swarm

ARISTOTLE UNIVERSITY OF THESSALONIKI

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Water resources management and GIS (part 2)

Spatial analyst techniques for the management of hydro-meteorological data. Application of GIS in EU's Water Framework and Flood Directives.

By

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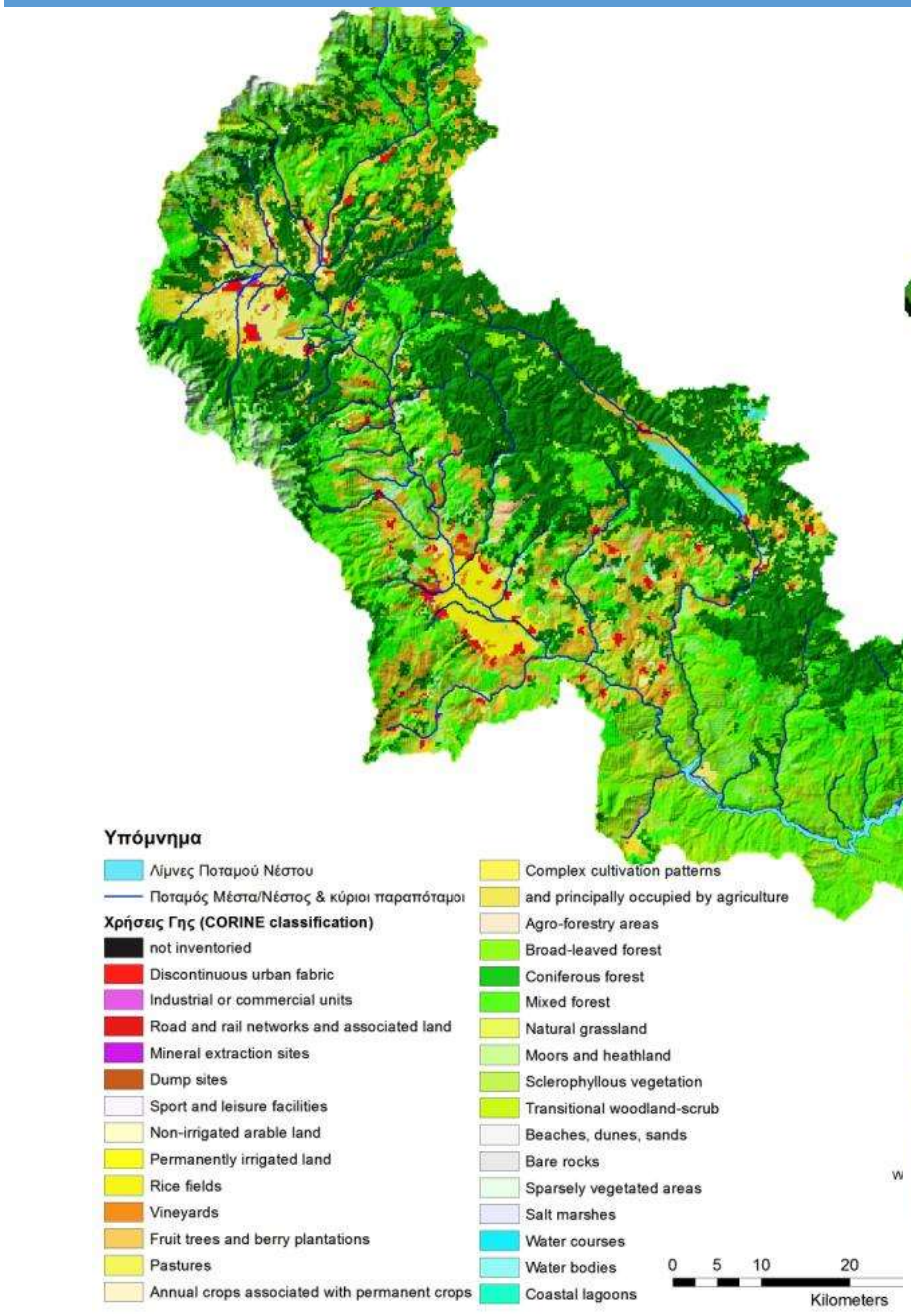
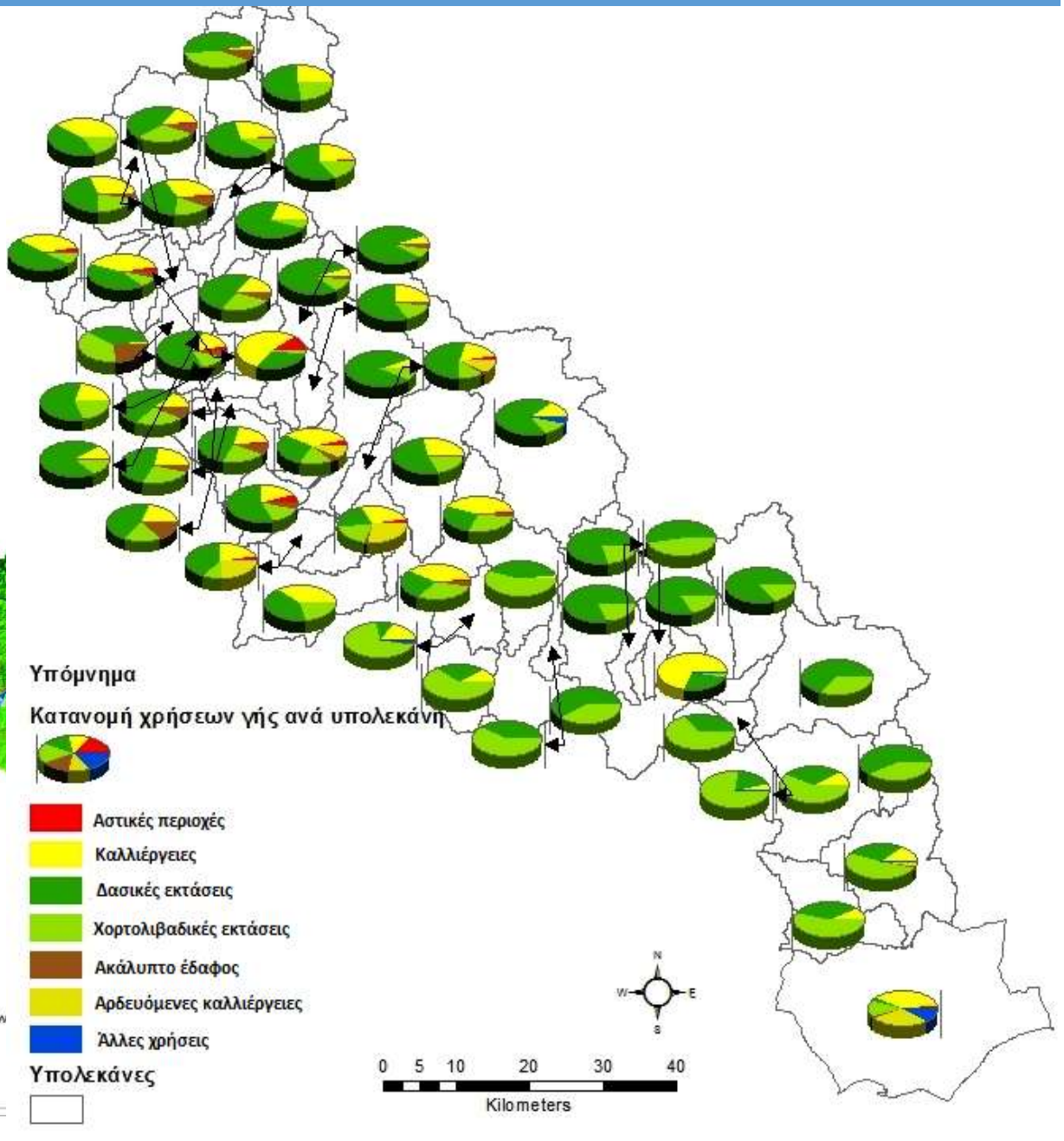
ArcGIS: Statistics (Analysis)

The Statistics toolset contains tools that perform standard statistical analysis (such as mean, minimum, maximum, and standard deviation) on attribute data as well as tools that calculate area, length, and count statistics for overlapping and neighboring features.

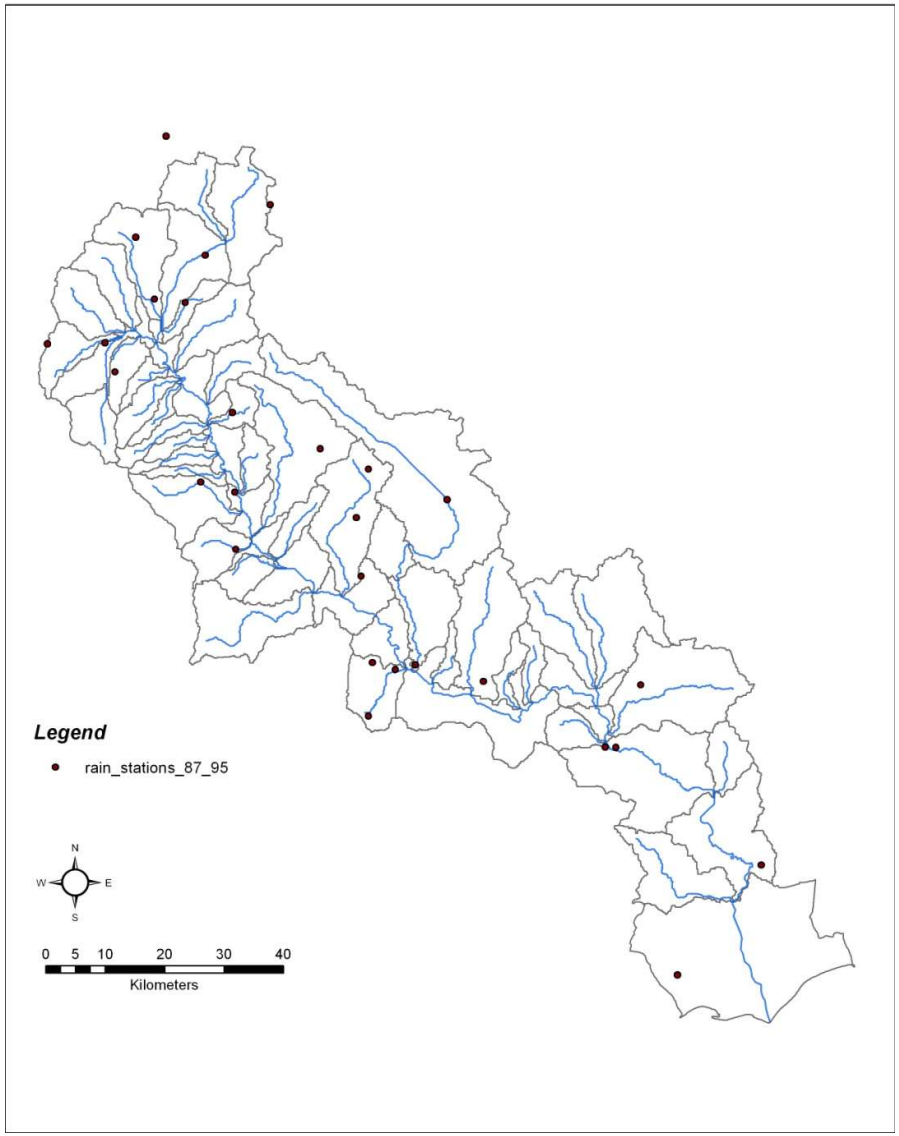
Tool	Description
Frequency	Reads a table and a set of fields and creates a new table containing unique field values and the number of occurrences of each unique field value.
Polygon Neighbors	Creates a table with statistics based on polygon contiguity (overlaps, coincident edges, or nodes).
Summary Statistics	Calculates summary statistics for field(s) in a table.
Tabulate Intersection	Computes the intersection between two feature classes and cross-tabulates the area, length, or count of the intersecting features.

ArcGIS: Statistics (Analysis)





ArcGIS: Distributing point information to space

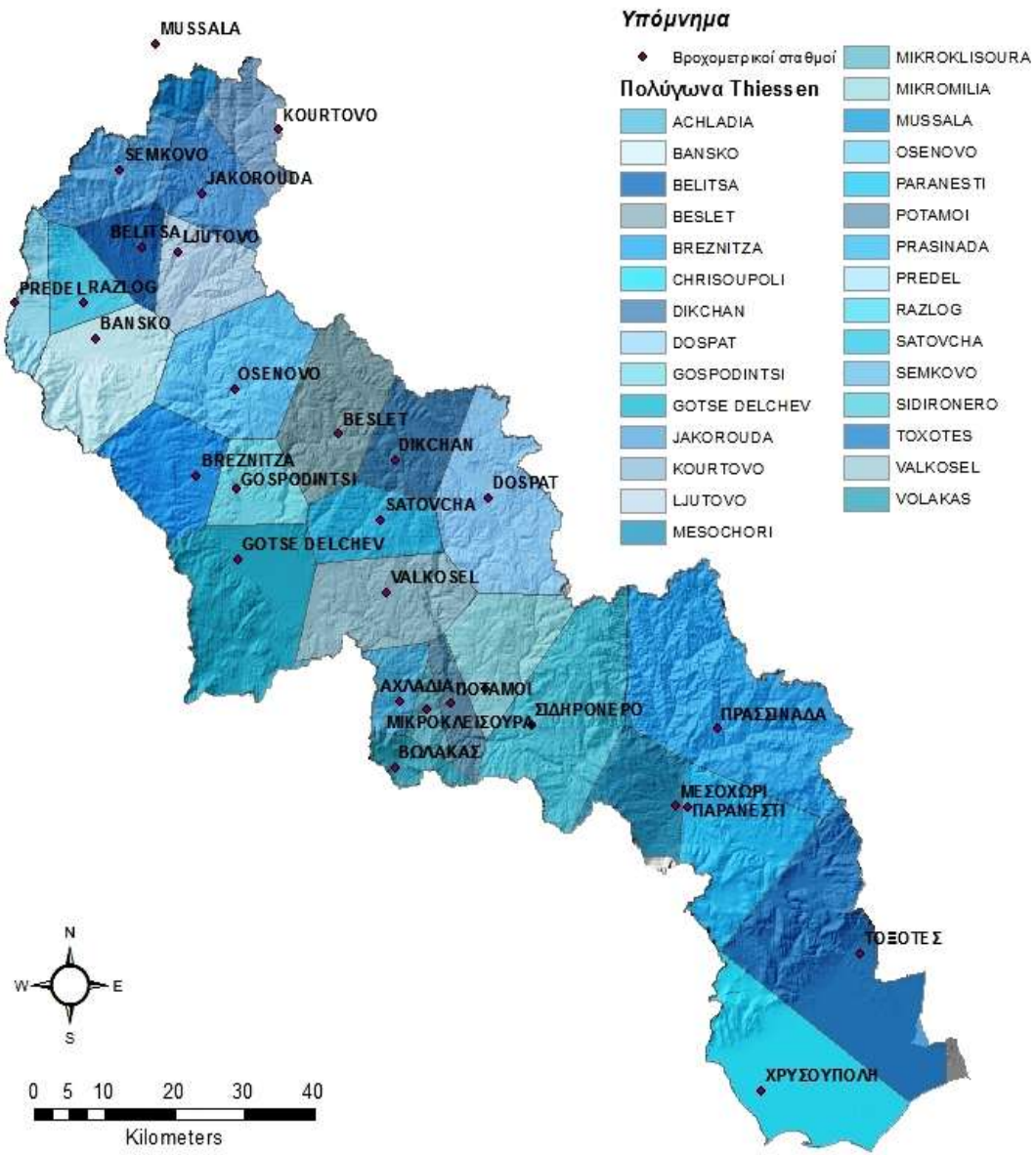


Thiessen polygons

Thiessen polygons can be used to apportion a point coverage into polygons known as Thiessen or Voronoi polygons.

- **Each polygon contains only one Input Features point.**
- **Each polygon has the unique property that any location within the polygon is closer to the polygon's point than to the point of any other polygon**

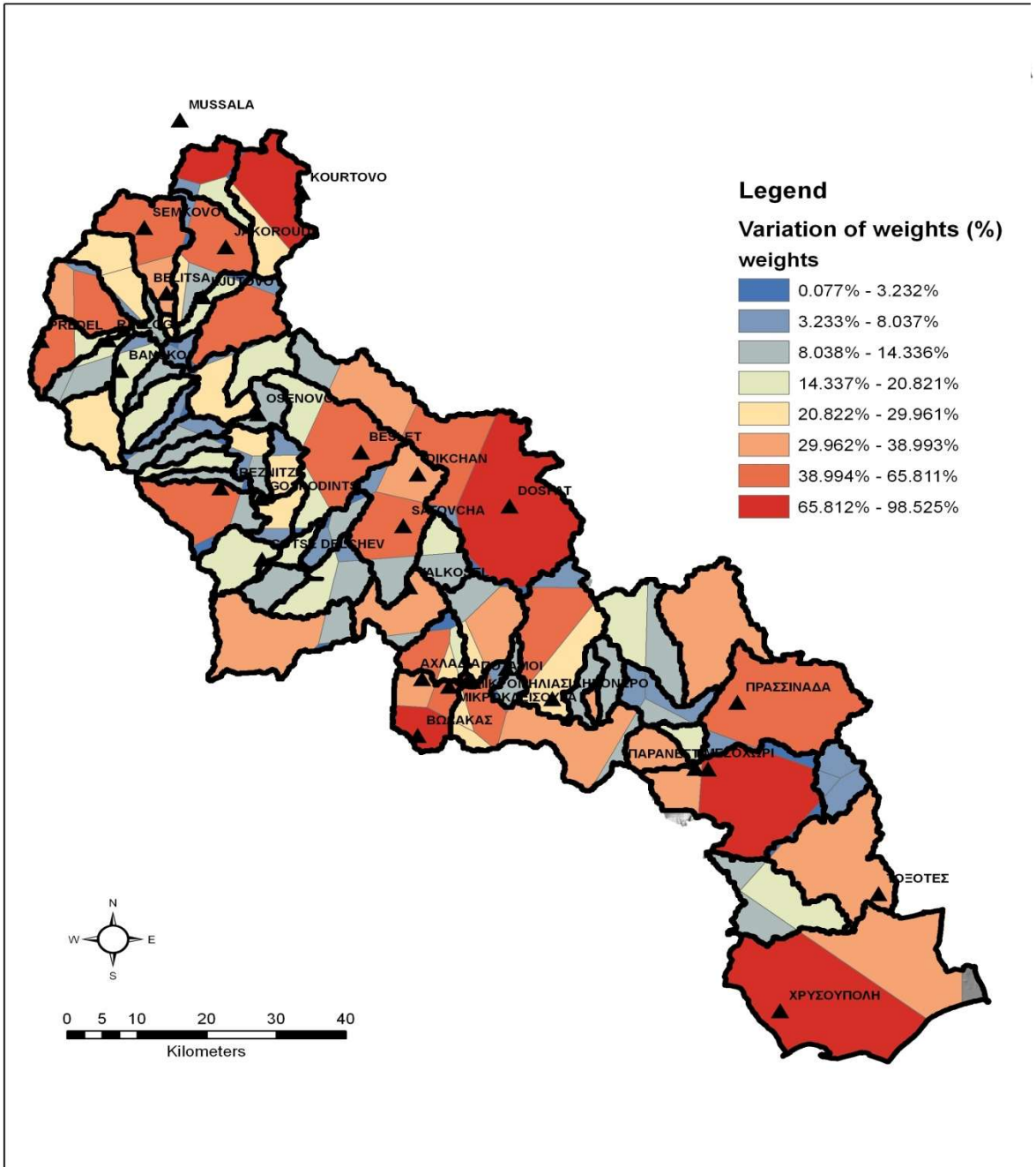
ArcGIS : Distributing point information to space



Thiessen polygons

In effect, the precipitation surface is assumed to be constant and equal to the gage value throughout the region.

ArcGIS : Computation of equivalent rainfall



Computation of equivalent rainfall per subbasin:

$$h_s = \sum_{i=1}^{k} w_i h_i$$

Where

K: the number of stations

h_i: point rainfall (mm)

w_i: the weight factor

ArcGIS : Spatial analyst, Interpolation

• In the mathematical field of numerical analysis, **interpolation** is a method of constructing new data points within the range of a discrete set of known data points.

• In GIS, interpolation is used to predict values for cells in a raster from a limited number of sample data points. It can be used to predict unknown values for any geographic point data, such as elevation, rainfall, chemical concentrations, noise levels, and so on.

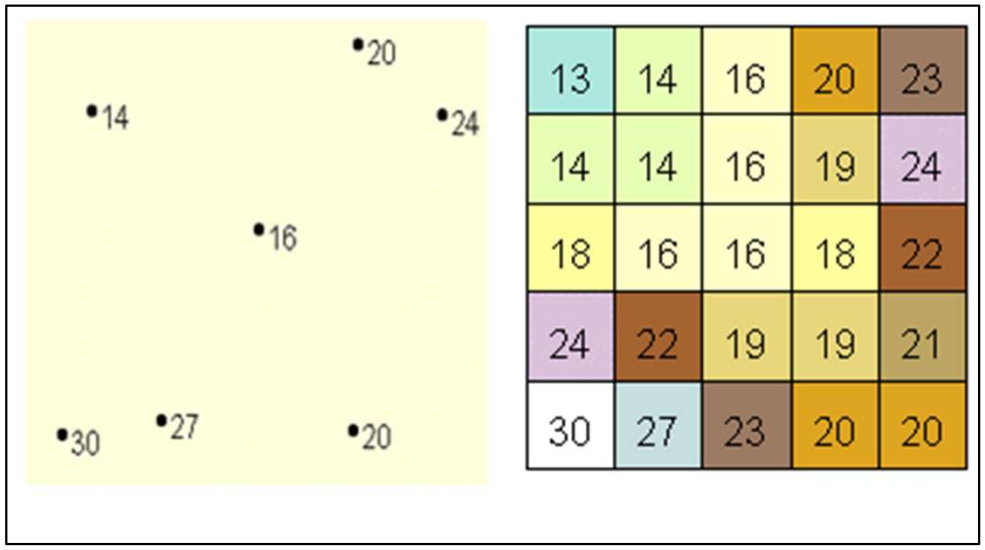


Fig. 1 : Rainfall

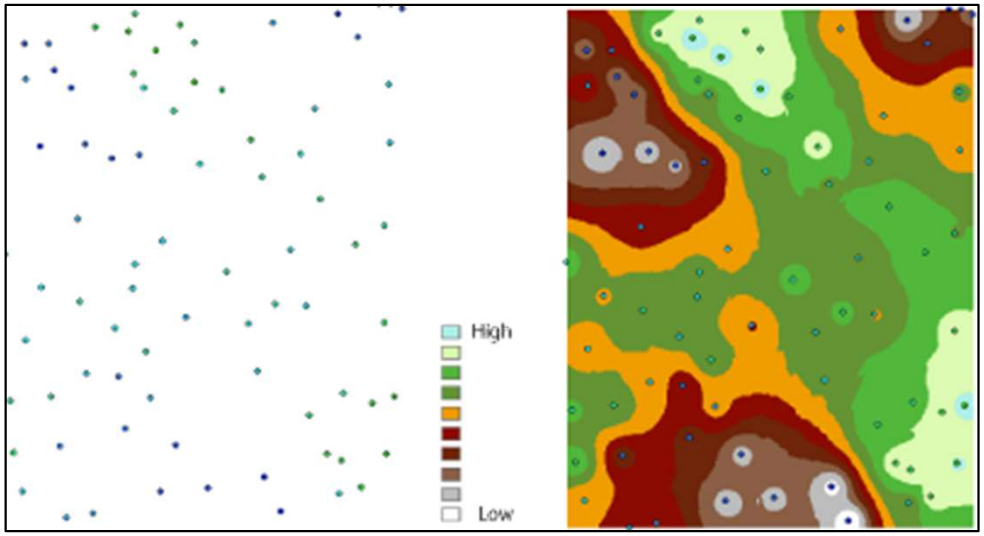


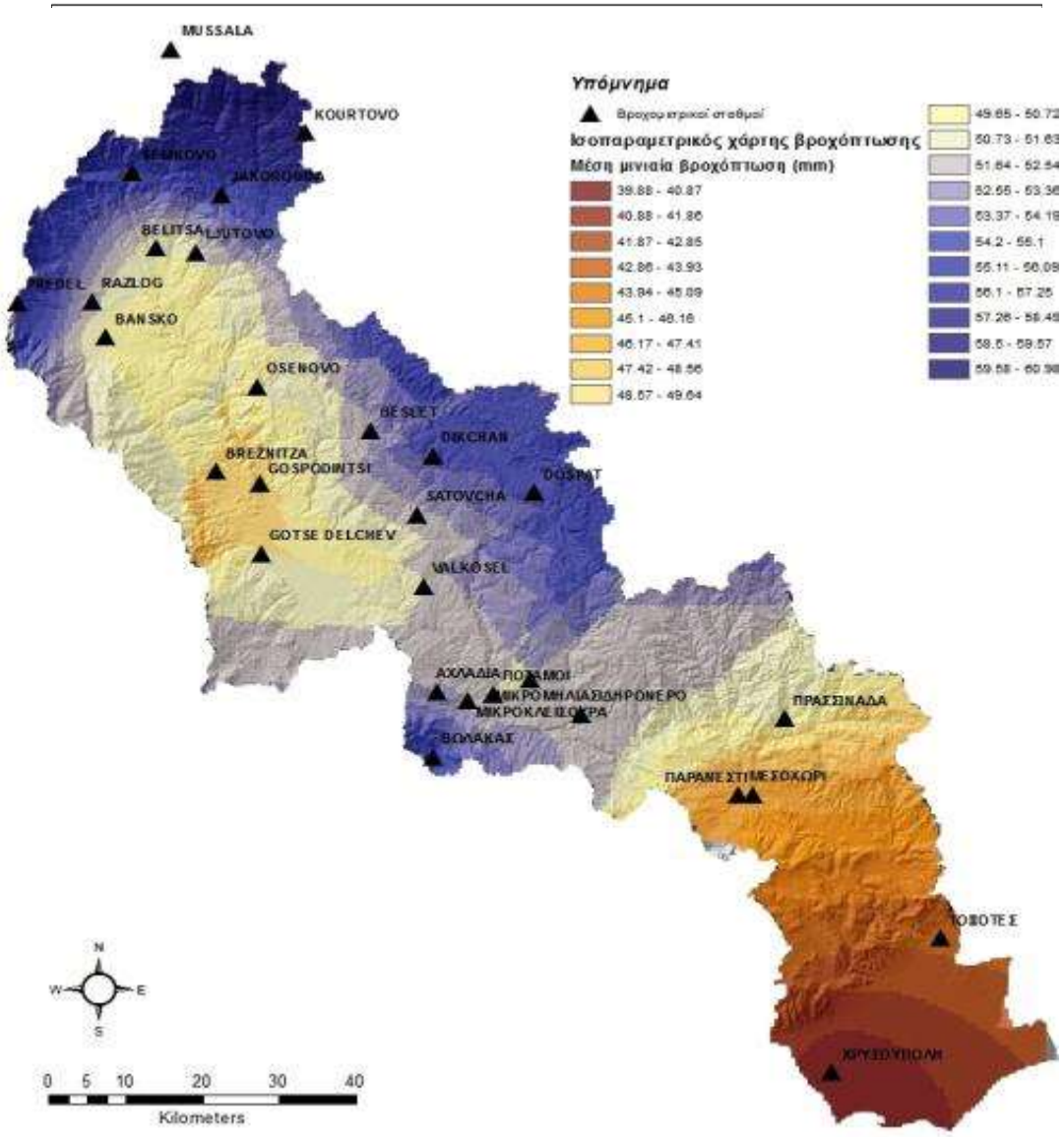
Fig. 2 : Elevation

ArcGIS : Spatial analyst, Interpolation

The assumption that makes interpolation a viable option is that spatially distributed objects are spatially correlated; in other words, things that are close together tend to have similar characteristics.

Tool	Description
IDW	Performs an inverse distance weighted interpolation on a point dataset.
Krige	Interpolates a raster from a set of points using kriging.
Kriging	Interpolates a grid from a set of points using kriging.
Natural Neighbor	Interpolates a surface from points using a natural neighbor technique.
PointInterp	Interpolates a raster from a set of points using a specified neighborhood.
Spline	Performs a two-dimensional minimum curvature spline interpolation on a point dataset resulting in a smooth surface that passes exactly through the input points.

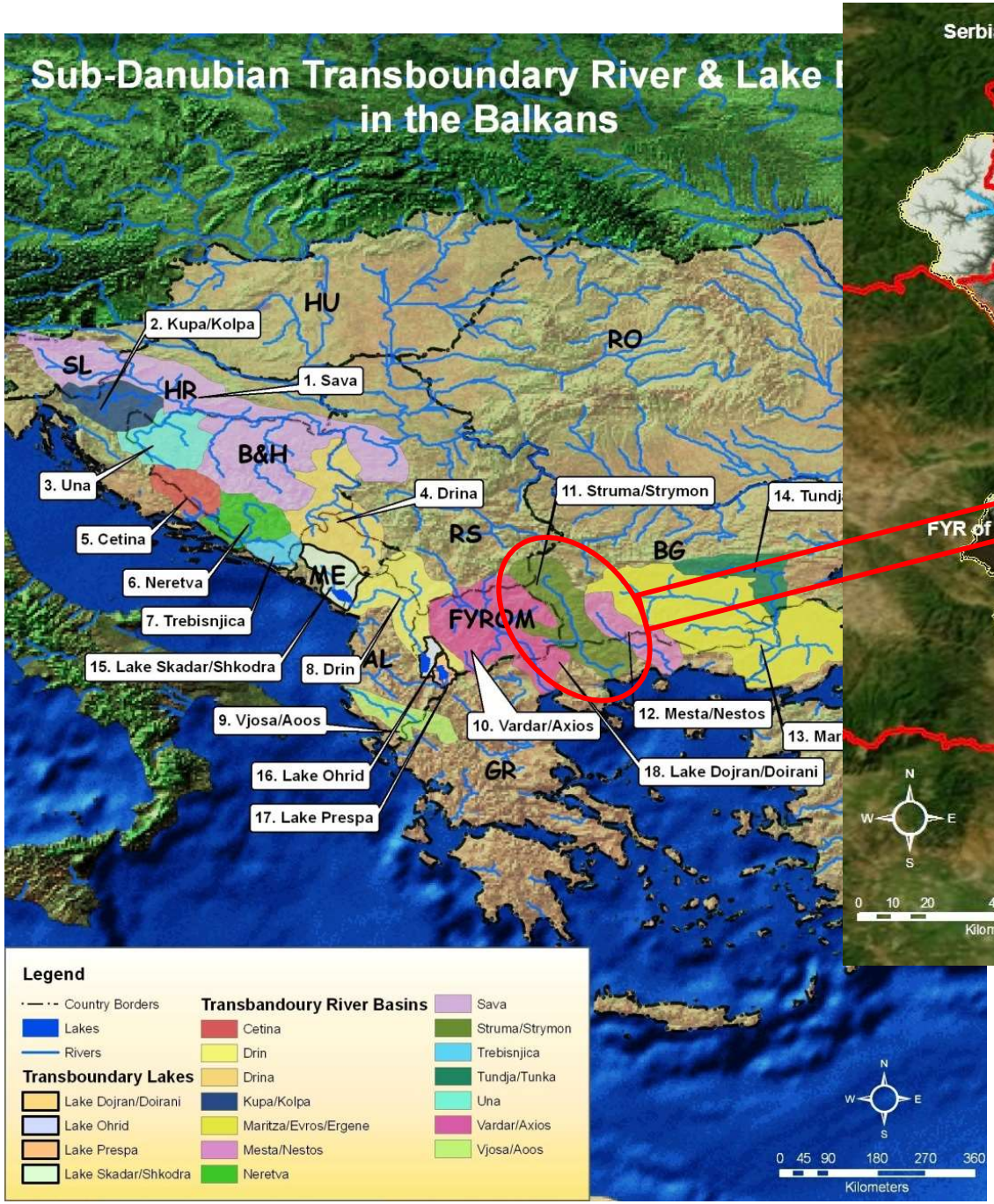
ArcGIS : Example with Kriging

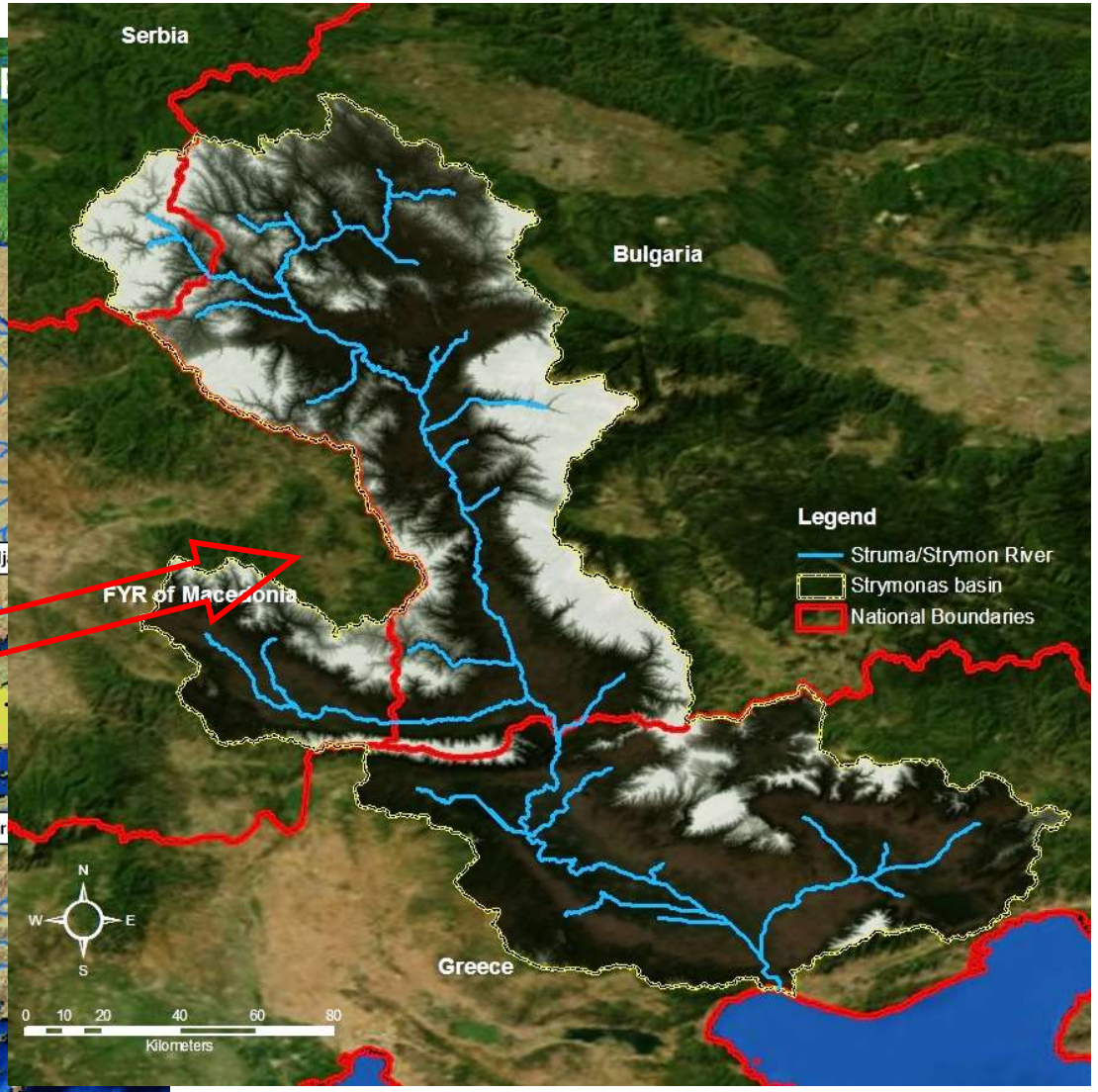


- The Inverse Distance Weighted (IDW) and Spline methods are referred to as deterministic interpolation methods because they are directly based on the surrounding measured values.

- Kriging is based on statistical models that include autocorrelation—that is, the statistical relationships among the measured points

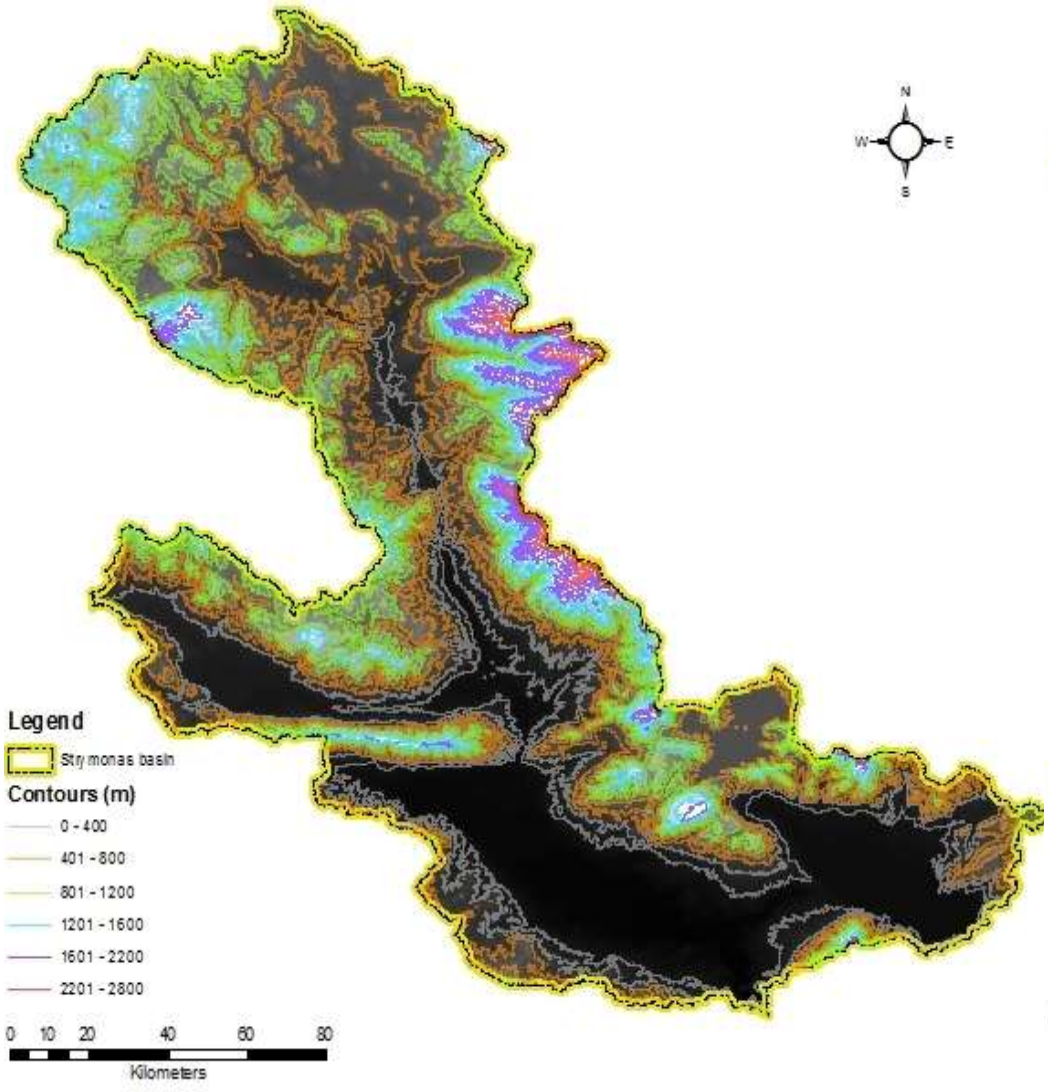
Case study: The Strymon River basin



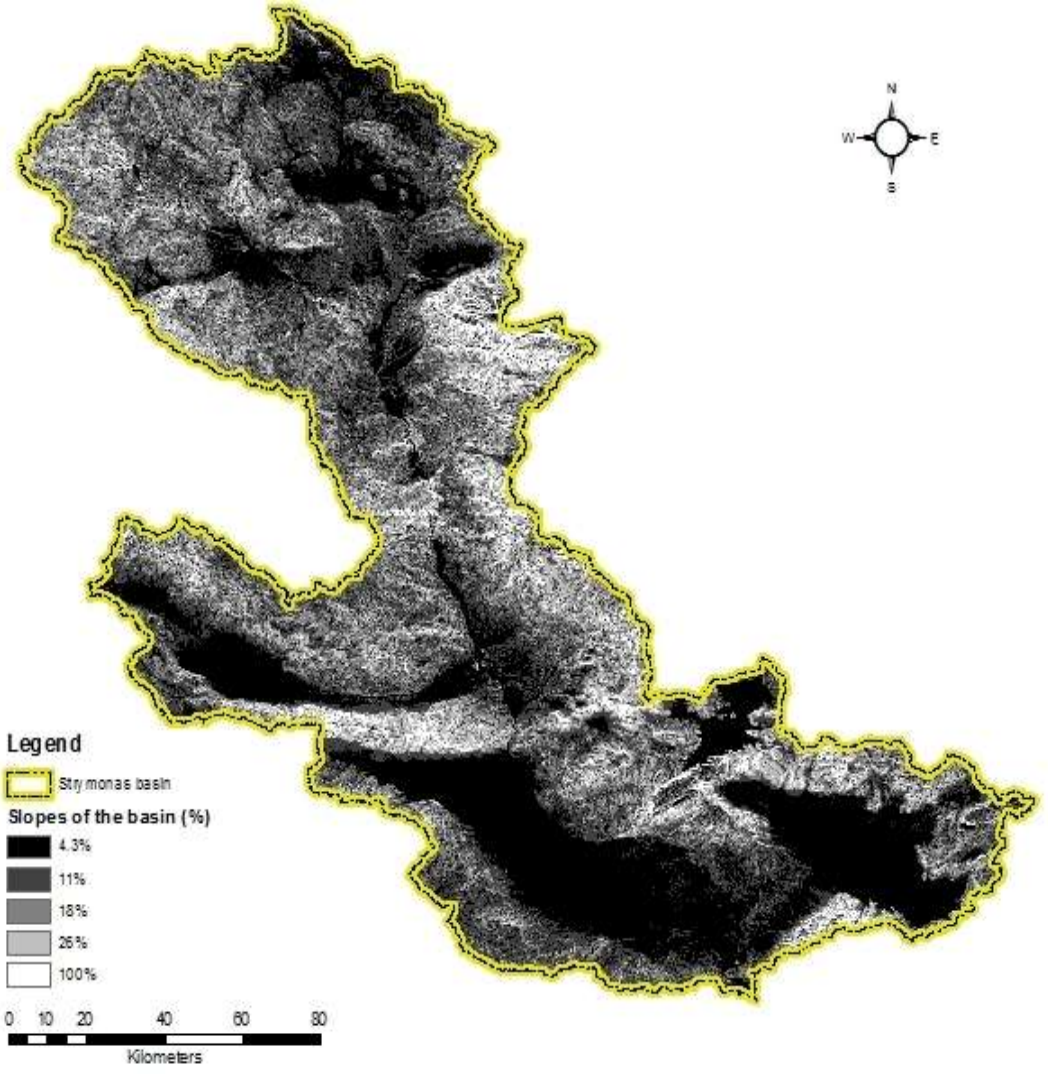


Basin area: 17,276 km²
8,734 km² (51%) in Bulgaria,
6,439 km² (38%) in Greece

Geographic Information Systems (GIS) on water resources

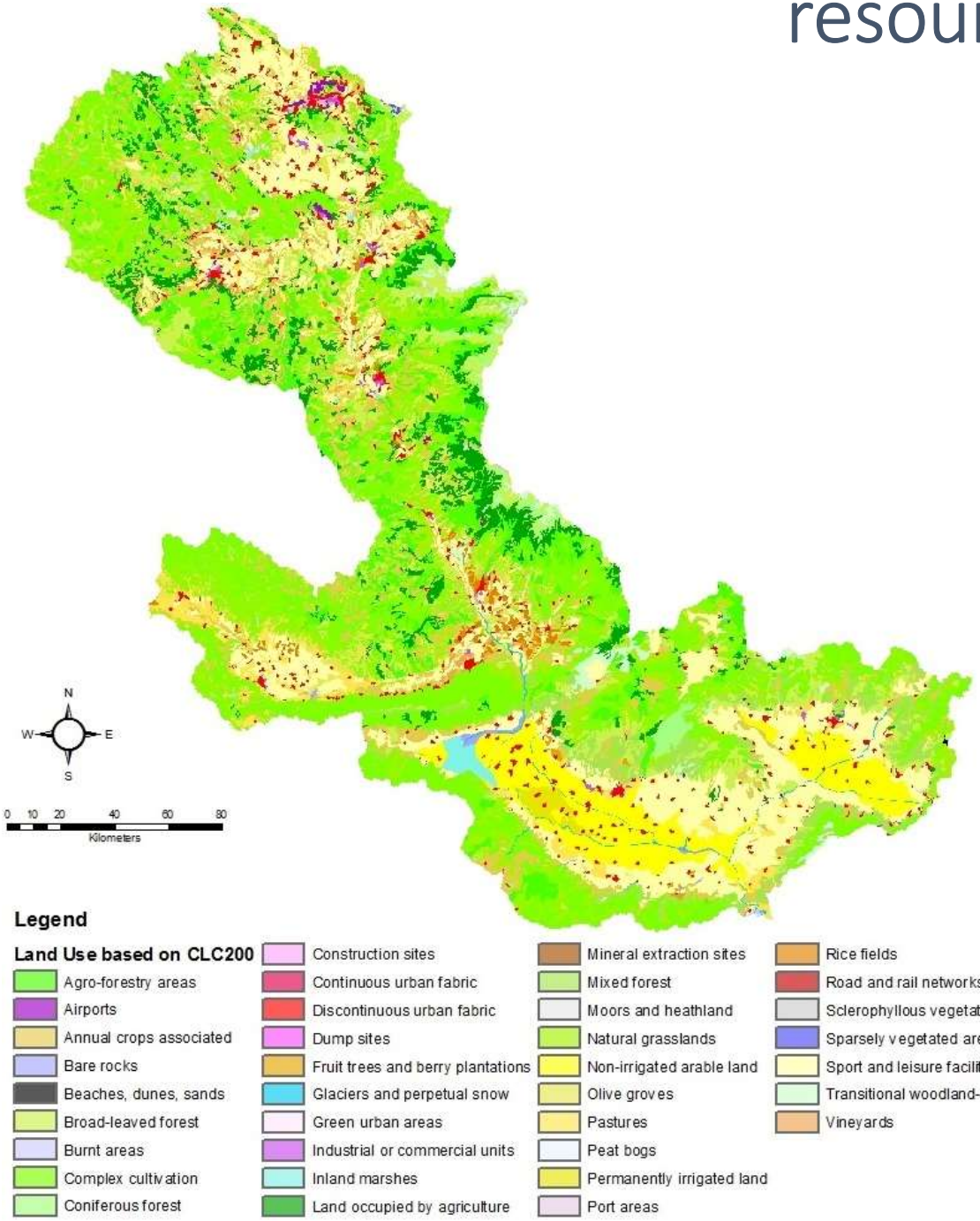


Elevation (contour lines of 400m)



Basin slopes

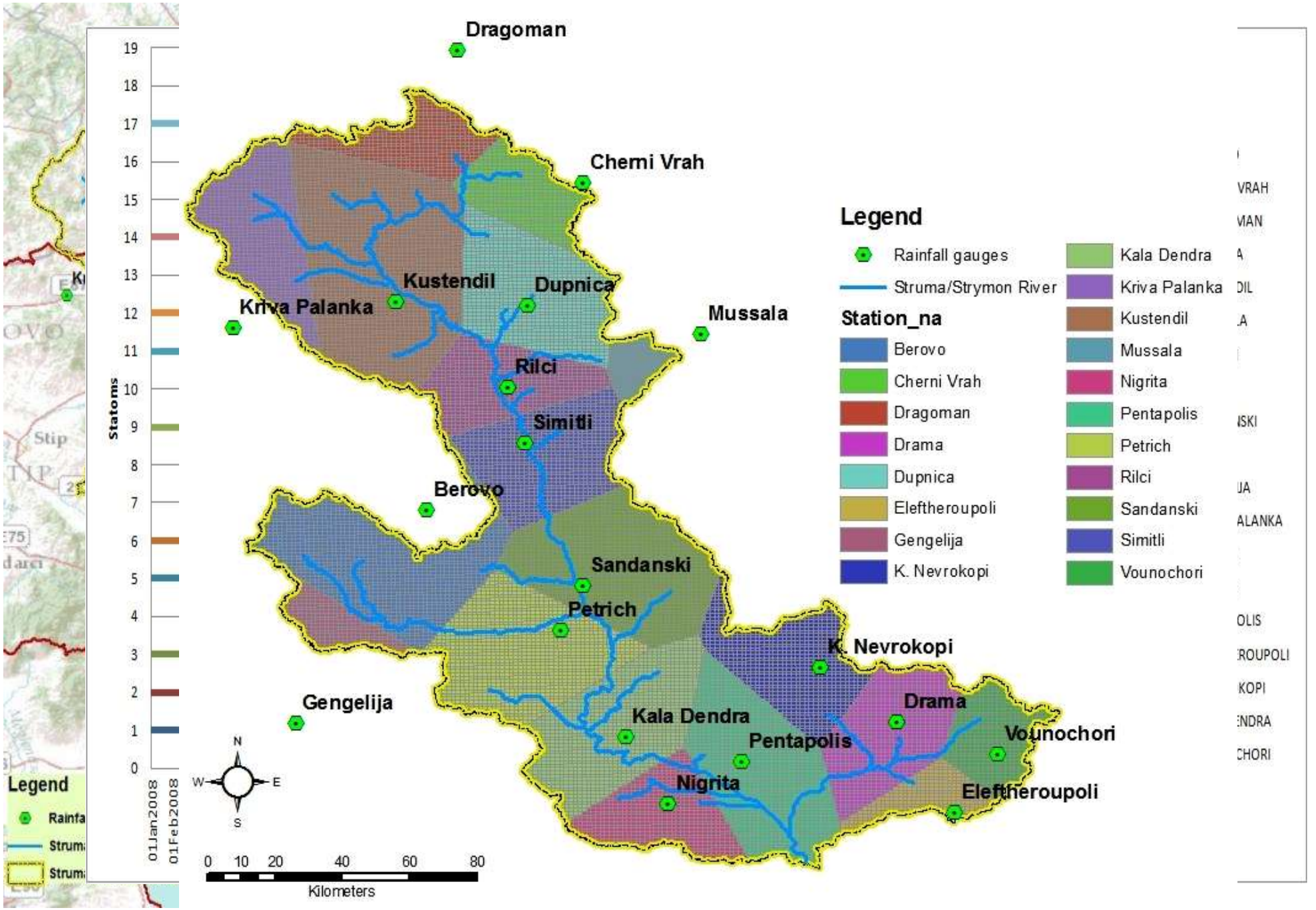
Geographic Information Systems (GIS) on water resources



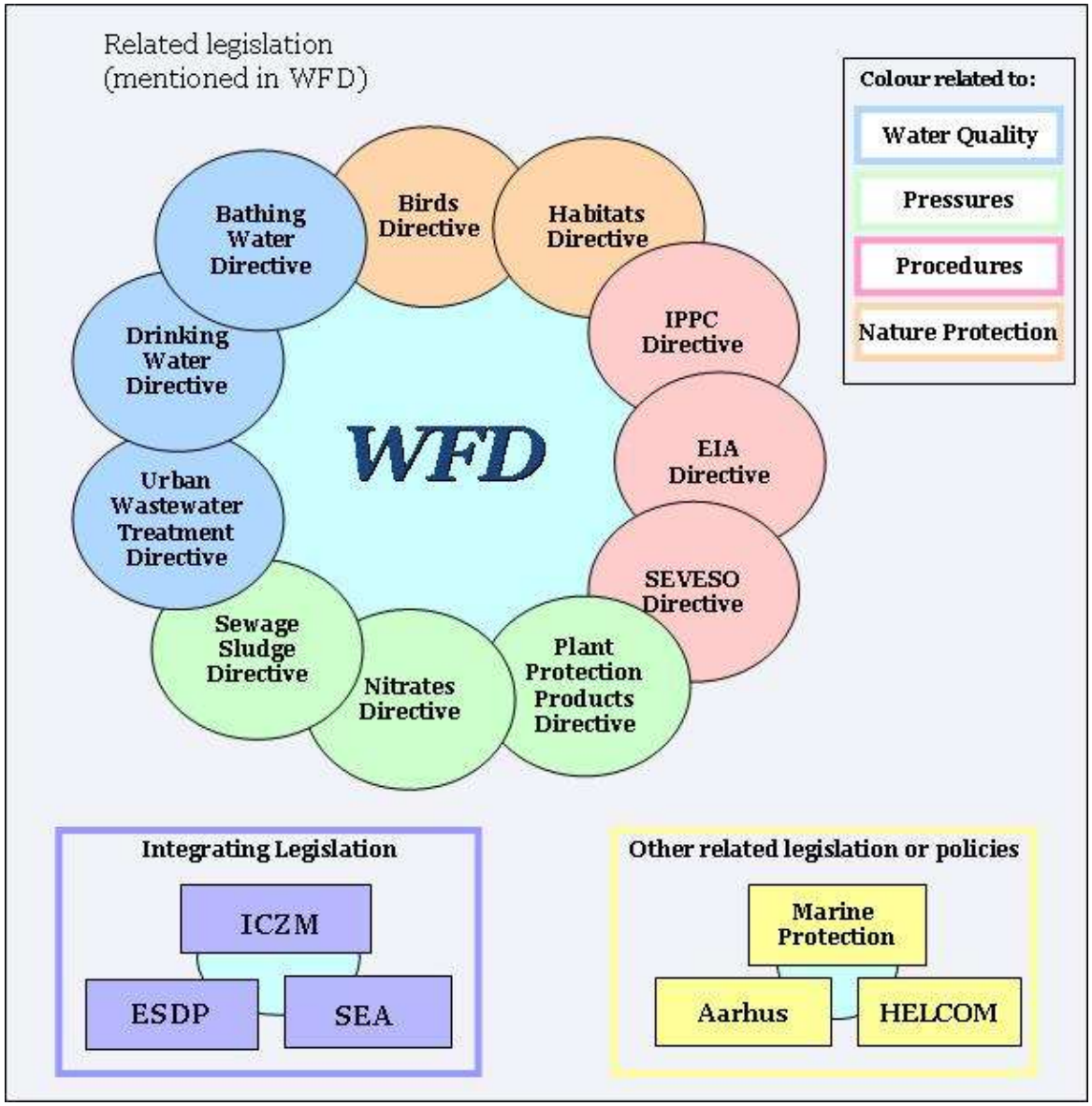
The Struma/Strymon basin can be characterised as a natural basin:

- **Forested areas (36.25%)**
- **Scrub/herbaceous vegetation areas (22.65%)**
- **Arable agricultural areas (21.95%)**
- **Pastures and the heterogenous agricultural areas (13.10%)**
- **Urban areas (1.95%)**

Precipitation distribution



Application in EU's WFD



The Water Framework Directive (WFD)

Water Framework Directive (WFD) 2000/60 is considered to be one of the most ambitious and comprehensive pieces of European environmental legislation to date.

The WFD aims at the integrated management and protection of the water resources

- Identifying and analyzing of environmental pressures and risks at river basin scale,
- **Identifying water bodies and protected areas**
- **Creation of monitoring networks for water resources (Article 8)**
- Defining environmental objectives, classification systems and environmental standards
- **Creation and storage of environmental data in geodatabases with use of GIS**
- Stakeholders participation (Article 14)

Definition of water body

The "water body" is a coherent sub-unit in the river basin (district) to which the environmental objectives of the directive are being applied.

The identification of water bodies is, first and foremost, based on geographical and hydrological determinants.

- ***"Body of surface water" means a discrete and significant element of surface water such as a lake, a reservoir, a stream, river or canal, part of a stream, river or canal, a transitional water or a stretch of coastal water***

- ***"Body of groundwater" means a distinct volume of groundwater within an aquifer or aquifers.***

Typology of water body

Classification: Typology A or Typology B

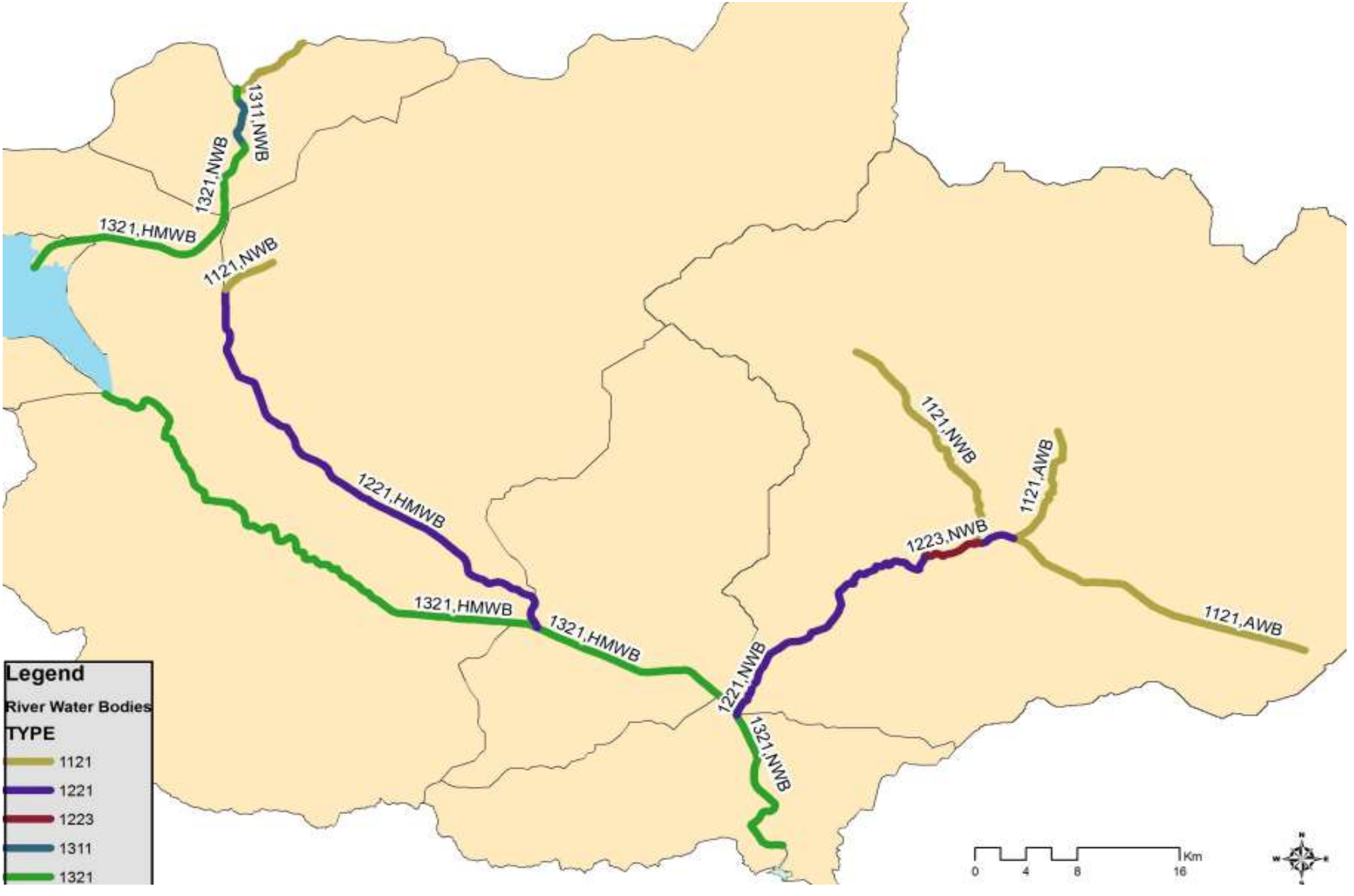
Example of Typology System B for Strymon River, Greece

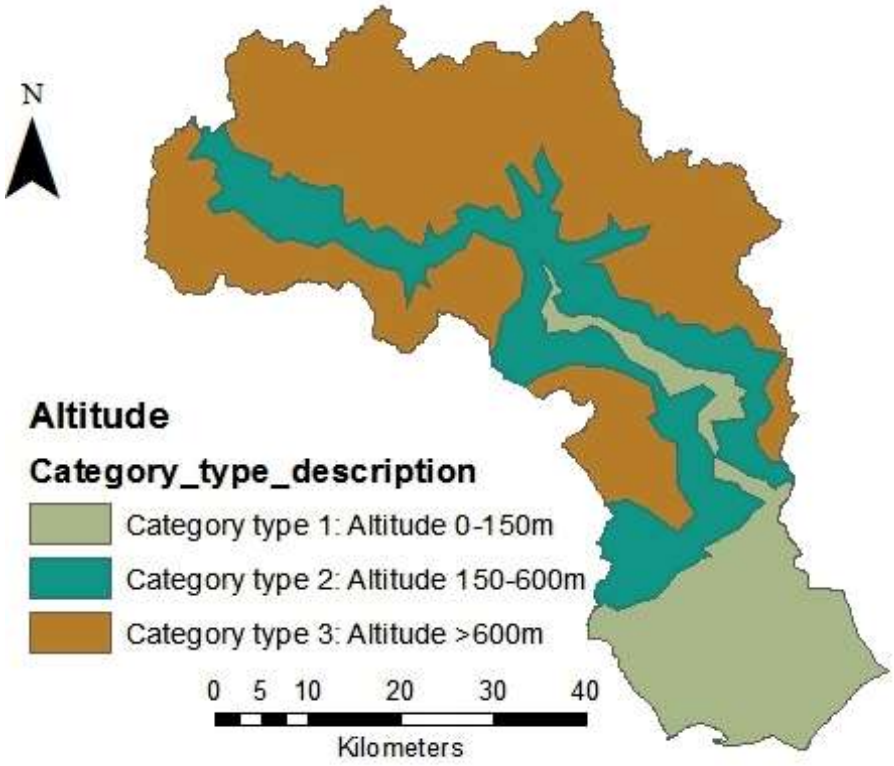
A four-digit numerical system was adopted to present the types

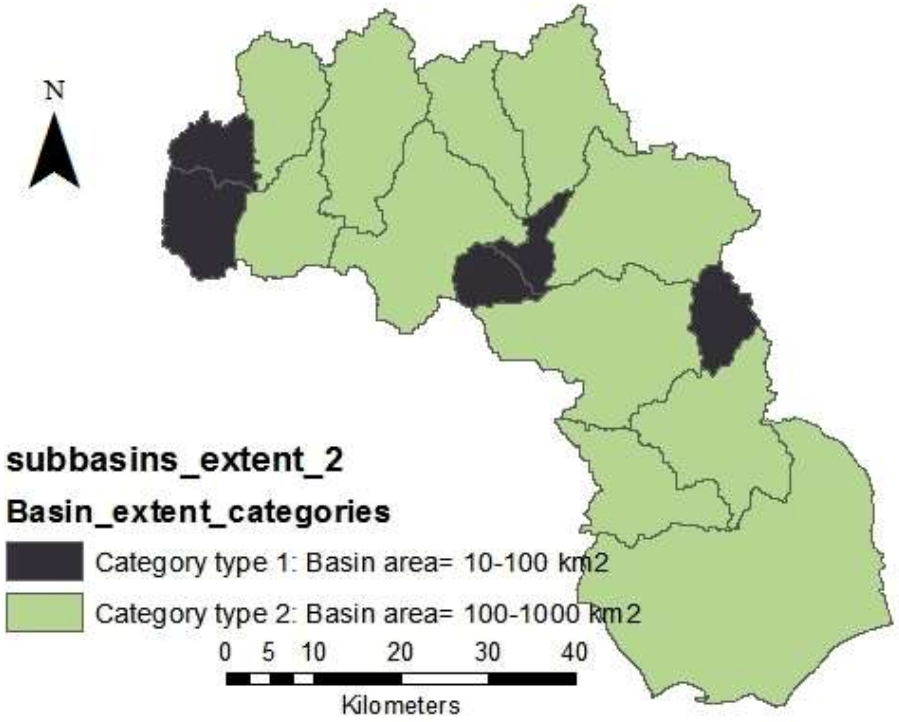
- 1st digit = altitude category
  - (1=0-150m or 2=150-600m or 3=>600m)
- 2nd digit = catchment area category
  - (1=0-100km2, or 2=100-1000km2 or 3=1000-10.000km2 or 4=> 10.000Km2
- 3rd digit = geology category
  - (1= Calcareous (Ca) or 2= Siliceous (Si) or 3= Organic (C))
- 4th digit = slope
  - (1=0-5^{o} or 2=5^{o}-15o or 3= >15^{o})

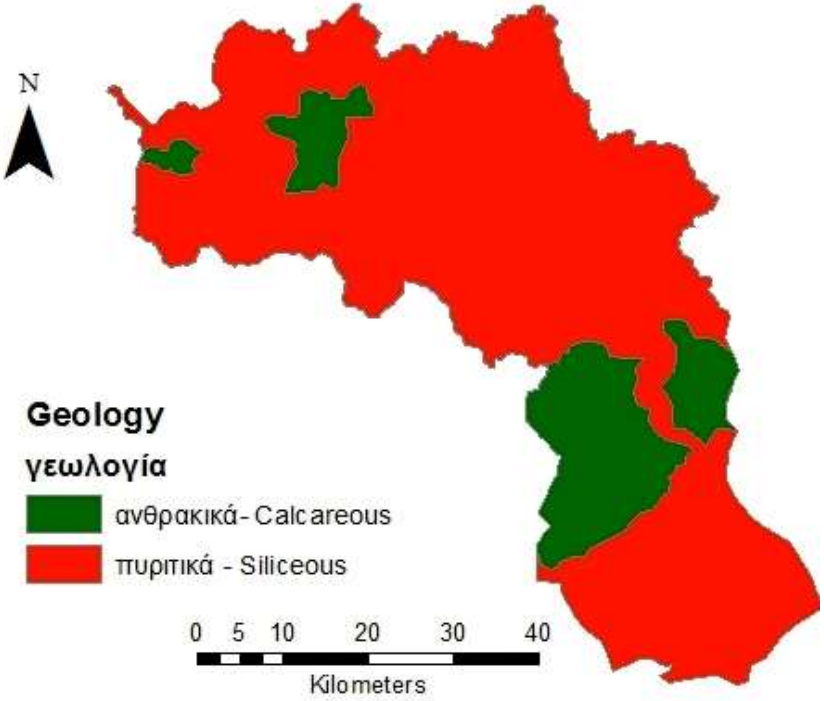
Example: 1211 = Altitude 0-150m, Catchment 100-1000m2, Geology Ca, Slope 0-5o

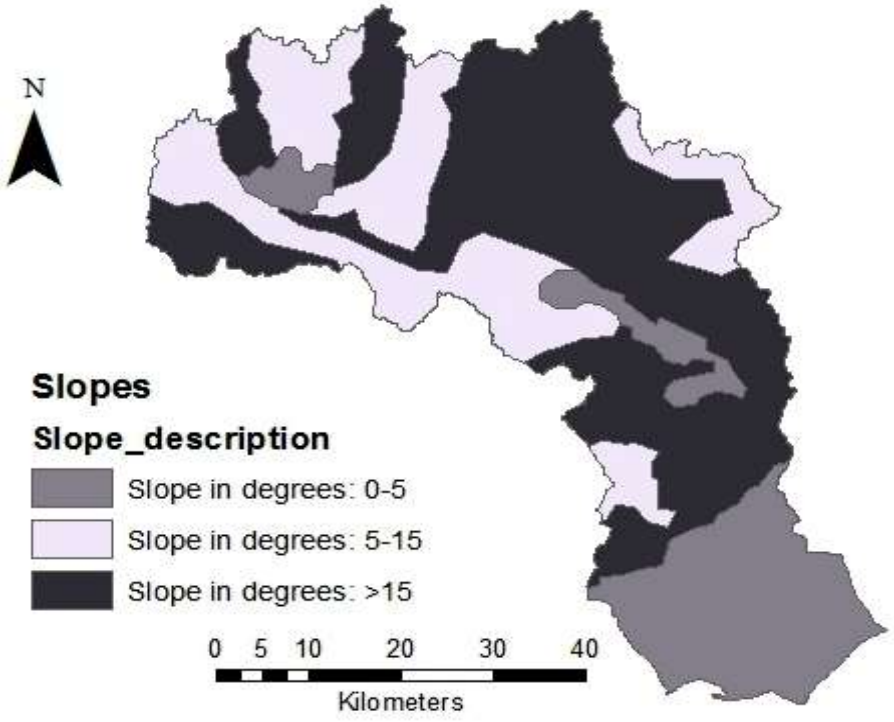
Results of application of Typology B

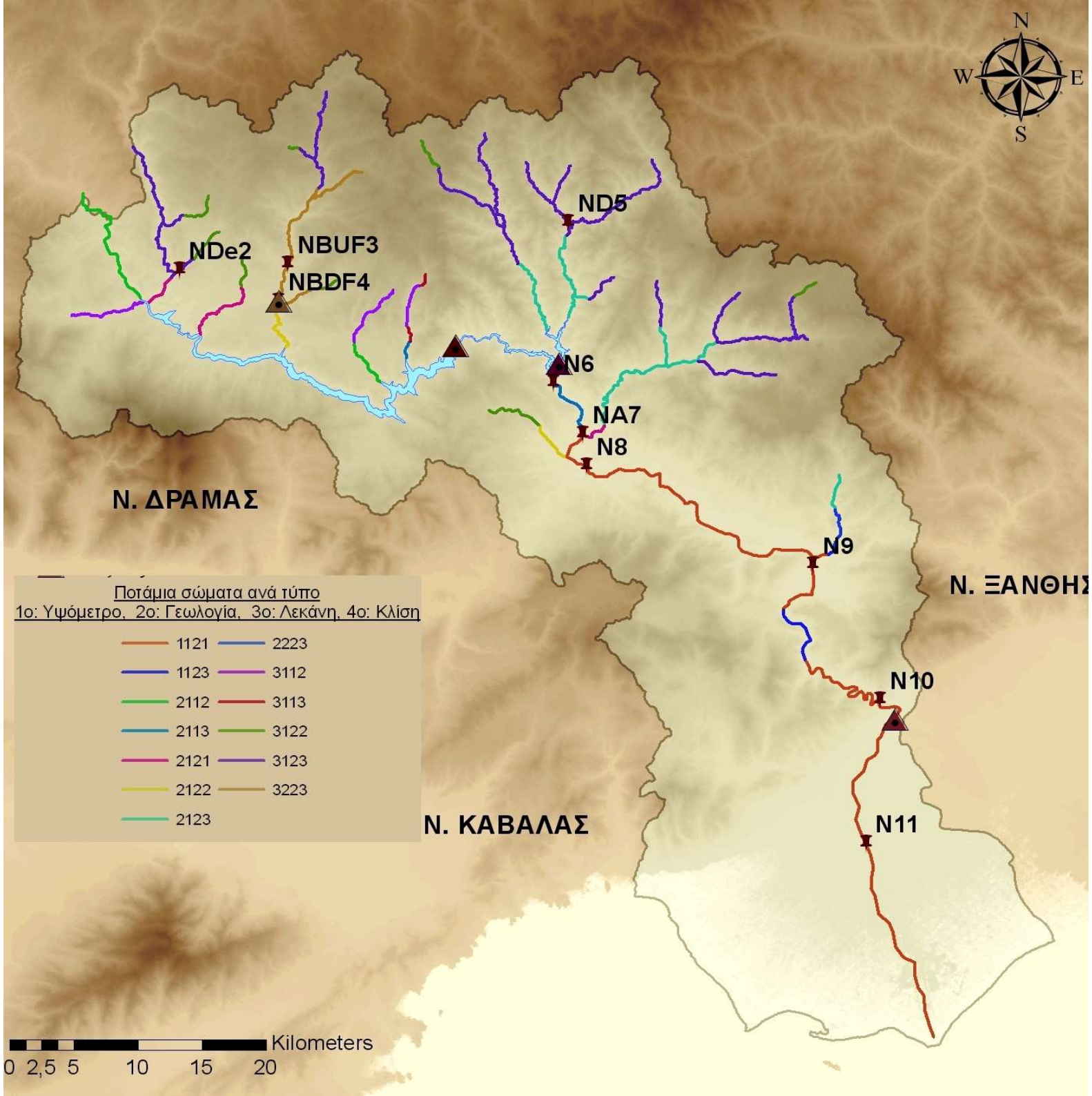



N
Altitude
Category_type_description
Category type 1: Altitude 0-150m
Category type 2: Altitude 150-600m
Category type 3: Altitude >600m
0 5 10 20 30 40
Kilometers

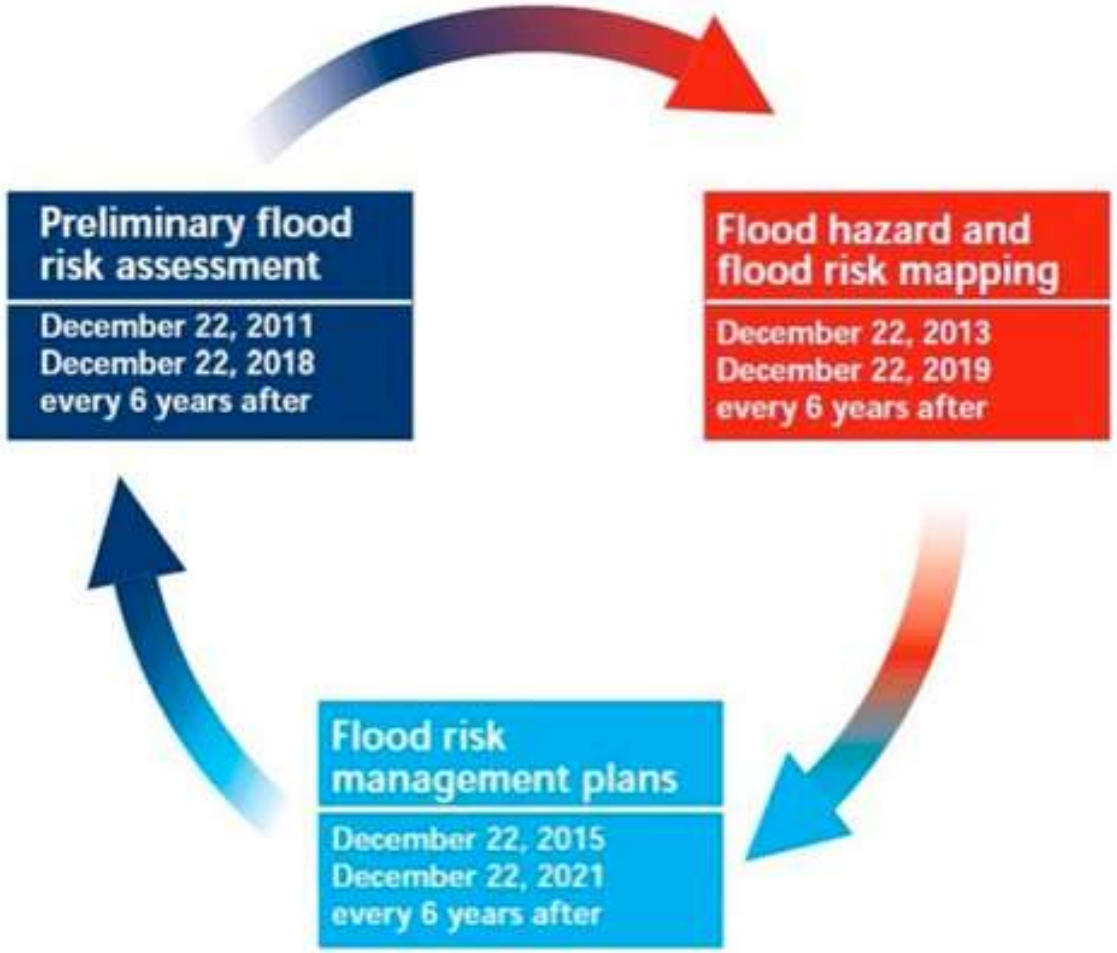

N
subbasins_extent_2
Basin_extent_categories
Category type 1: Basin area= 10-100 km2
Category type 2: Basin area= 100-1000 km2
0 5 10 20 30 40
Kilometers


N
Geology
γεωλογία
ανθρακικά - Calcareous
πυριτικά - Siliceous
0 5 10 20 30 40
Kilometers


N
Slopes
Slope_description
Slope in degrees: 0-5
Slope in degrees: 5-15
Slope in degrees: >15
0 5 10 20 30 40
Kilometers


N
W
E
S
NDe2
NBUF3
NBDF4
ND5
N6
NA7
N8
N9
N10
N11
Ν. ΔΡΑΜΑΣ
Ν. ΞΑΝΘΗΣ
Ν. ΚΑΒΑΛΑΣ
Ποτάμια σώματα ανά τύπο
1ο: Υψόμετρο, 2ο: Γεωλογία, 3ο: Λεκάνη, 4ο: Κλίση
1121
1123
2112
2113
2121
2122
2123
2223
3112
3113
3122
3123
3223
Kilometers
0 2,5 5 10 15 20

Application in EU's Floods Directive

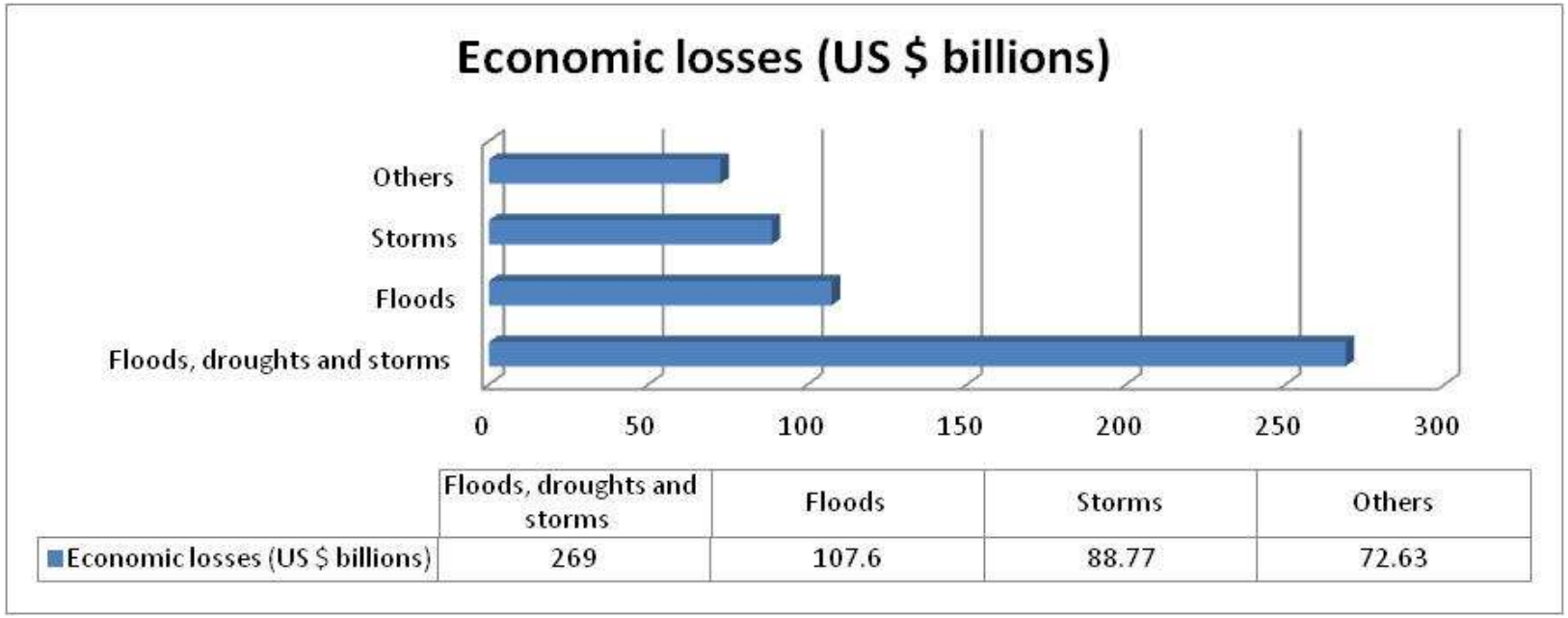


Floods in Europe? Impacts?

Floods and storms in Europe account respectively for 40 % and 33% of the total economic damages for the period 1989-2008.

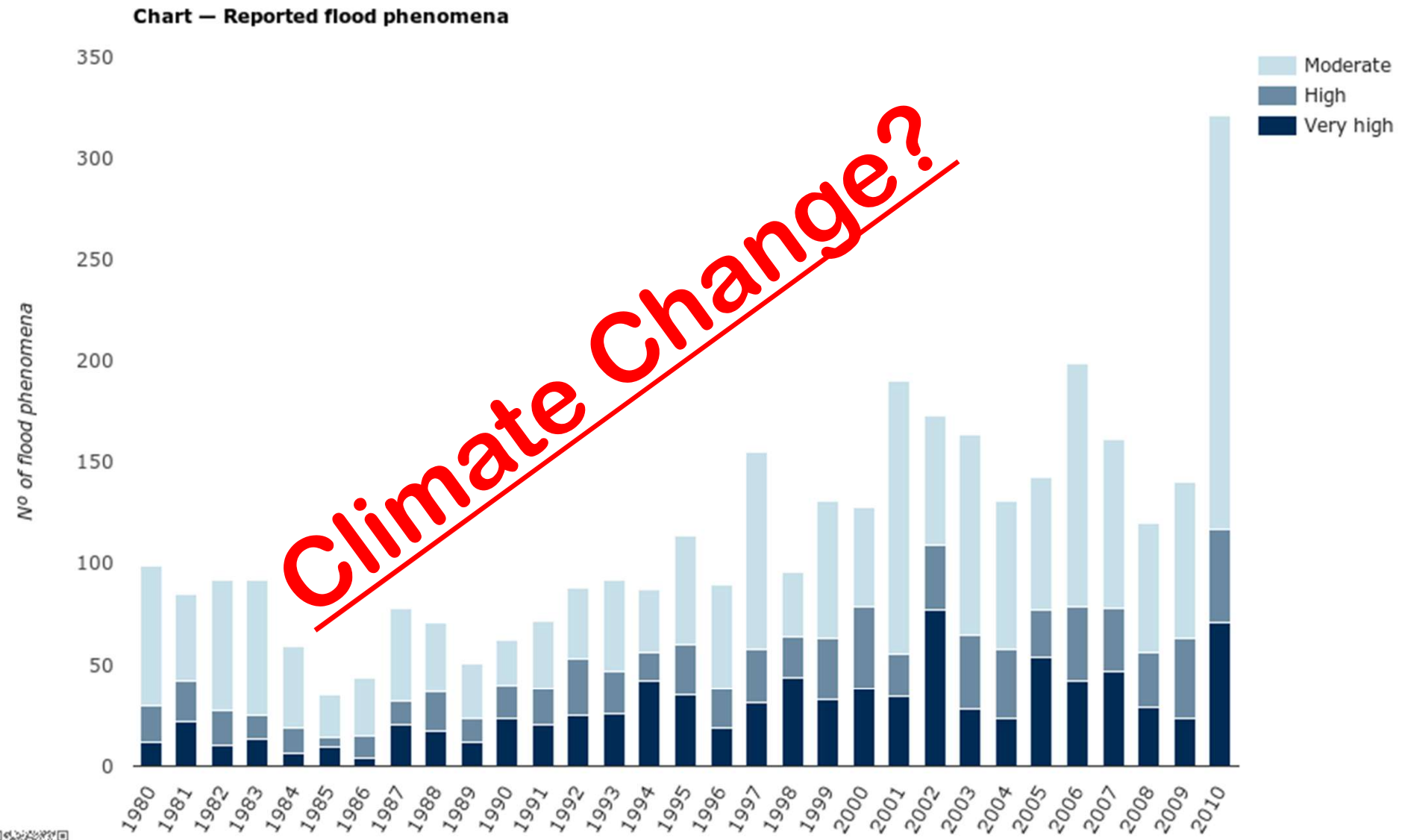
<u>The trend will probably continue to rise as floods and storms are expected to become more frequent and severe in the future in Europe</u>. *(source: UNISDR)*

In the past 20 years, 953 disasters killed nearly 88,671 people in Europe, affected more than 29 million others



	Floods, droughts and storms	Floods	Storms	Others
Economic losses (US $ billions)	269	107.6	88.77	72.63

Floods in Europe? Impacts?



Floods in Europe? Impacts?

European flood risk directive 2007/60

The European "Directive on the assessment and management of flood risks", endorsed in 18 September 2007, aims to reduce the adverse consequences on human health, the environment, cultural heritage and economic activity associated with floods in the Community.

Article 6 of the Floods Directive requires Member States to prepare

1. **flood hazard and**
2. **flood risk maps**

(at the river basin level and at the most appropriate scale) for the areas of potential significant flood risk identified under Article 5 or 13.1(a), or for the areas for which Member States decided to prepare flood maps according to Article 13.1(b).

Definitions adopted in the EFD 2007/60

Flood: is a temporary covering by water of land normally not covered by water. This shall include floods from rivers, mountain torrents, Mediterranean ephemeral water courses, and floods from the sea in coastal areas, and may exclude floods from sewerage systems

Flood risk: is the combination of the probability of a flood event and of the potential adverse consequences to human health, the environment and economic activity associated with a flood event

Flood hazard maps: demonstrate areas which could be flooded according to three probabilities (low, medium high) complemented with: type of flood, the flood extent; water depths or water level as appropriate; where appropriate, flow velocity or the relevant water flow direction

Flood risk maps: indicate the potential adverse consequences associated with floods under several probabilities, expressed in terms of: the indicative number of inhabitants potentially affected; type of economic activity of the area potentially affected; installation which might cause accidental pollution in case of flooding

Requirements for Member States

- Preliminary flood risk assessment: the aim of this step is to evaluate the level of flood risk in each river basin district or unit of management and to select those areas on which to undertake flood mapping and flood risk management plans.

- Flood mapping comprising of flood hazard maps and flood risk maps: the flood hazard maps should cover the geographical areas which could be flooded according to different scenarios; the flood risk maps shall show the potential adverse consequences associated with floods under those scenarios.

- Flood risk management plans: on the basis of the previous maps, the flood risk management plans shall indicate the objectives of the flood risk management in the concerned areas, and the measures that aim to achieve these objectives.

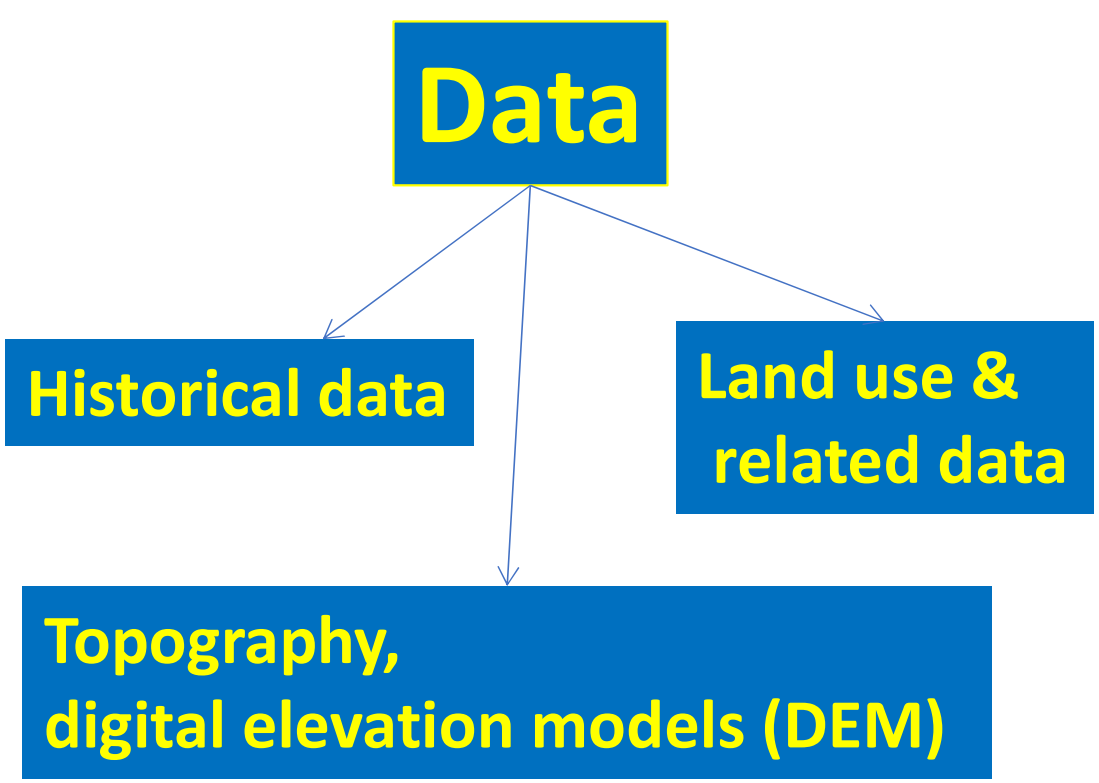
To be completed by 2011

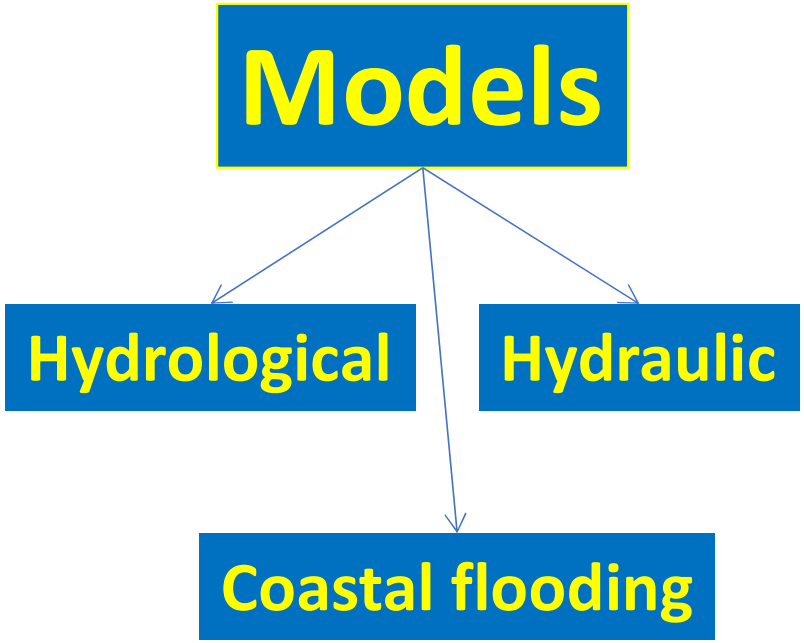
To be completed by 2013

To be completed by 2015

Production of flood maps

<u>To produce the maps data and models are required</u>





Data requirements

Topography, digital elevation models (DEM)

To enable accuracy of inundation modelling as well as to secure the identification of the endangered properties, detailed and accurate digital maps and digital elevation models (DEM) are required. Taking into consideration the most flat character and the very slight slope of the floodplain as well as that of the river flood surface, appropriate selection of horizontal and vertical accuracy of the maps/DEM has significant impact on the reliability and accuracy of the end product.

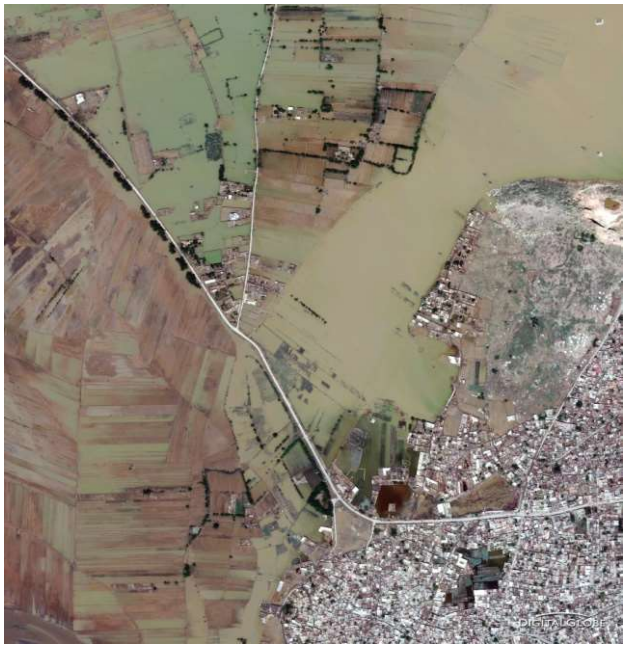
Minimum requirements are 10 m*10 m (possibly 5 m*5 m) horizontal and minimum 0.5 m vertical resolution.

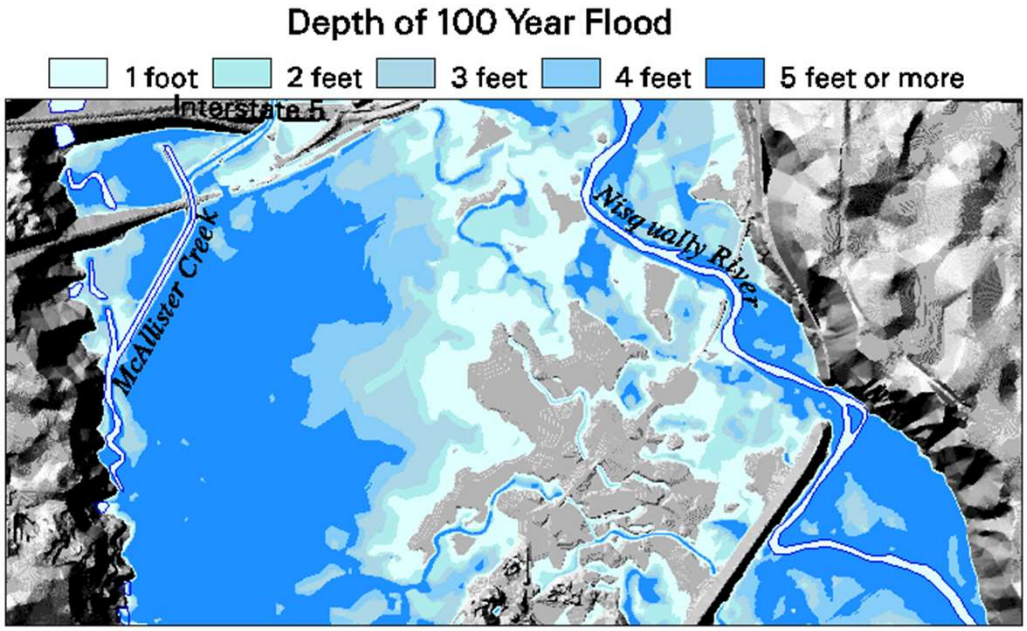
Possible tools/methods to generate DEMs of the required accuracy:

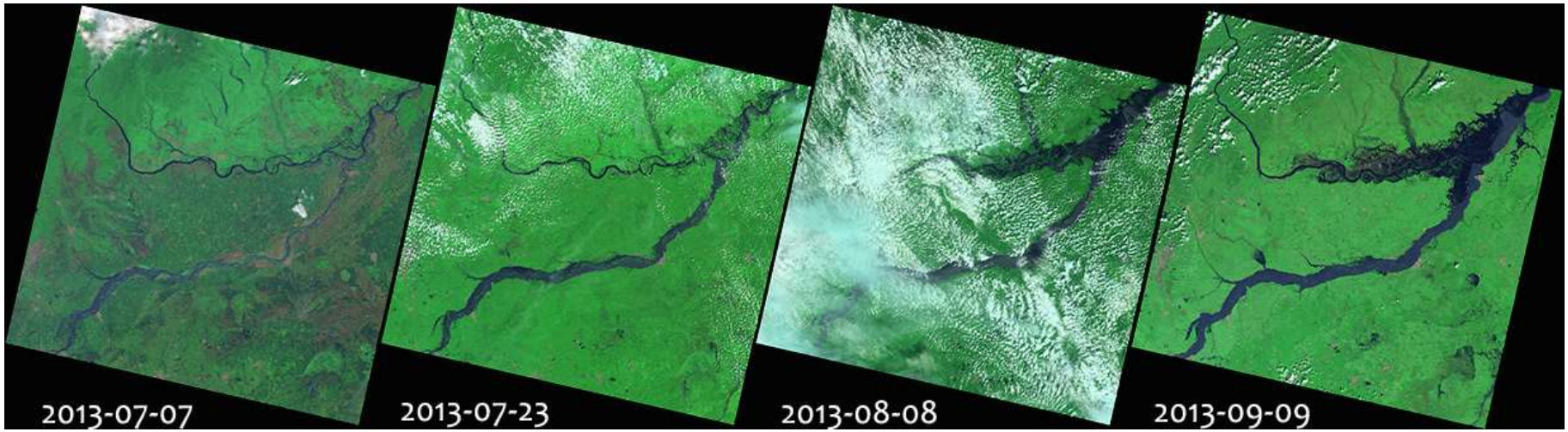
- **LiDAR**
- **SAR and variations (IFSAR, GeoSAR, AIRSAR)**
- **orto-maps, DTM derived from digital satellite images**
- **DEMs derived from the vectorised contour lines of 1:10 000 scaled digital map segments**

Data requirements

Topography, digital elevation models (DEM)







Data requirements

Historical data

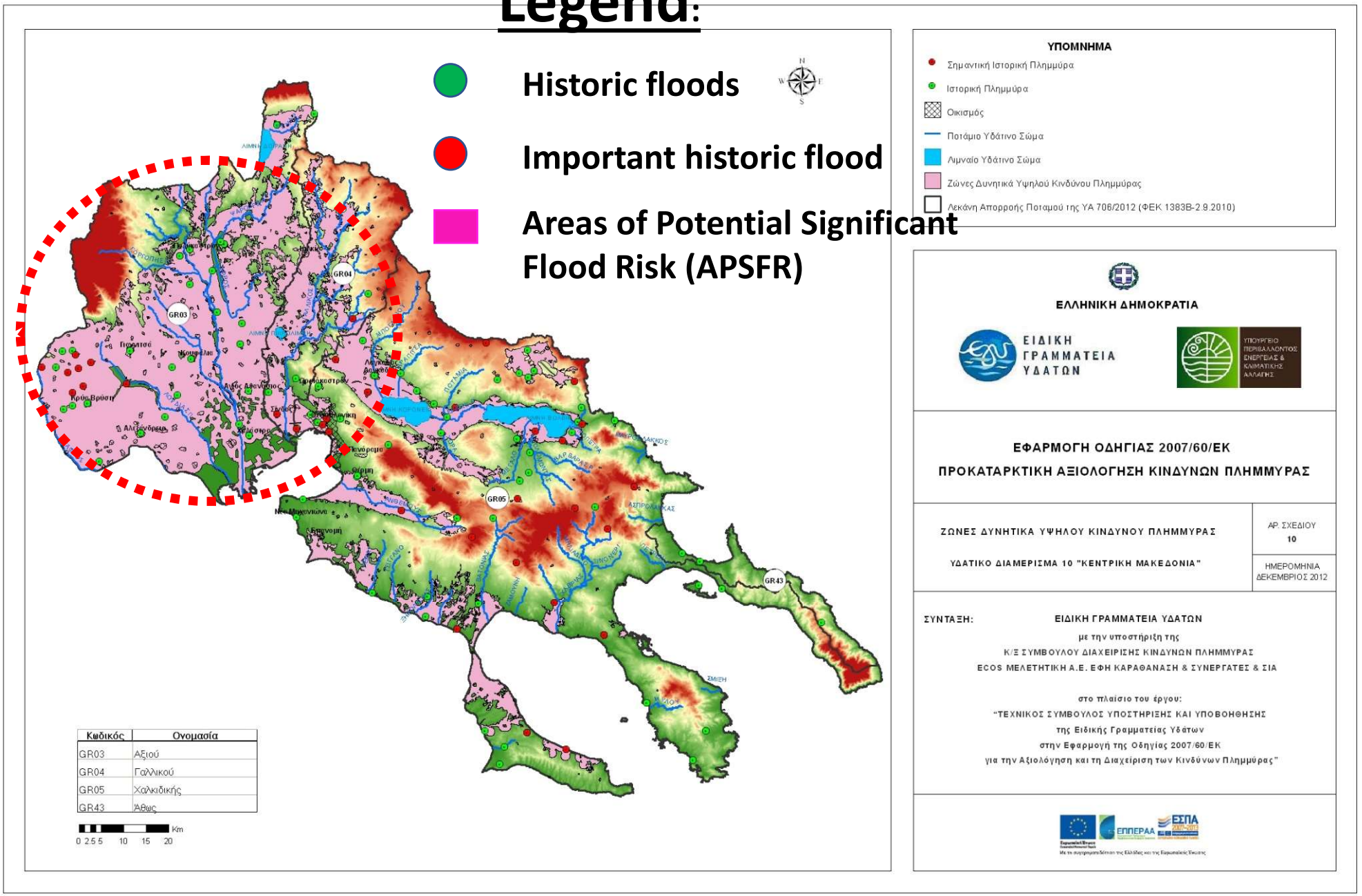
Historical data are very important for public awareness rising as well as for the calibration of flood modelling (as long as past and modelling conditions can be compared).

Historical data interesting to be collected are:

- Flood maps
- Water level records in river
- Velocity records (gauge)
- Flood marks
- Pictures, painting or drawing
- Newspapers relating flood events
- Historical reports or books on floods, focusing on damages and on protection upgrade studied or decided after the flood
- Aerial and satellite photos.

Data requirements

Legend:



Data requirements

Land use and related data

The types of land use and related data used by European countries and the place where to get them are as described below:

- **Population data –** data acquisition: statistics (ZIP-code based registers)
- **Corine Land Cover:** The pan-European project CORINE Land Cover (CLC) provides a unique and comparable data set of land cover for Europe. It is part of the European Union programme CORINE
- **Economical data –** data acquisition: land use maps, statistics, (ZIP-code based registers)
- **Basic services:** transportation, energy supply, communication, water supply, sewerage, healthcare, social and education facilities– partly from statistics, or ZIP code based registers, land registry, databases and maps of linear infrastructures.
- **Environment – pollution sources and protected areas**: facilities and pipelines of chemical industry, filling stations, agricultural pollution sources (herbicides, pesticides, fertilizers, manure, poisonous substances and nutrients), wastewater treatment plants, waste storage, septic tanks;
- **Protected areas** – Natura 2000, nature conservation– thematic databases and maps.
- **Cultural heritage –** thematic databases and maps

Flood modelling

Hydrological models:

Various rainfall-runoff models or statistical models are used to determine hydrological parameters of the flood waves (which are input data of hydrodynamic models). The rainfall-runoff models are typically used to simulate the flash floods of mountain torrents and watercourses of mountain toe regions, but are also used for flood forecasting purposes even in large catchments where the time required for accumulation and runoff enables early warning of operational and/or emergency organisations.

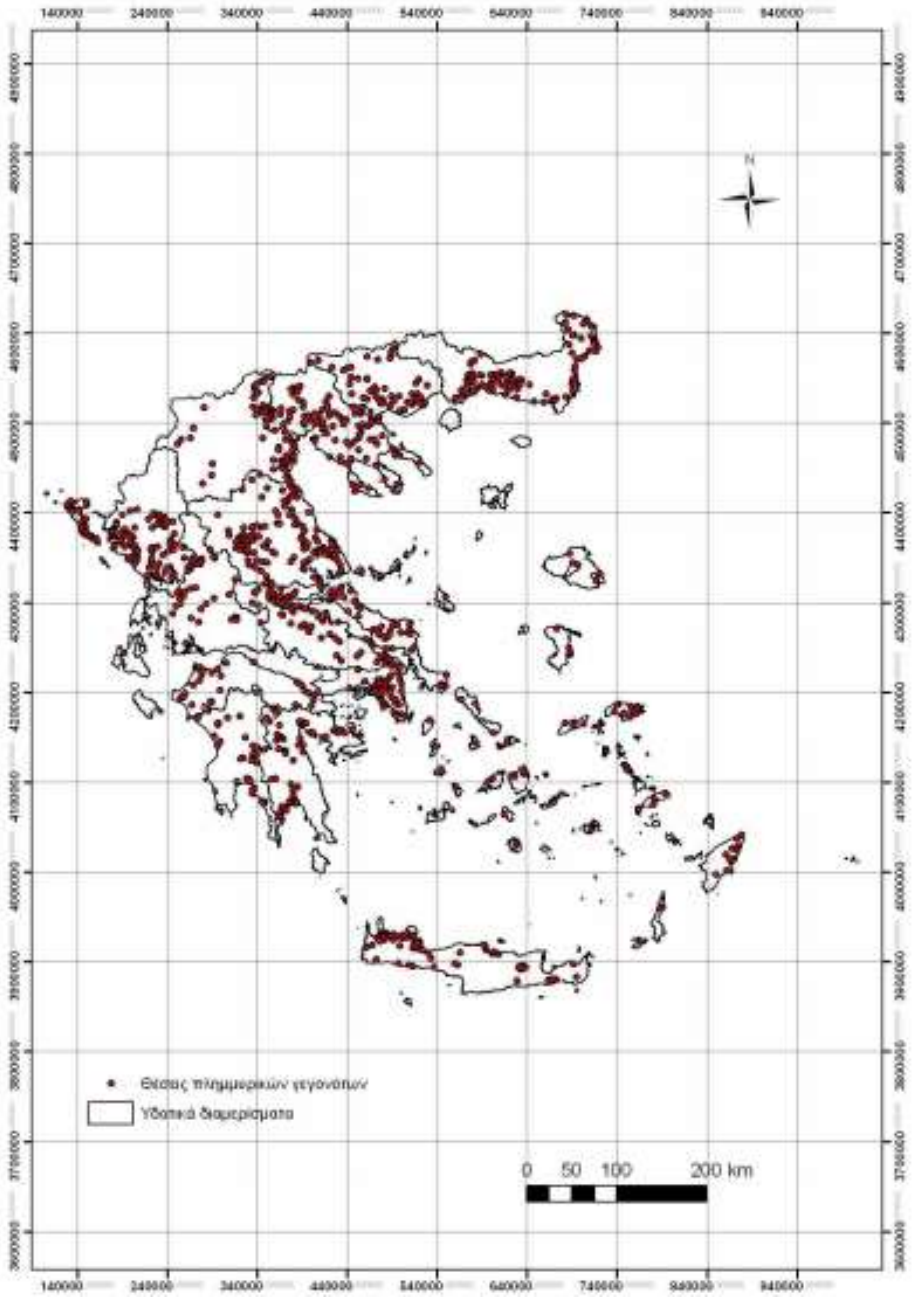
Hydraulic models:

River flood routing (flood propagation in rivers) can be described by one dimensional (1D) mathematical model. This solution is suitable for the modelling of inundation of open floodplains.

In case of sophisticated morphological conditions application of quasi 2D or 2D models might be necessary.

Flood distribution and inundation maps need to be examined through the use of 2D models

Preliminary Flood Risk Assessment – PFRA summary results



Greece: 1077 historic floods at different locations, which correspond to 1627 flood events, i.e. there are locations where more than one flood has occurred.

Flooding typology:

•211 floods have designated as "Flash floods",

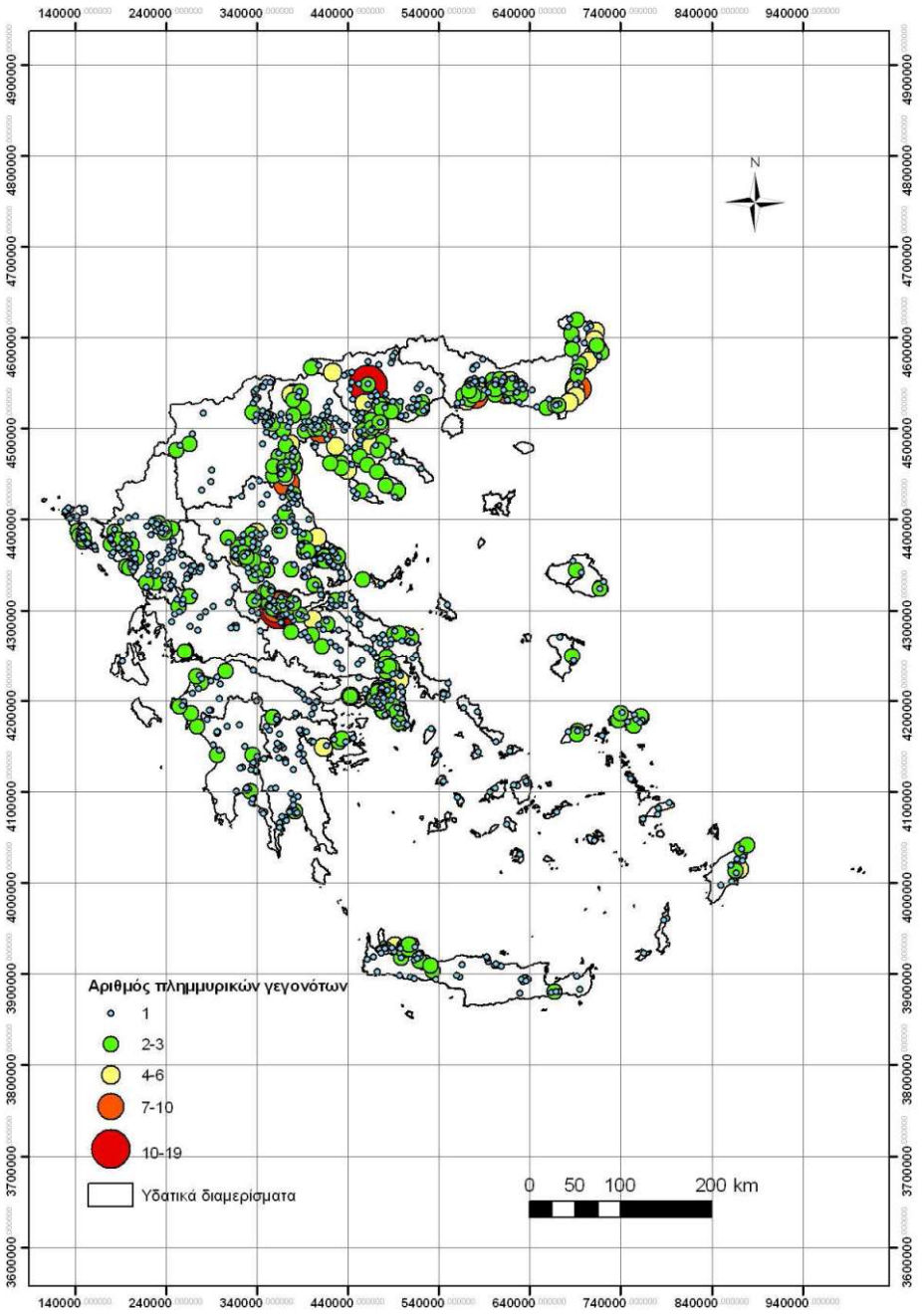
•18 have designated as "Other rapid onset",

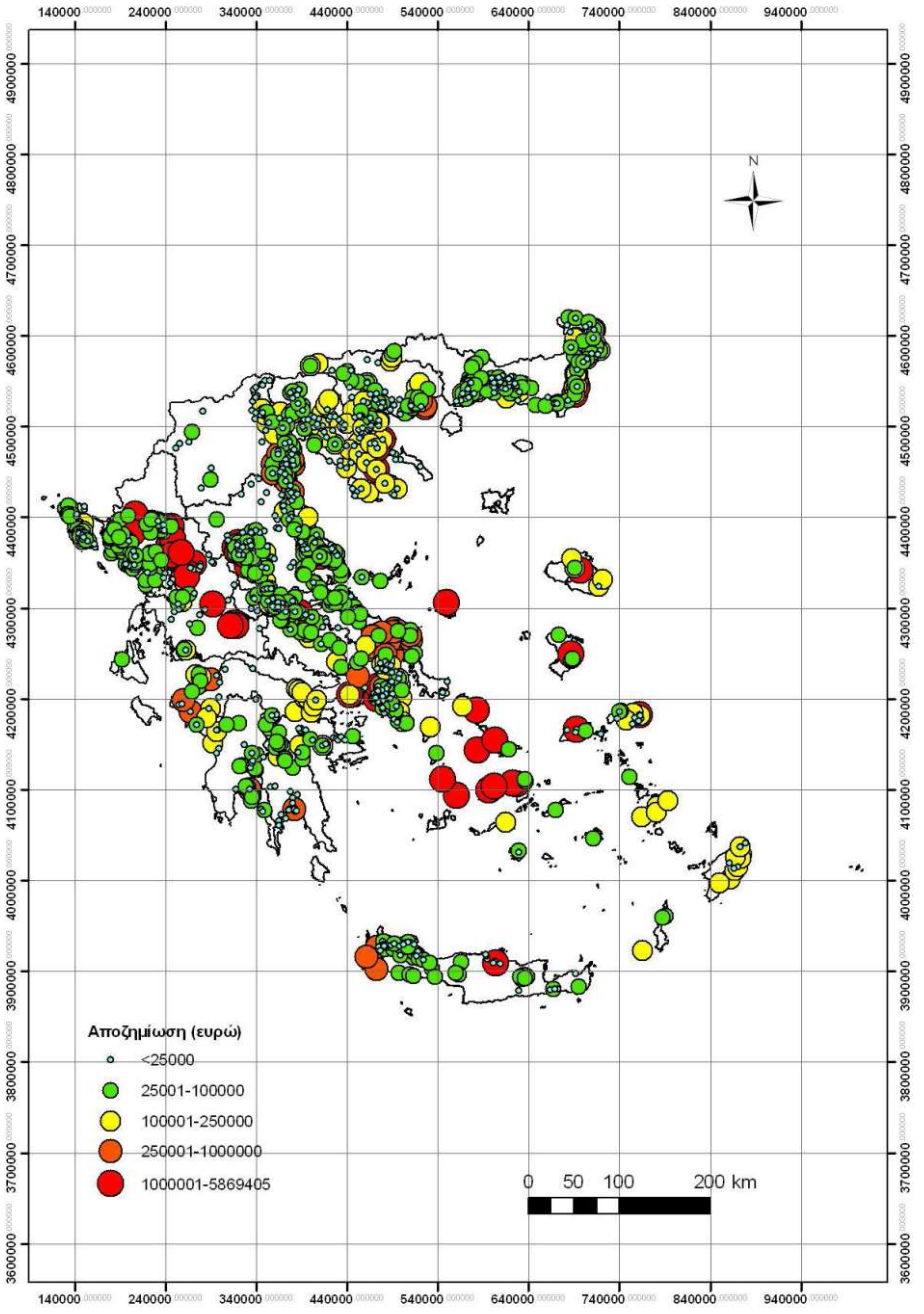
• 6 as "High Velocity Flow,

•1342 flood events there are "No data available on the characteristics of flooding".

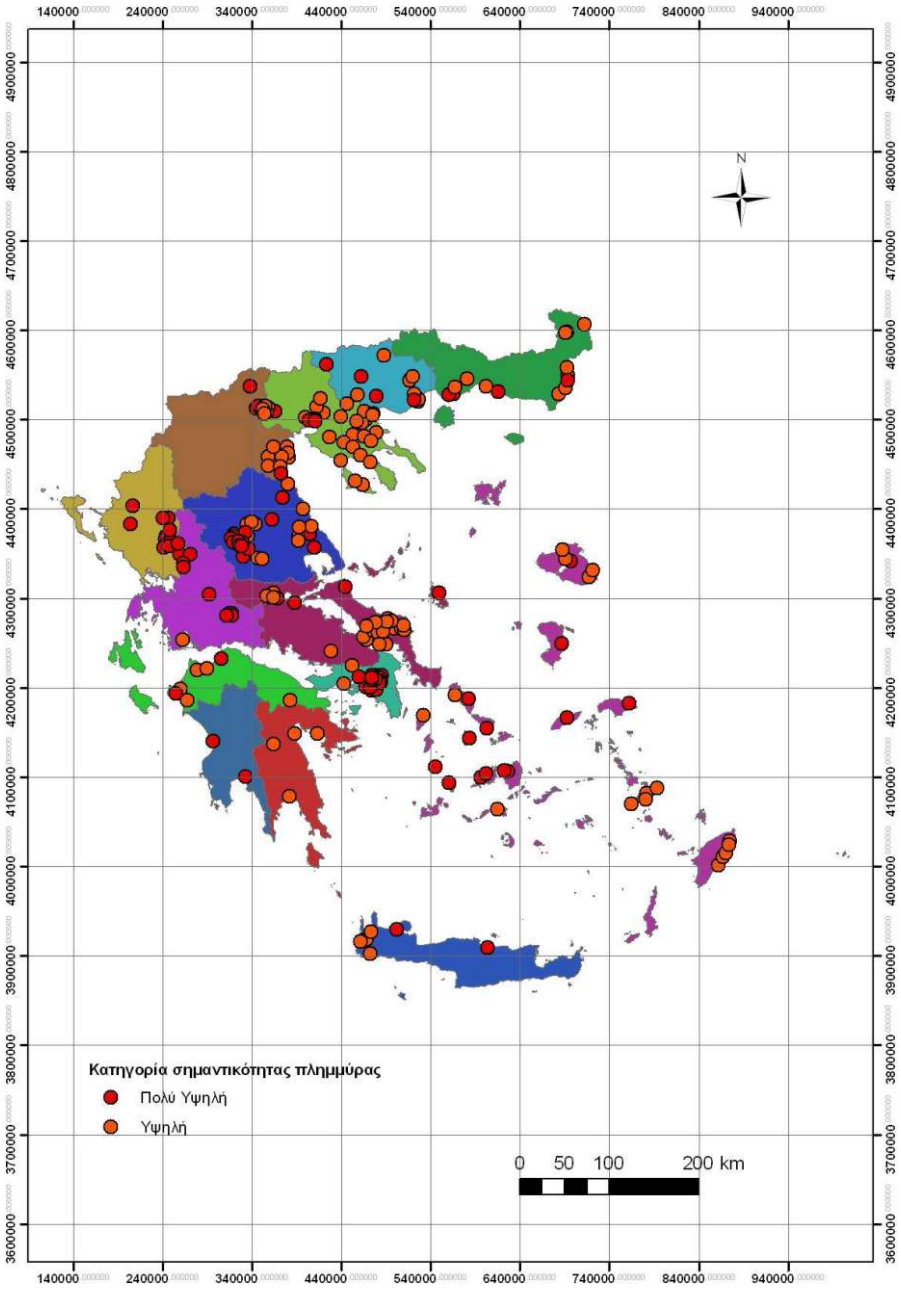
Axios : 36 historic floods at different locations.

Preliminary Flood Risk Assessment – PFRA summary results



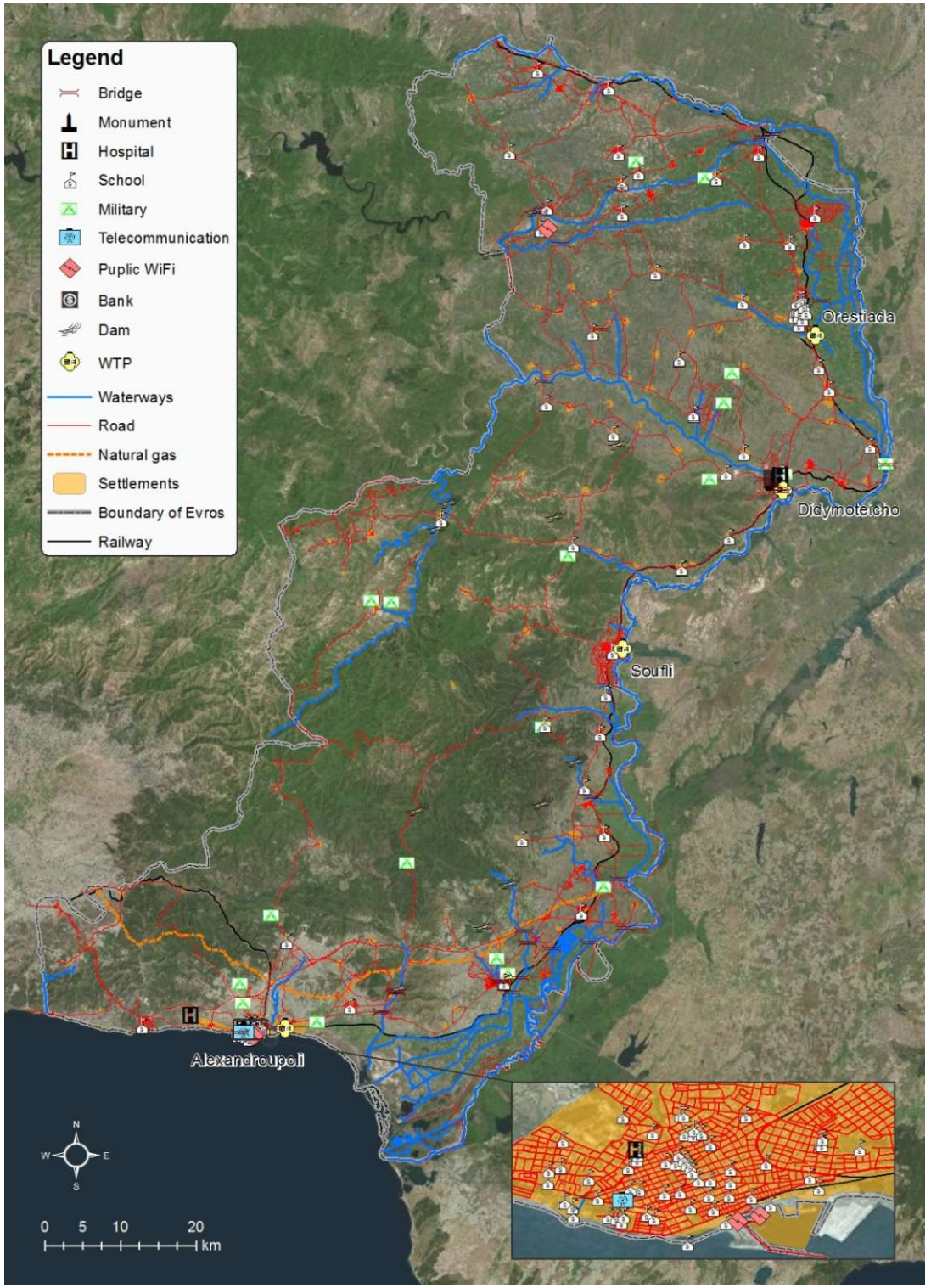


Preliminary Flood Risk Assessment – PFRA summary results



Significant historic floods

- 249 locations are denoted as significant historic flooding locations at national level.
- These locations correspond to 297 significant flooding events, i.e. there are locations where more than one significant flood has occurred.
- 61 floods are categorized as floods of type A31, i.e. flash floods. Unfortunately, these flash floods were almost all correlated to B11 category, i.e they have adverse consequences to human health (53 fatalities).


Legend
Bridge
Monument
Hospital
School
Military
Telecommunication
Puplic WiFi
Bank
Dam
WTP
Waterways
Road
Natural gas
Settlements
Boundary of Evros
Railway
Orestiada
Didymoteicho
Soufli
Alexandroupoli
N
W
E
S
0 5 10 20
km

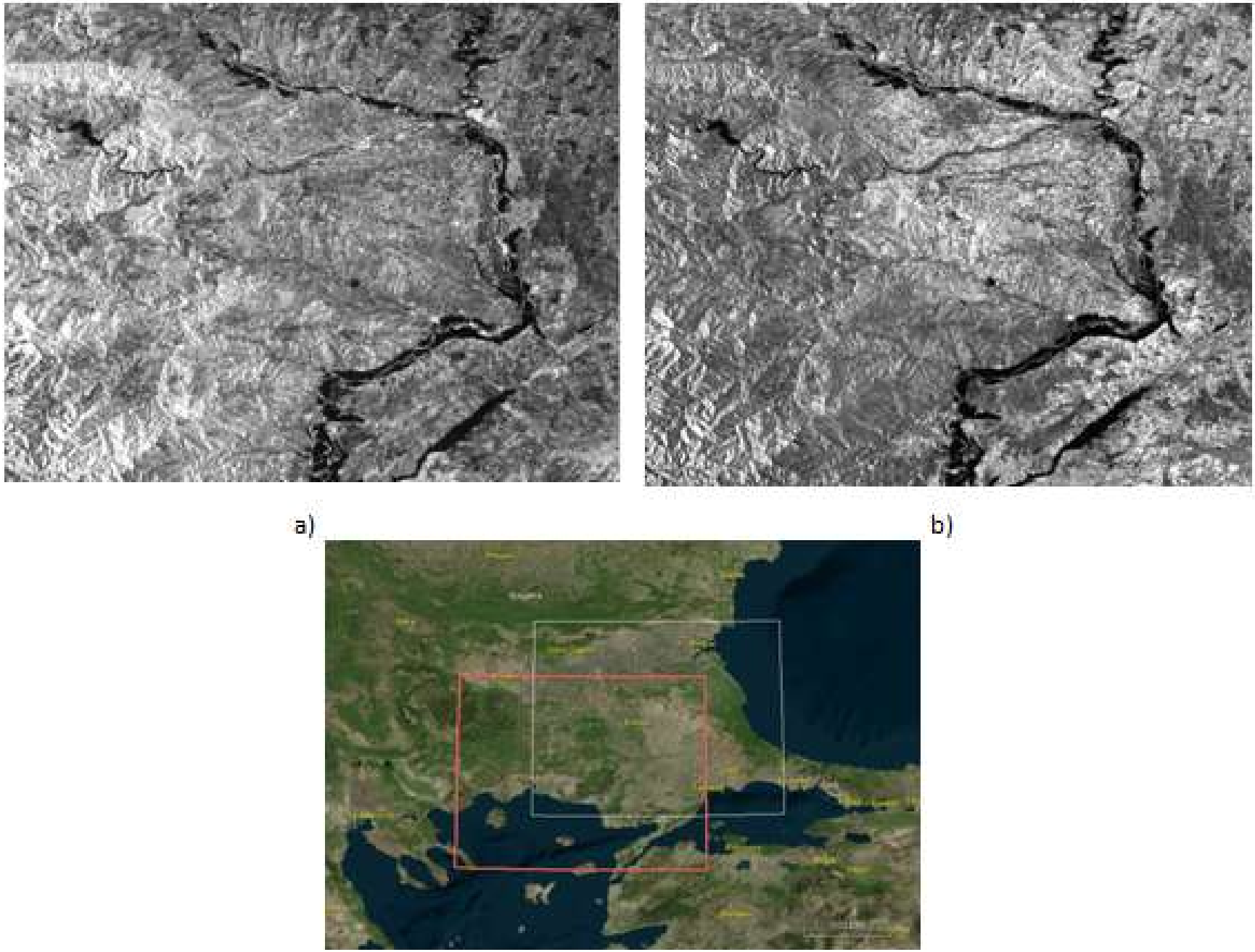
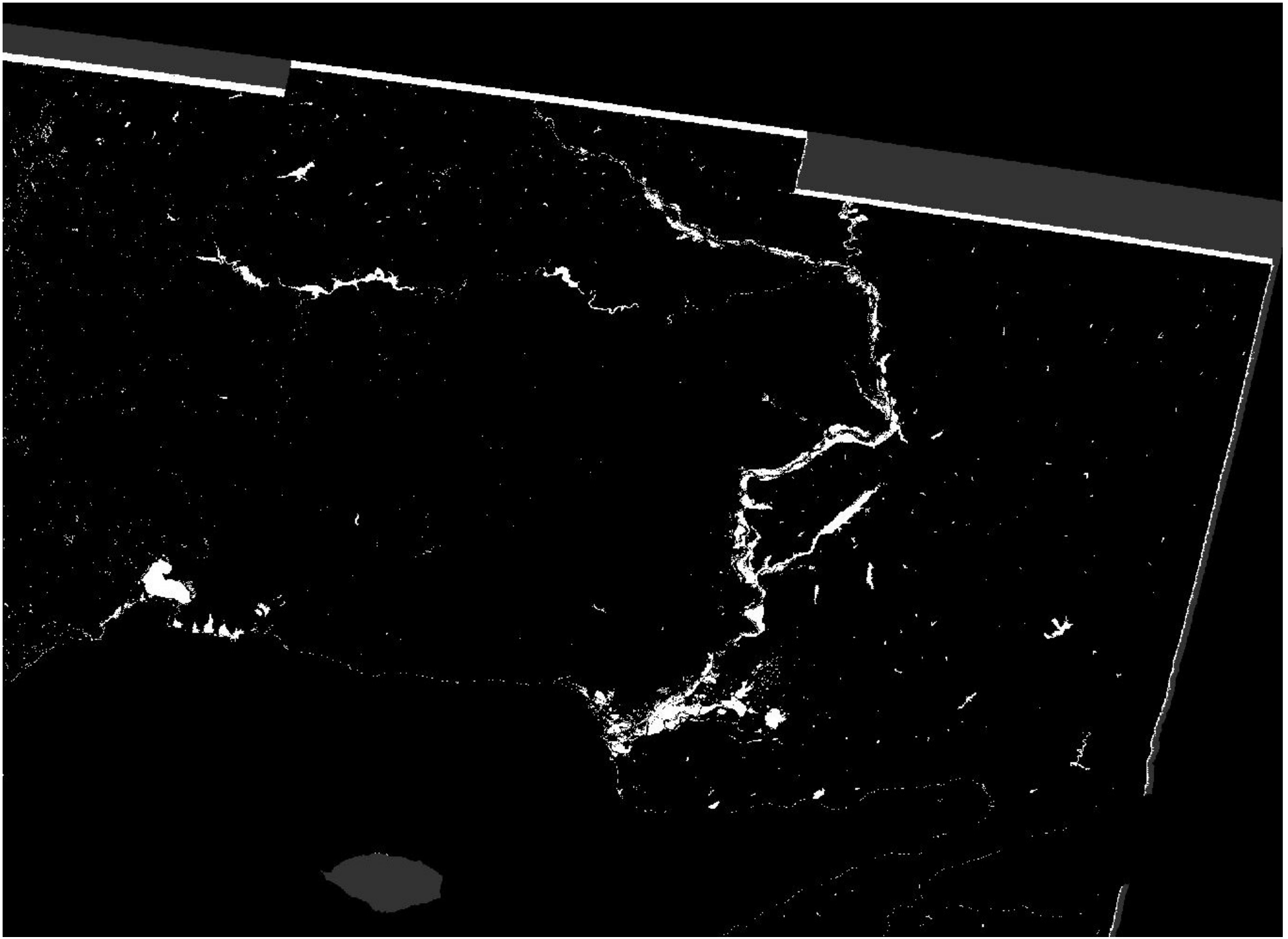
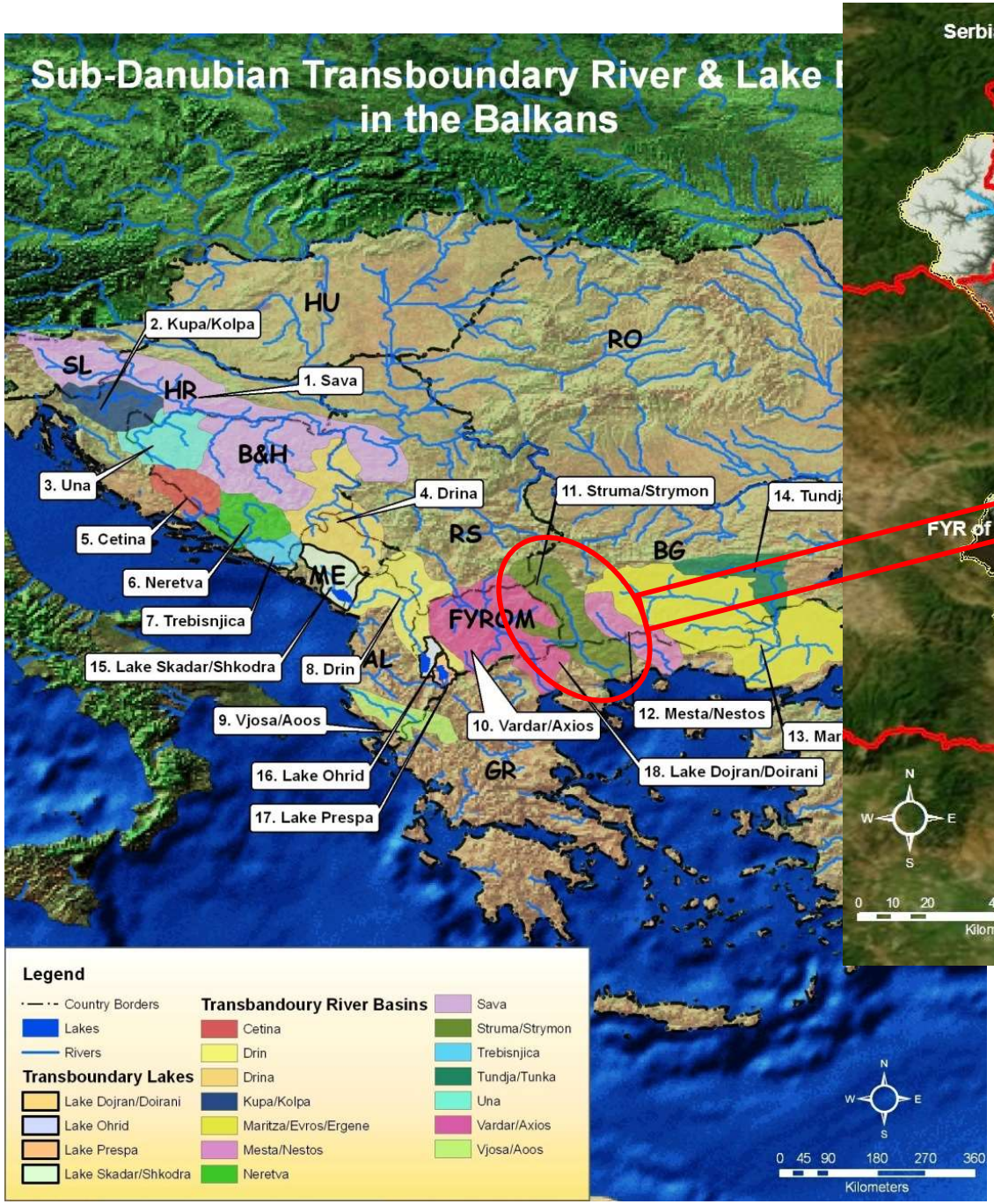


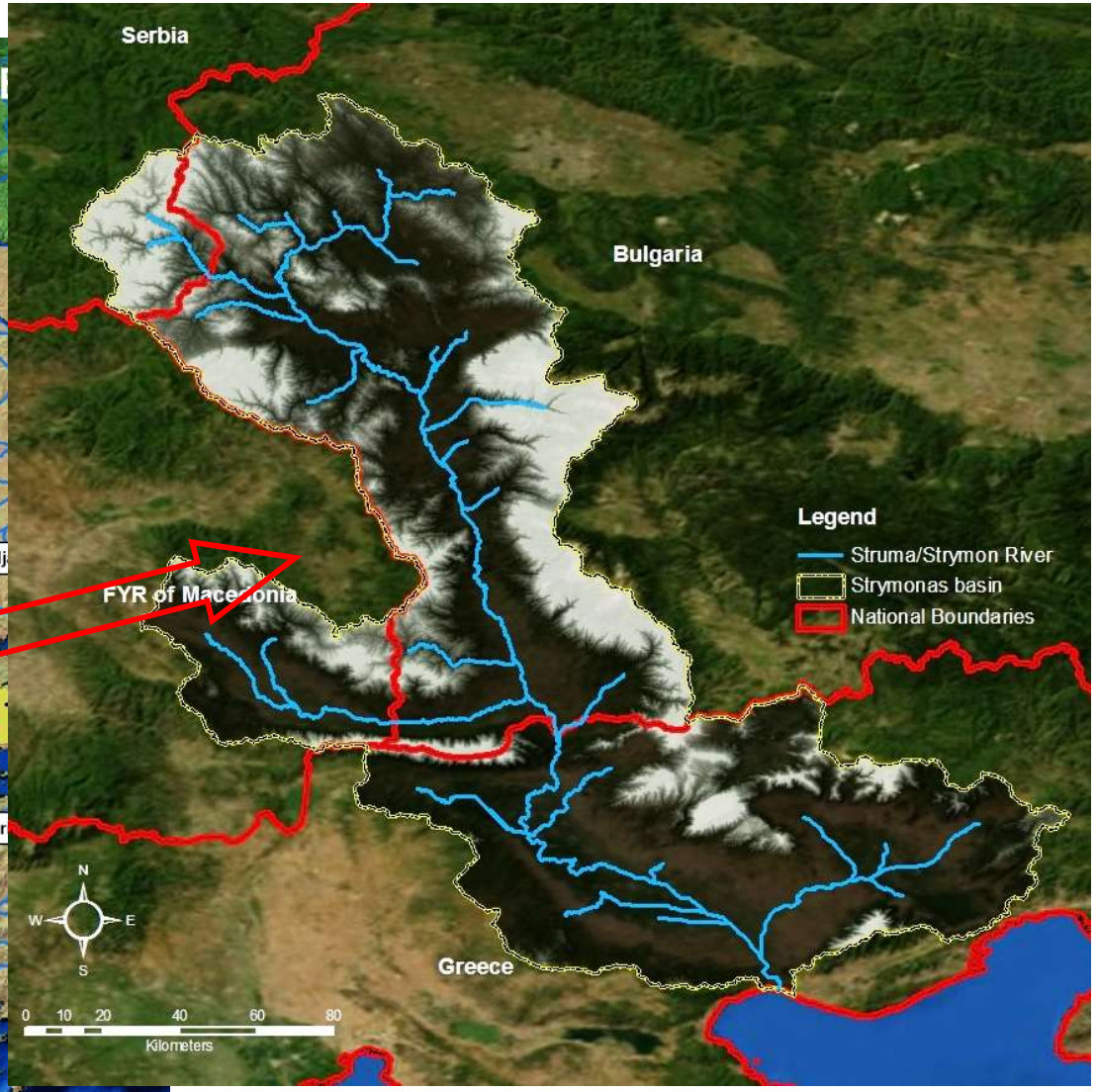
Figure. Time-series SAR images over a section of Evros River for a) 12/12/2014 and b) 13/12/2014.




Legend
Evros River
Flooded Areas
River Basin
Evros
N
W
E
S
0
10
20
40 Kilometers

Case study: The Strymon River basin

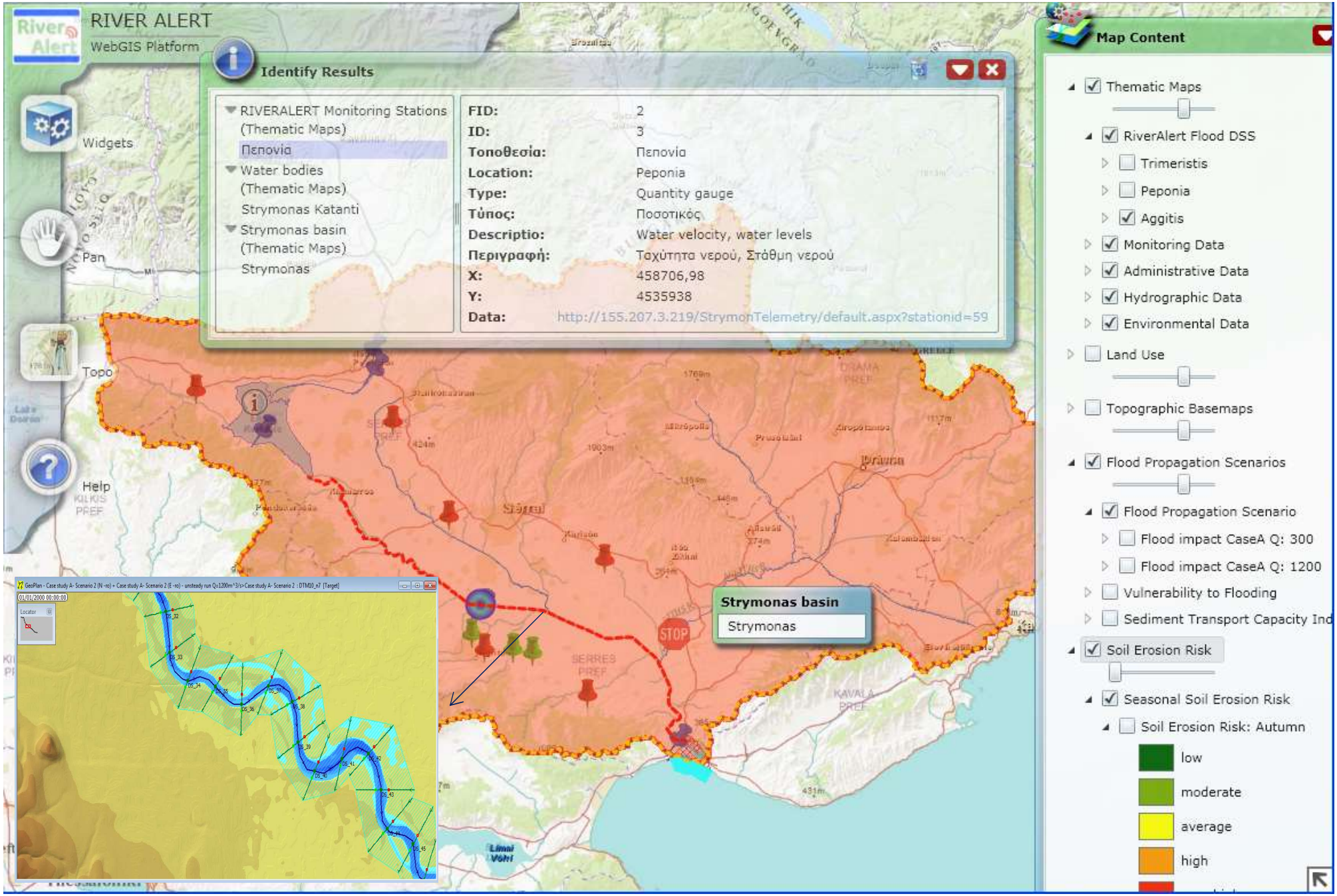




Basin area: 17,276 km²

- **8,734 km² (51%) in Bulgaria,**
- **6,439 km² (38%) in Greece,**
- **7% in FYROM, 4% in Serbia**

WebGIS for real time monitoring



WebGIS for real time monitoring

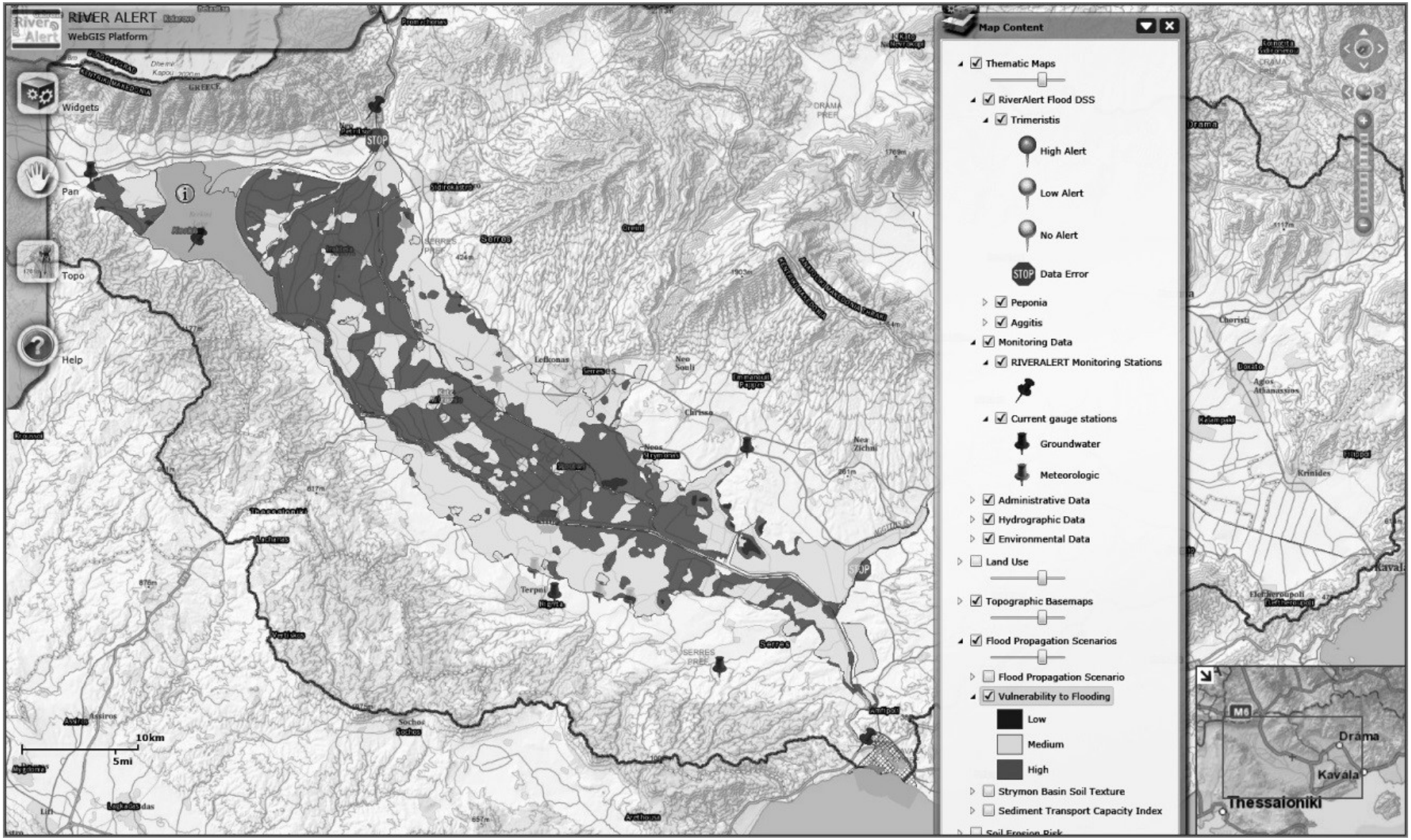


Illustration of monitoring stations and their operational status, and the area's vulnerability to floods for the Greek part of the Strymon transboundary river basin (Skoulikaris et al., 2014- IAHS Publications 363)

INSPIRE Directive

```
/MODSURNG_91915_V6H2/DOSPAT/FLOW/01JAN1991 - 01JAN1995/1DAY/MODSURNG/
M3/SEC
INST-VAL
05Aug
```

Modèle

Modèle

que

```
C   in the following OPEN.
C
      OPEN  ( UNIT=10, FILE='gpcp_v2_psg.1987', ACCESS='DIRECT',
     +          FORM='UNFORMATTED', STATUS='OLD', RECL=144*4,
     +      IOSTAT=iret )
        IF  ( iret .NE. 0 )  THEN
          WRITE (*, *) 'Error: open error', iret,
     +                 ' on file gpcp_v2_psg.1987'
          STOP
        END IF
C
C       Compute the number of records to skip, namely 1 for the header
C       and 72 for each intervening month.
C
        nskip = 1 + ( month - 1 ) * 72
C
C       Read the 72 rows of data and close the file.
C
        DO  10 j = 1, 72
c           READ ( UNIT=10, REC=j+nskip, IOSTAT=iret )
        READ ( UNIT=10, REC=j+nskip)
     +           ( data (i, j), i = 1, 144 )
          IF  ( iret .NE. 0 )  THEN
            WRITE (*, *) 'Error: read error', iret,
     +                   ' on file gpcp_v2_psg.1987'
            STOP
```

```
**********
**********
**********
**********
0.2306    0.2338
0.3997    0.4175
0.6100    0.6496
0.8544    0.9214
1.1265    1.2254
1.4193    1.5538
1.7273    1.9003
2.0464    2.2601
2.3734    2.6296
2.7058    3.0058
```

```
size=(char
 1.8736877
 2.1380784
-3.3073869
-4.8036740
-1.3563481
```

Dor

changement climatique

nées

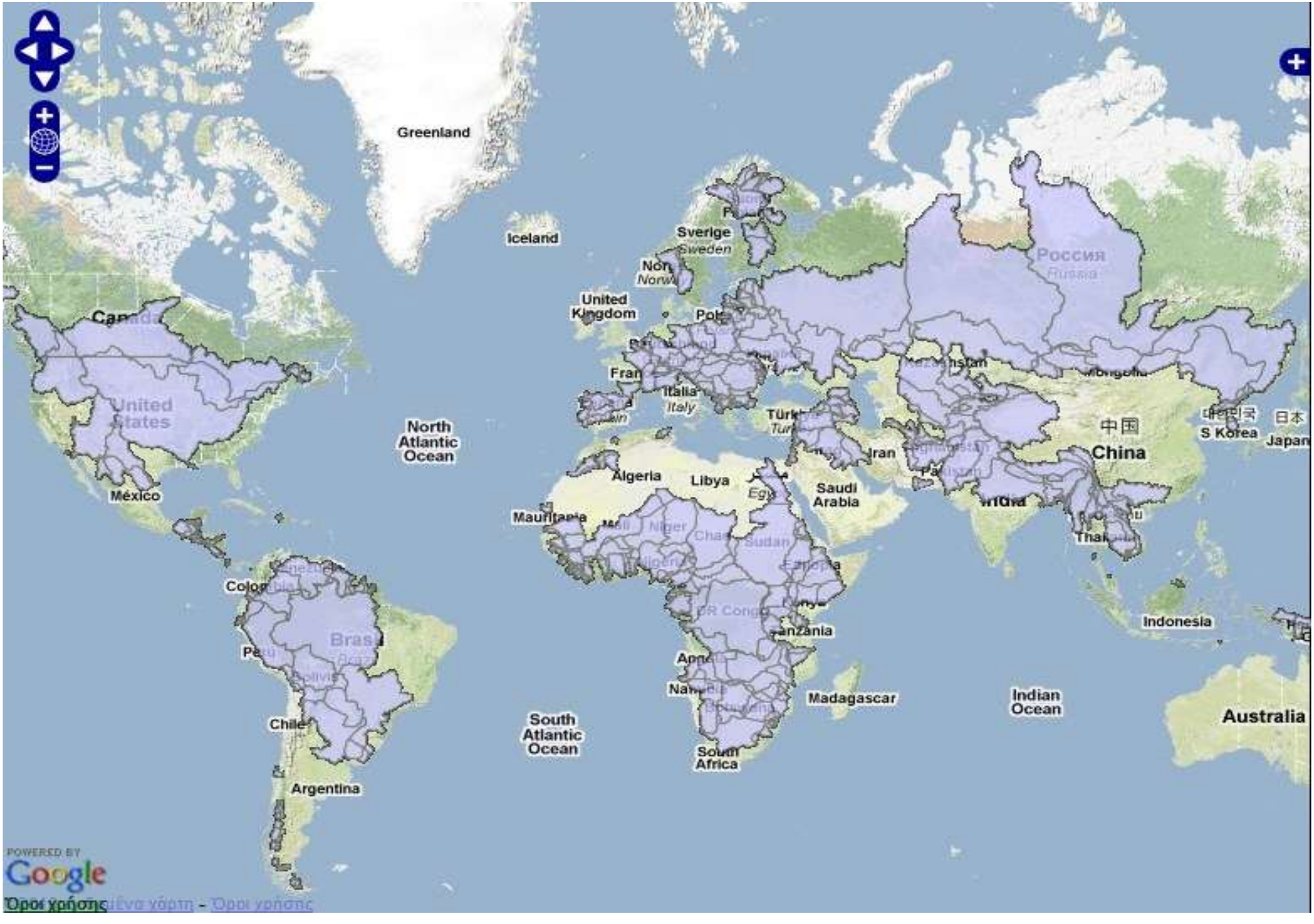
```
 -----------
 Negative latitudes indicate South and negative longitude indicate West.

INDEX   LATITUDE                  INDEX    LONGITUDE
   1)   88.750                       1)   1.250
   2)   86.250                       2)   3.750
   3)   83.750                       3)   6.250
```

Homogenization of data

- **Spatial homogenization**
- **Temporal homogenization**
- **Values with common units**

The necessity is greater for the management of international water resources

The world's transboundary river basins



Spatial homogenization of data

The INSPIRE Directive

The INSPIRE (Infrastructure for Spatial Information in the European Community) directive (2007) aims to create a European Union (EU) spatial data infrastructure.

This will aim at making available relevant, harmonised and quality geographic information to support the formulation, implementation, monitoring and evaluation of policies and activities which directly or indirectly impact the environment.

A European Spatial Data Infrastructure will assist in policy-making across boundaries

Principles of the INSPIRE Directive

- **Data should be collected only once**
- **It should be possible to combine seamless spatial information from different sources across Europe and share it with many users and applications.**
- **Easy to find what geographic information is available, how it can be used to meet a particular need, and under which conditions it can be acquired and used.**

Spatial data themes of INSPIRE

INSPIRE requires EU Members States to share 34 different spatial data themes through a network of 'services'.

Annex I

1 Coordinate reference systems
2 Geographical grid systems
3 Geographical names
4 Administrative units
5 Addresses
6 Cadastral parcels
7 Transport networks
8 Hydrography
9 Protected sites

Annex II

1 Elevation
2 Land cover
3 Orthoimagery
4 Geology

Annex III

1 Statistical units
2 Buildings
3 Soil
4 Land use
5 Human health and safety
6 Utility and governmental services
7 Environmental monitoring Facilities
8 Production and industrial facilities
9 Agricultural and aquaculture facilities
10 Population distribution and demography
11 Area management / restriction / regulation zones & reporting units
12 Natural risk zones
13 Atmospheric conditions
14 Meteorological geographical features
15 Oceanographic geographical features
16 Sea regions
17 Bio-geographical regions
18 Habitats and biotopes
19 Species distribution
20 Energy Resources
21 Mineral Resources

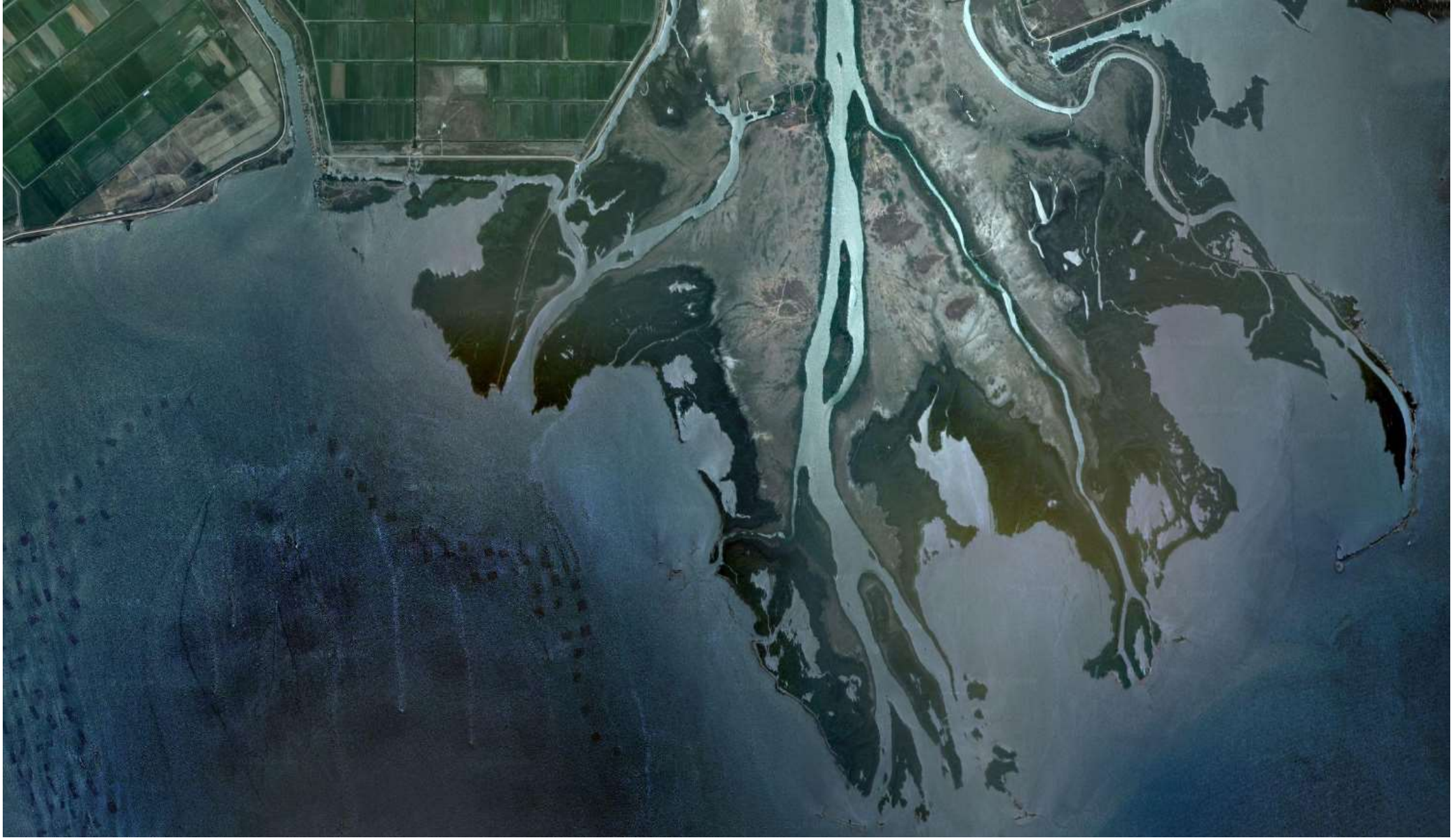
Implementing Rules of INSPIRE

The directive also requires the adoption of the following rules:

- **Metadata: Descriptions of available information (spatial data sets, series and services).**
- **Data specifications: Agreements on how data should be defined and presented, or modelled into 'virtual reality' - for example, defining the width of a highway lane for standardized mapping.**
- **Network and sharing services: Discovery, view, download, transformation and invoke services.**

Example of metadata

```
<gmd:MD_Metadata xmlns:gmd="http://www.isotc211.org/2005/gmd
" xmlns:xsi="http://www.w3.org/2001/XMLSchema-
instance" xmlns:xlink="http://.....
  <gmd:organisationName>
  <gco:CharacterString>
  MEDDE/DGPR/SRNH - Bureau des risques météorologiques
  </gco:CharacterString>…..

      <NameofAPSFR>CENTRE_GUADELOUPE</NameofAPSFR>
      <LAT>16.294</LAT>
      <LON>-61.414</LON>
      <TypeofFloods>
      <SourceofFlooding>A12</SourceofFlooding>
      <SourceofFlooding>A11</SourceofFlooding>
      <SourceofFlooding>A14</SourceofFlooding>


  <SummaryofMethodology>
  Un TRI est une portion du territoire guadeloupéen
  présentant les caractéristiques suivantes :
```



Thank you for your attention!

hskoulik@civil.auth.gr