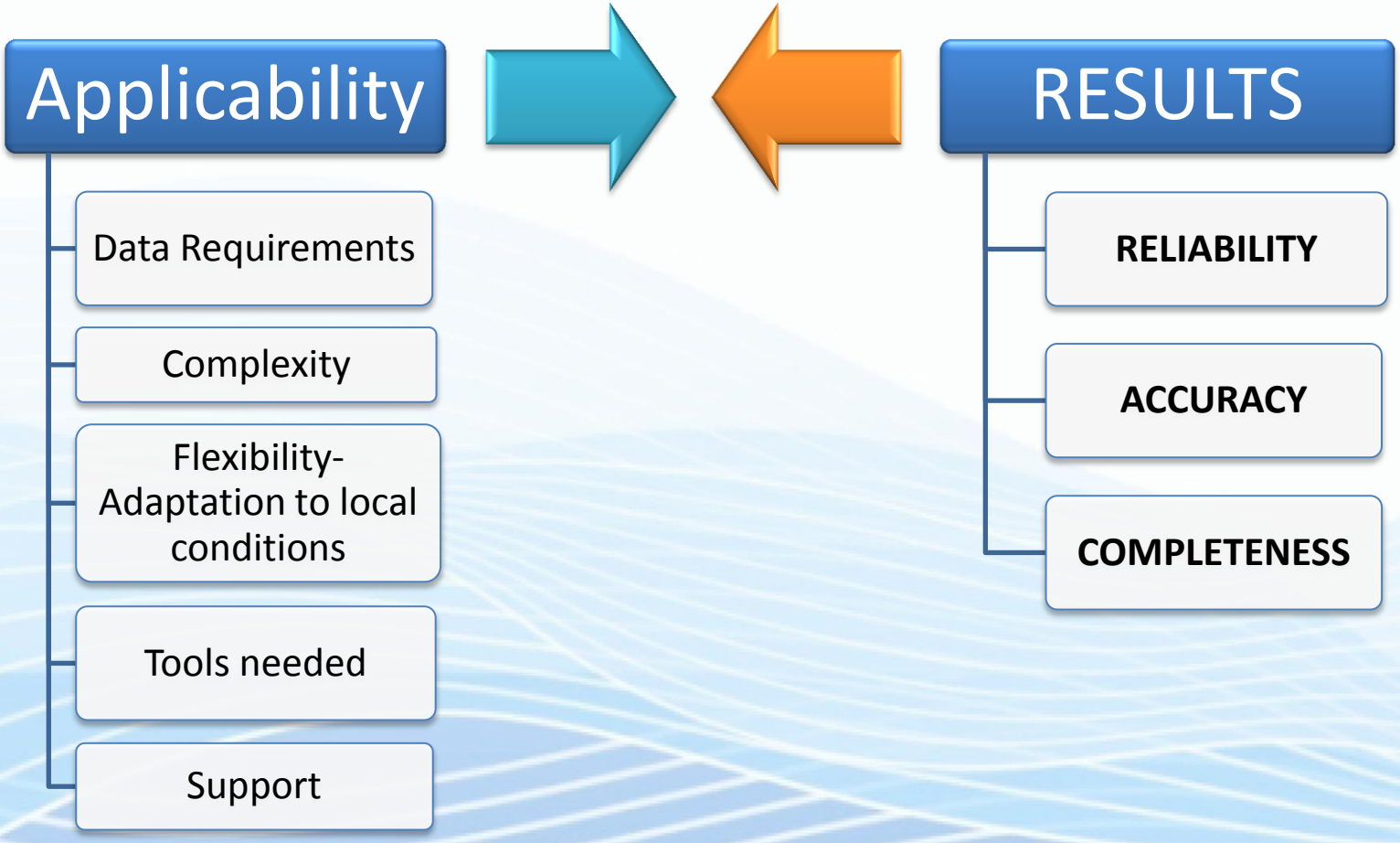
# Criteria to select a methodology to be widely used



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# From a Stream Basin to … flooding Hot spots!

The basic idea:

1. Use already…. used methodologies (no need to prove anything in terms of reliability and accuracy)
2. Use “flexible methodologies” which can be adapted to various conditions (in terms of locality-different parts of the entire Black Sea area)
3. Locate Flash Flood “Hot Spots” to assess the assets at RISK
4. Complete with assessing the source of sediments in order to prevent them from filling the “area at risk”

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# From a Stream Basin to … flooding Hot spots!

5. Use Hydraulic Model on a local (or “site specific”) scale to assess all necessary flooding parameters (area and depth of inundation, overflow level etc) in order to design preventive measures.
6. Apply those measures and channel the flood downstream (“assess and apply” on a “repetitive” mode, until flood is channeled to an area with minimal or even positive consequences)

# Methodologies considered - TWI

- The **Topographic Wetness Index** was proposed to predict quick response flow by using morphometric parameters [1,2,3,4,5] but has been used since then to delineate flood prone areas [6,7,8,9,10].
- The SAGA Wetness Index (Bohner et.al, 2002) is similar to TWI, but it is considered to predict soil moisture for areas, in a more realistic and higher potential than the TWI.

[Boehner, J., Koethe, R. Conrad, O., Gross, J., Ringeler, A., Selige, T.: 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, (2002)]

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# Topographic Wetness Index - TWI

- The simplicity of the model comes from the use of the topographic index, **k = a /** tan **b**,

  where **a** is the area draining through a point from upslope and **tan b** is the local slope angle.
- It was used as an index of hydrological similarity.
- All points with the same value of the index are assumed to respond in a hydrologically similar way.
- **High index values** indicated **areas which tend to saturate first**.

# TWI – selected References

1. Beven, K. and Kirkby, M. : A physical variable contributing area model of catchment hydology, Hydrolog. Sci. Bull., 24(1), 43– 69, (1979).
2. Beven K.: TOPMODEL: A Critique. Hydrological processes, Vol.11, pp. 1069-185 (1997).
3. Moore, I. D., Burch, G. J., and Mackenzie, D. H.: 'Topographic effects on the distribution of surface soil water and the location of ephemeral gullies', *Trans. Am. Soc. Agr. Engrs.,* 31, 1098- 1107, (1988).
4. Kirkby, M. J. 1988. `Hillslope runoff processes and models', J. Hydrol., 100, 315±340.
5. Kirkby, M. J. 1997. `TOPMODEL: a personal view', Hydrol. Process., 11, 1087±1097.
6. Sørensen R., U. Zinko, and J. Seibert: On the calculation of the topographic wetness index: evaluation of different methods based on field observations. Hydrol. Earth Sys. Sci. Discuss., 2, 1807–1834, European Geosciences Union, (2005).
7. Versini P.-A., Gaume E., and Andrieu H.: Assessment of the susceptibility of roads to flooding based on geographical information – test in a flash flood prone area (the Gard region, France), Nat. Hazards Earth Syst. Sci., 10, 793–803, (2010).
8. Lu Dong: Evaluation of high quality topographic data for geomorphological and flood impact studies in upland area: North York Moors, UK. Durham E-Theses, Durham University, UK, (2006).
9. Manfreda S., Di Leo M., Sole A.: Detection of Flood-Prone Areas Using Digital Elevation Models. Journal of Hydrologic Engineering, 16 (10):781-790, 2011, (2011).
10. Qin C.Z., Zhu A.X., Pei T., Li B.L., Scholten T., Behrens T., Zhou C.H.: An approach to computing topographic wetness index based on maximum downslope gradient. Precision Agric, 12:32–43, DOI 10.1007/s11119-009-9152-y, (2011).
11. De Risi Rafael : “A Probabilistic bi-scale framework for Urban Flood Risk Assessment, PhD Thesis,Dept. of Structures for Engineering and Architecture, University of Naples Federico II, p.198, Naples, (2013).

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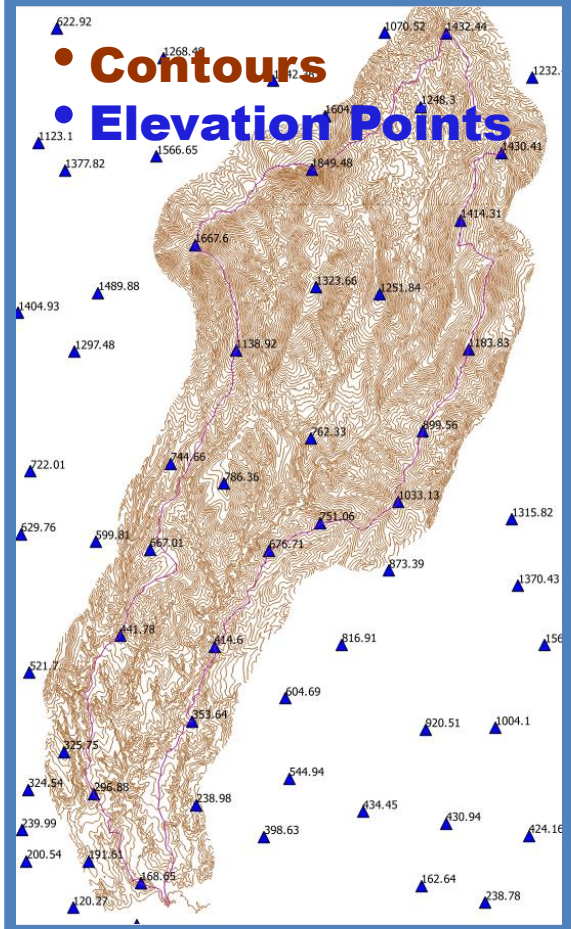
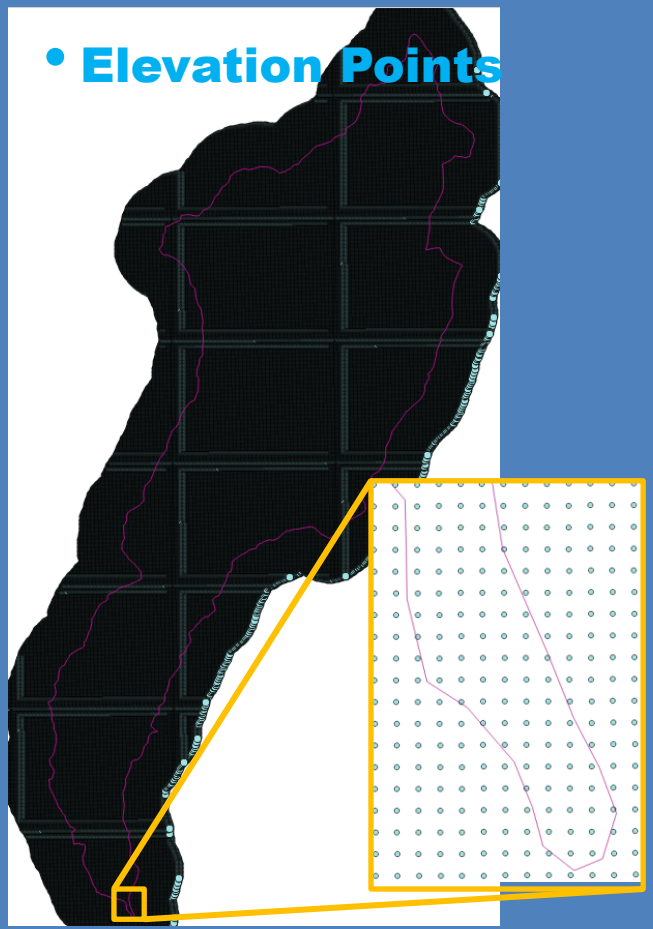
# Input

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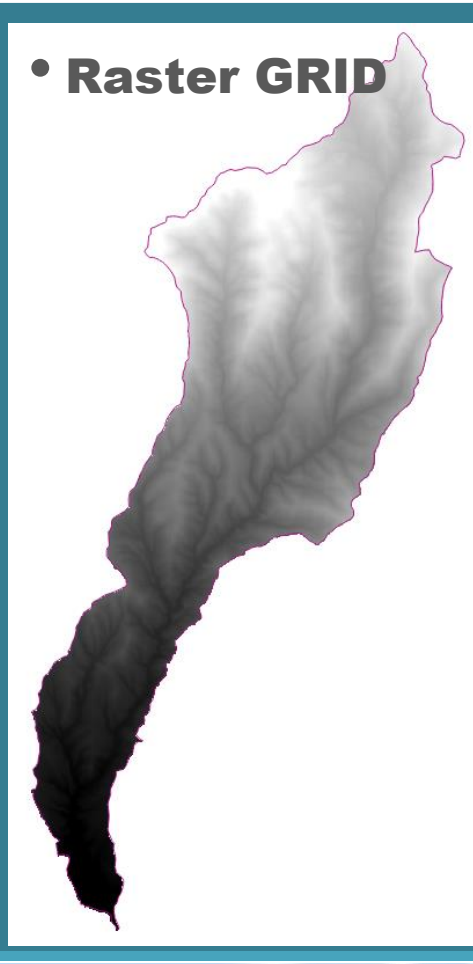

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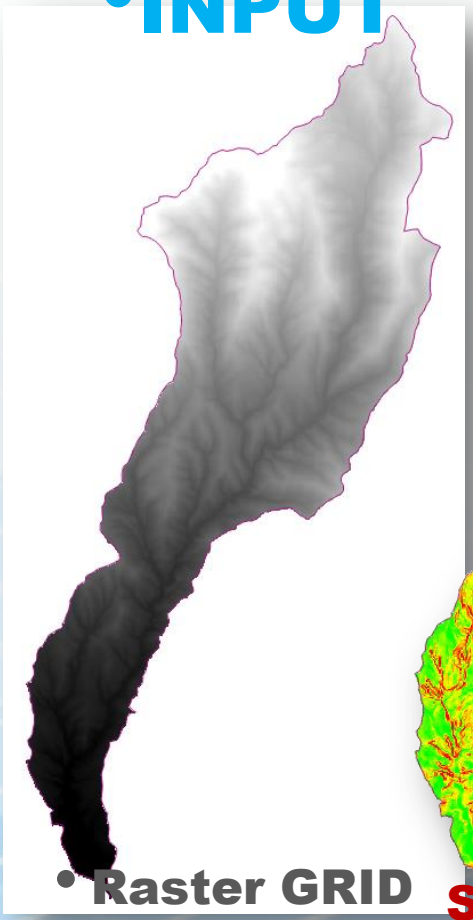
•INPUT

•PRODUCTS



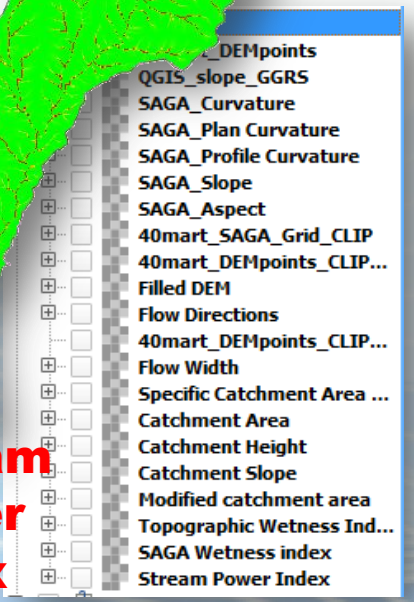
• Raster GRID

Slope & Derivatives

TWI

SAGA WI

Stream Power Index



# Methodologies considered – Stream Power

- The Stream Power Index[12,13,14,15] model was developed to assess the potential flow erosion at the given point of the ground surface. The model combines slope gradient and catchment area.
- Stream Power (SP) is a measure of the rate of stream water energy dissipation against the stream bed and banks, it can provide an estimation on the impetuosity of water during a potential flood event.
- Stream Power calculations have been used to assess the flash flood hazard in several cases. [16, 17, 18, 19, 20]

# Methodologies considered - TWI

- Stream Power Index-SPI is calculated as:

$$SPI = \rho * g * q$$

where ρ*g is the unit weight of water and q is the discharge per unit width.

- The index provides a measure of the time rate of energy expenditure and is being used since 1988 in assessing erosion, sediment transport as a measure of the flowing water erosive power.
- Parameter “q” is often assumed to be proportional to slope (β) and Specific Catchment Area (As) which is the upslope area per unit width of contour and is related to the runoff volume, so q=As*tanβ.

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# Stream Power Index – selected References


12. Rhoads, B.L.: Stream power terminology, Professional Geographer, 39(2), 189-195, (1987).
13. Moore, I.D., Grayson, R.B., Ladson, A.R.: 'Digital terrain modelling: a review of hydrogical, geomorphological, and biological applications Hydrological Processes, Vol.5, No.1 (1991).
14. Knighton, A.D: Downstream variation in stream power, Geomorphology, 29, 293-306, (1999).
15. Vikrant Jain, Nicholas Preston, Kirstie Fryirs, Gary Brierley: Comparative assessment of three approaches for deriving stream power plots along long profiles in the upper Hunter River catchment, New South Wales, Australia. Geomorphology 74, pp.297–317, ScienceDirect, Elsevier, (2006).
16. Sambaziotis, E. & Fountoulis, I.: Estimation of flash flood hazards in the Pidima-Arfara area (messinia, Greece), Based of the study of instantaneous unitary Hydrographs, Longitudinal Profiles and stream power. Proc. 11th International conference of Geological Society of Greece, Athens, 24-26 May 2007, Bull. Geol. Soc. Greece, XXXX/4, p. 1621-1633, (2007).
17. Fountoulis I., Mariolakos I., Andreadakis Emm., Karagiozi E., Sambaziotis E., & Kapourani E.: Flood Hazard And Risk In Laconia (Peloponnesus, Greece). Poster presented in the 3rd International Conference “AQUA 2008” on Water Science and Technology, Athens, (2008).
18. Diakakis M.: A method for flood hazard mapping based on basin morphometry: application in two catchments in Greece. Natural hazards 56: pp. 803-814, (2011).
19. Karagiozi, E., Fountoulis, I., Konstantinidis, A., Andreadakis, Emm., Ntouros, K.: Flood Hazard Assessment based on Geomorphological Analysis with GIS tools - The case of Laconia (Peloponnesus, Greece). Proceedings, Symposium GIS Ostrava 2011, 24-26 January (2011).
20. Barker Douglas M., Lawler Damian M., Donald W. Knight, David G. Morris, Helen N. Davies and Elizabeth J. Stewart: Longitudinal distributions of river flood power: the combined automated flood, elevation and stream power (CAFES) methodology. EARTH SURFACE PROCESSES AND LANDFORMS, John Wiley & Sons, Ltd. (2008)

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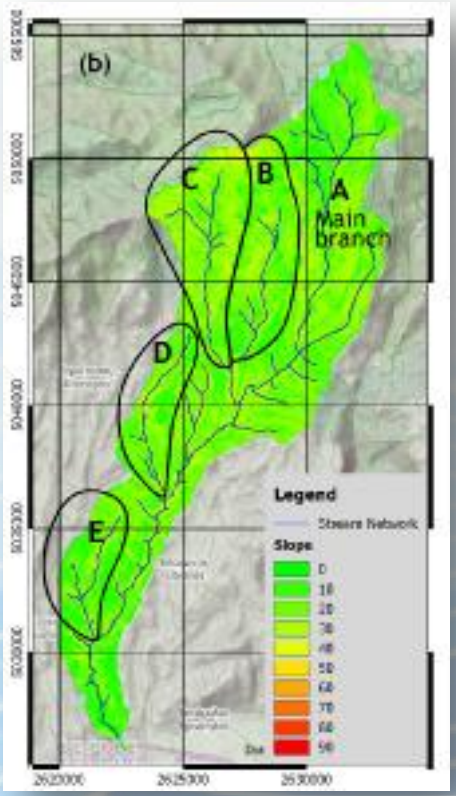
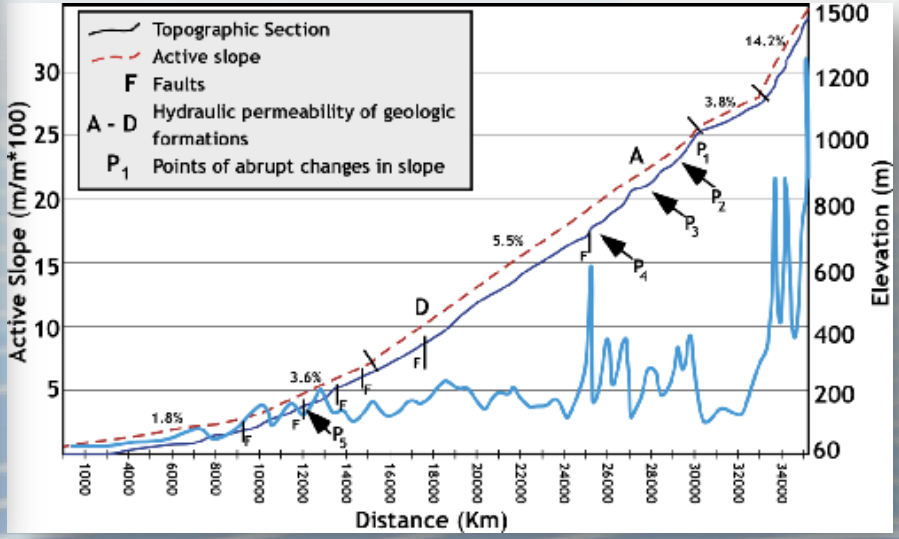
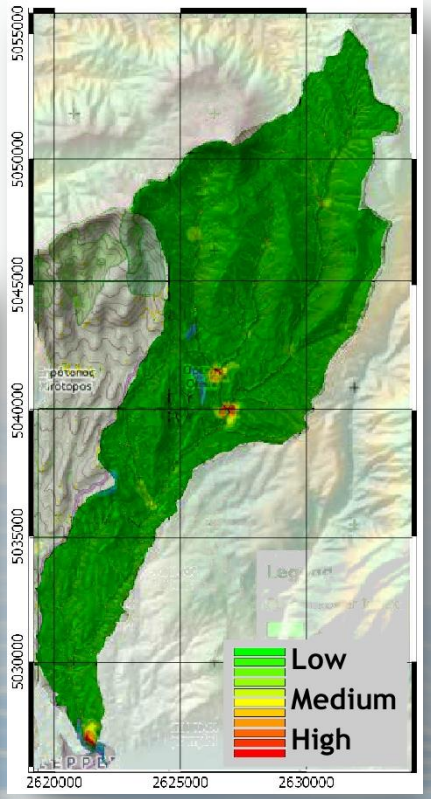
# Stream Power

**Stream basin is divided in sub-basins**




**Stream Power is calculated for the sub-basin contribution in the main stream**



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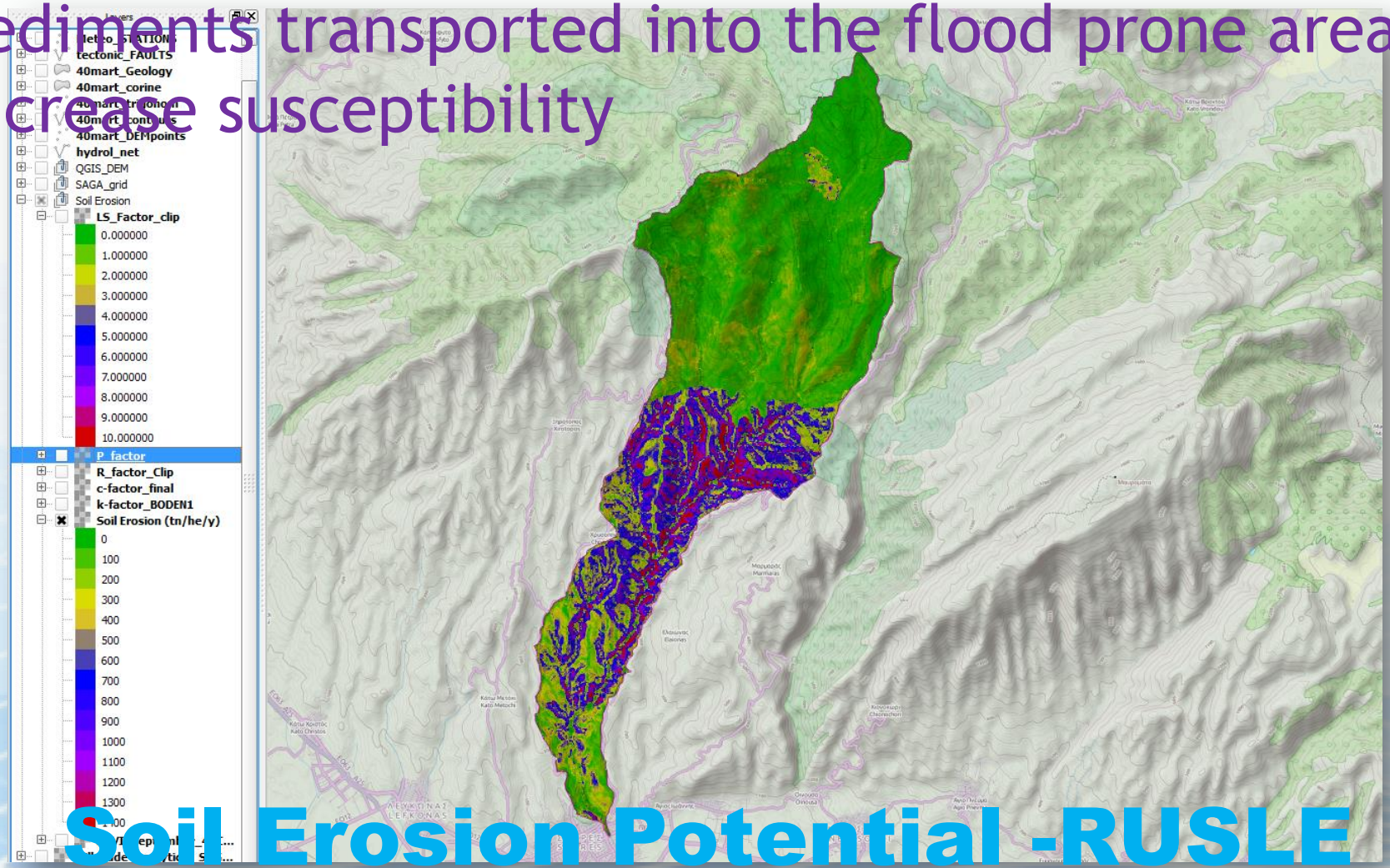
# Sediments transported into the flood prone areas increase susceptibility




## Soil Erosion Potential -RUSLE

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# TWI and SPI evaluation – Pilot implementation

- Topographic Wetness Index and Stream Power methodologies were evaluated in terms of their ability to locate flood prone areas.
- Test area was the northern part of the city of Serres, Greece where flash floods have previously occurred several times during the last 100 years.
- The area is covered by recreation installations and houses and **is at a higher level than the city center**, which means that flood water from this area flows into the city.

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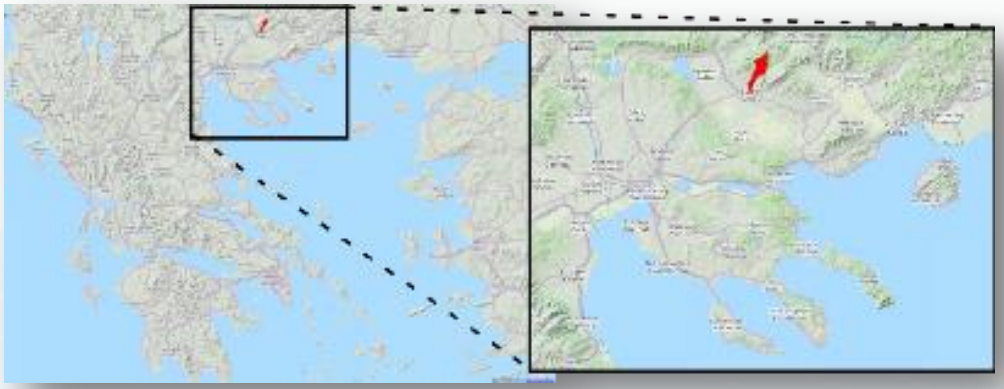
# Location



# Past Floods (impact)

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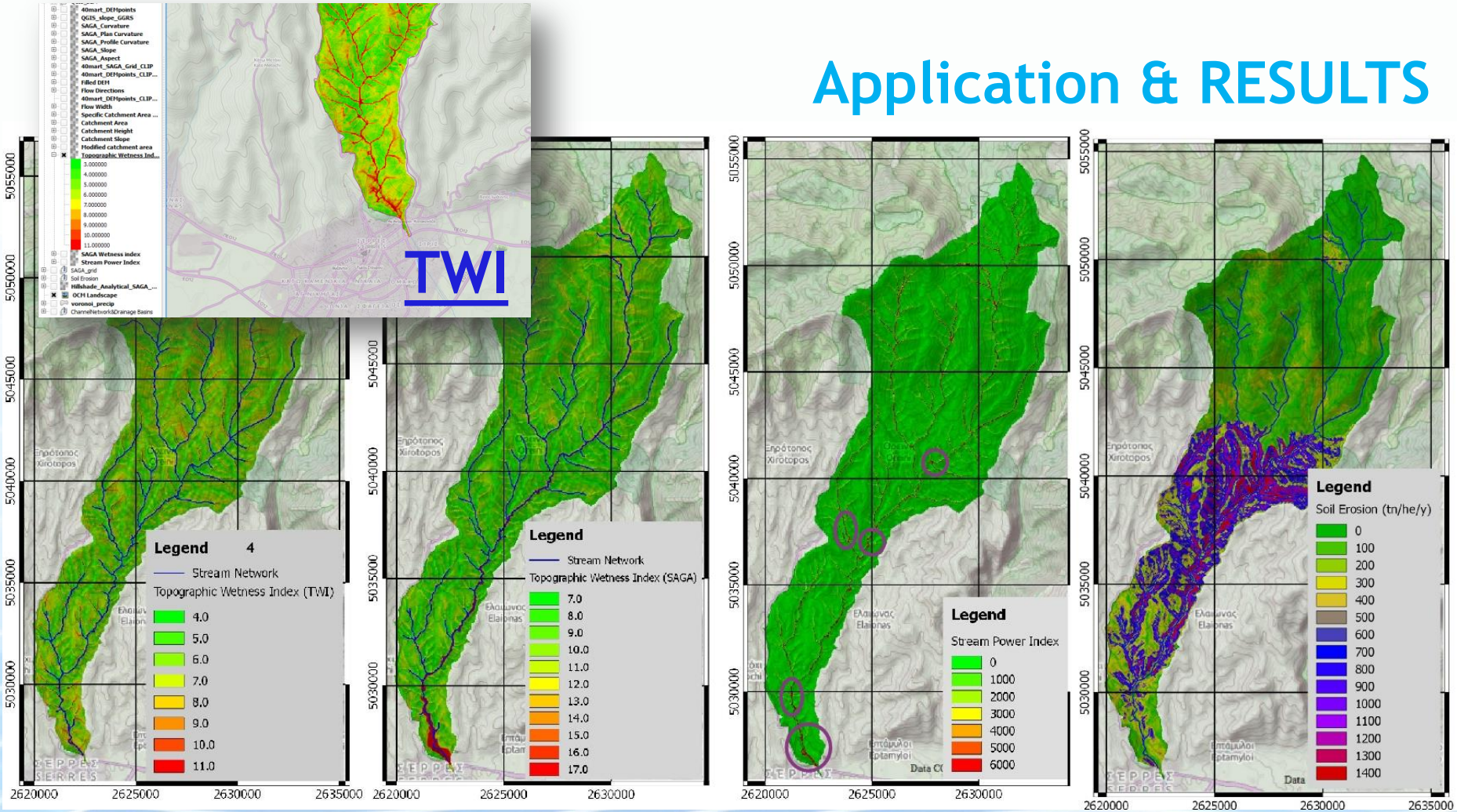
# Application & RESULTS



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# Conclusions

- Topographic Wetness Index and Stream Power methodologies were evaluated in terms of their ability to locate flood prone areas. Test area was the northern part of the city of Serres, Greece where flash floods have previously occurred several times during the last 100 years.
- Both methodologies used, indicated successfully as the flood prone area the same are where flooding repeatedly occurred.
- RUSLE methodology was additionally used in order to help decide about the location of sediment retention measures.
- The combined use of those methodologies on a regional scale for locating flood prone areas can assist in flash flood disaster prevention.

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# Thank You!


**Acknowledgments:**

The research was partially funded by the EU within the context of the Black Sea Basin Joint Operational Programme 2007-2013

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