UNESCO-IHE
4th International SWAT Conference
Delft 4-6 July 2007

"LAND Use Change Effects on River Sediment Yields in Western Greece "

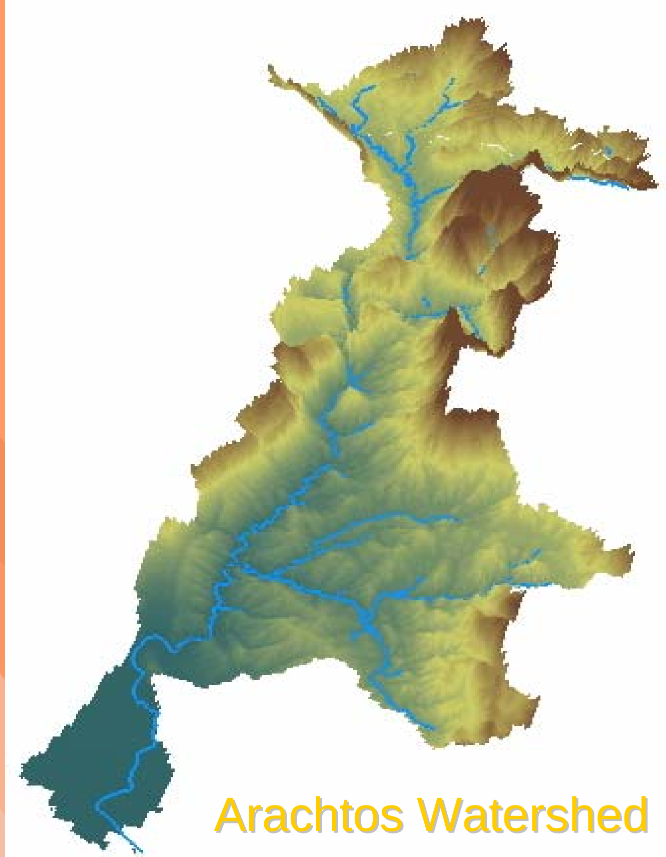
Y. Panagopoulos, E. Polyzoi and M. Mimikou

Laboratory of Hydrology and Water Resources Management, Department of Water Resources and Environmental Engineering, School of Civil Engineering, National Technical University of Athens

The Greek- Pilot Hydrological Basin

The water district of Epirus generally, has a great amount of water potential, big rivers and secondary torrents

Selected Study Area: Arachtos Watershed

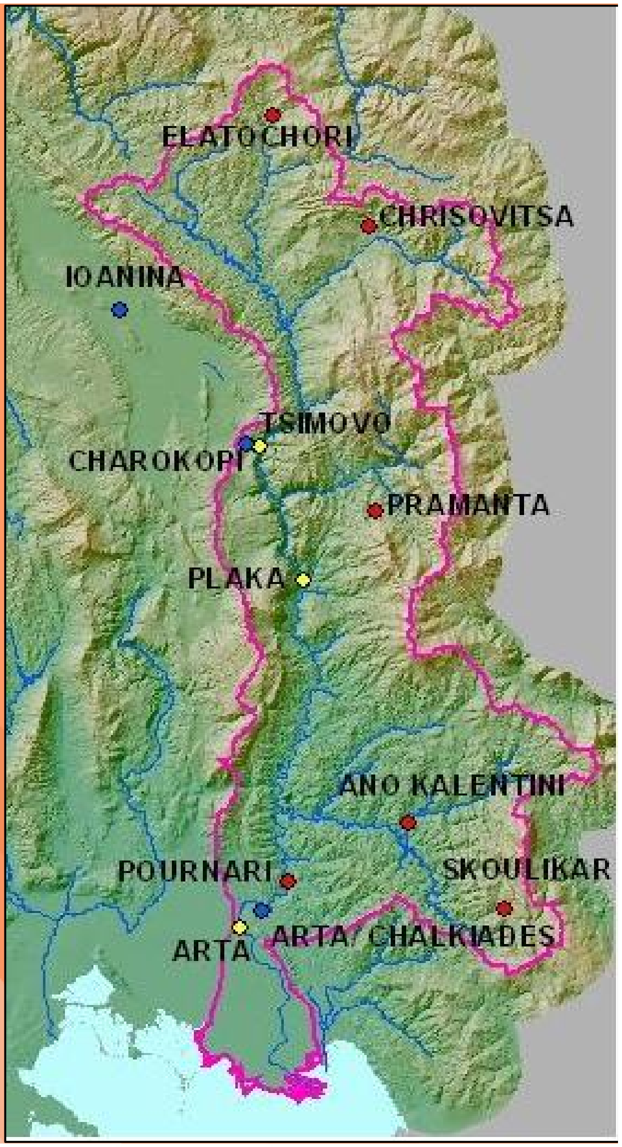


Criteria of choice

- ✓ Intense Meteorological and Hydrological Phenomena (Rainfalls, Flows)
- ✓ Significant Erosive Processes – Soil Losses
- ✓ Anthropogenic Intervention along the river (Dam Pournari)
- ✓ Changes in the status of the coast

Arachtos Watershed

- Arachtos springs from the mountain range of Pindos and flows into the Amvrakikos gulf
- The mean annual precipitation is about 1500 mm
- The area of the basin is 2000 km^2
- The climate is characterized as Mediterranean with a hot and dry summer and a wet and not very cold winter
- The mean annual temperature is 15°C
- The elevation range is 0 – 2400m
- The length of the main stream is about 110 km and the average annual flow 60m^3/s
- Sites with available observations of flows and sediment yields (Tsimovo, Plaka and Arta)
- Arta city is located 3 km downstream the Pournari site



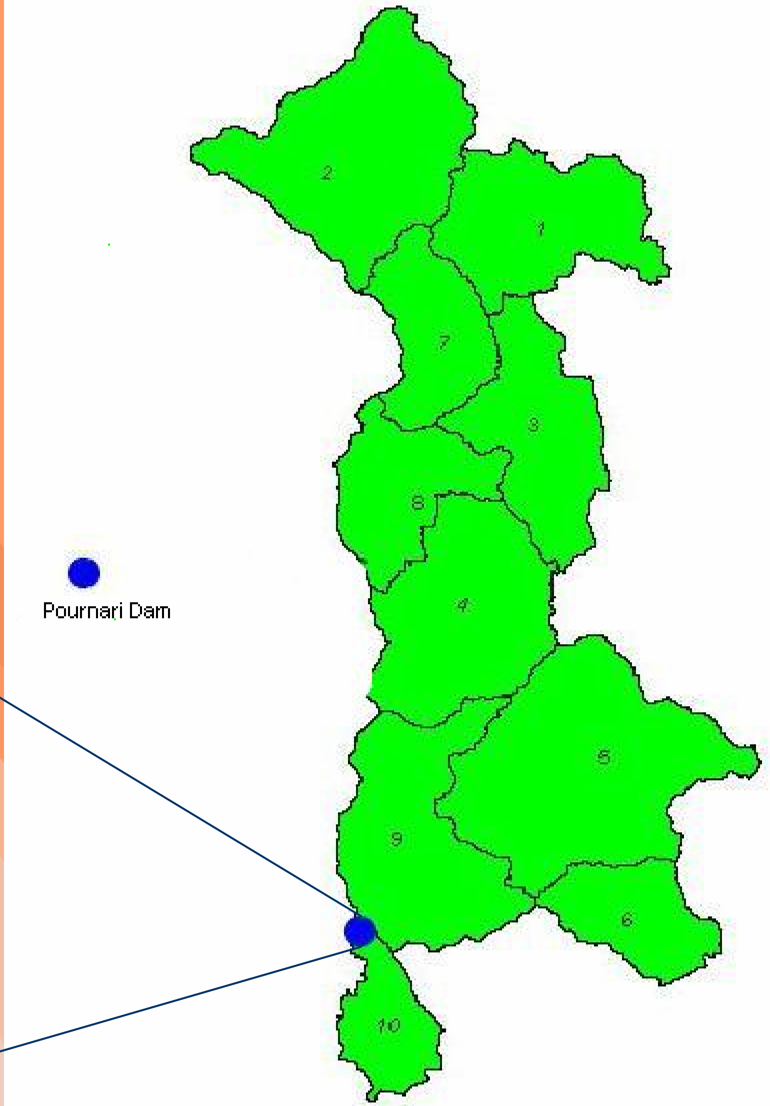
NATIONAL TECHNICAL UNIVERSITY OF ATHENS
SCHOOL OF CIVIL ENGINEERING, LABORATORY OF HYDROLOGY AND WATER RESOURCES MANAGEMENT
PROFESSOR M.A. MIMIKOU

Anthropogenic Intervention

From 1981 the Arachtos river has suffered alterations due to a big dam construction of total storage capacity: 865 x 10^6 m^3 (Pournari)

Multiscope:

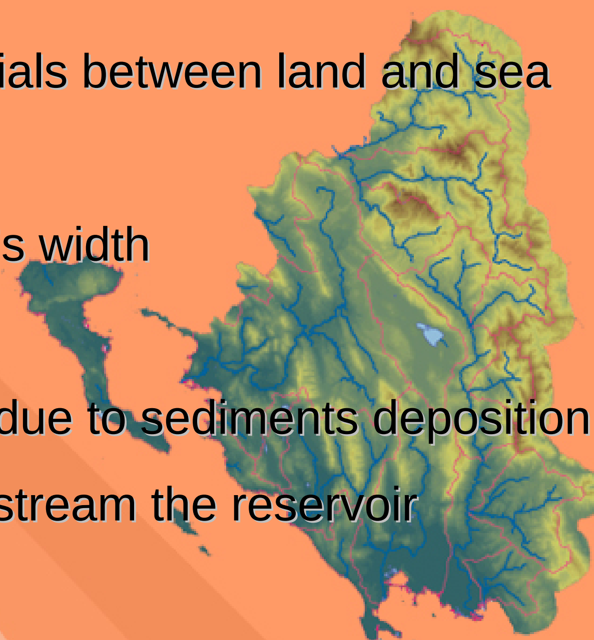
- Hydropower production
- Water supply for the city of Arta
- Flood protection
- Irrigation in summer months



Current Situation

The dam operation during the last 25 years has caused:

- Disturbance in the coastal zone environment
- Disturbance of the dynamic equilibrium of exchanged materials between land and sea
- Significant retreat of the lowest part of the river mouth
- Changes of the river curvature and enlargement of the river’s width
- Changes in the shape of lagoons
- Significant decrease of the reservoir dead storage capacity due to sediments deposition
- Significant decrease of the annual sedimentation rate downstream the reservoir



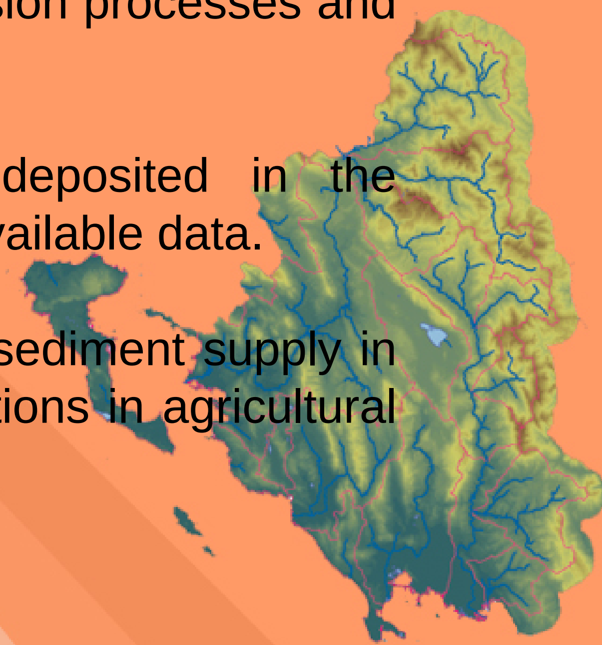
The dam trap efficiency has been estimated above 90%

Targets of the Study

★ Modelling of the Arachtos river basin with the SWAT model (AVSWAT2000) in order to completely simulate the erosion processes and sediment transport mechanisms.

★ Accurately quantify sediments transported and deposited in the reservoir bed by calibrating the model in three sites of available data.

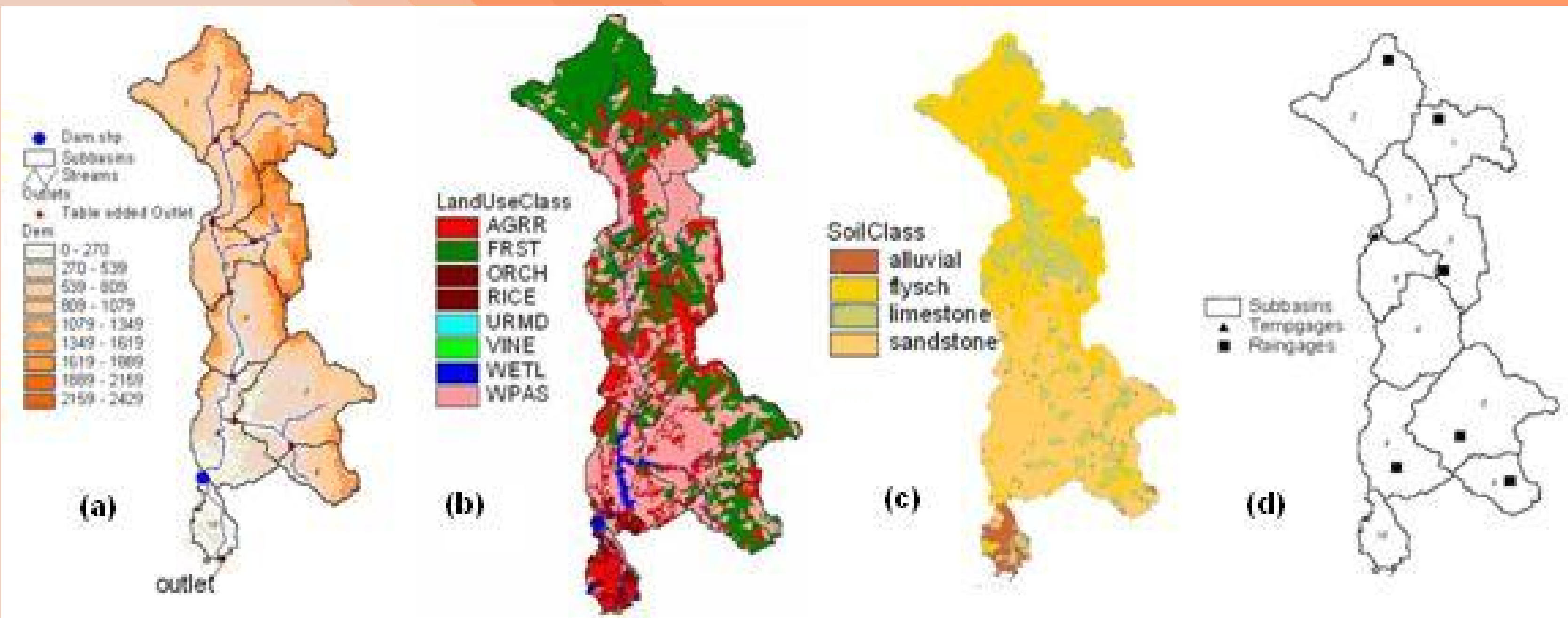
★ Quantifying the reduction of catchment erosion and sediment supply in the reservoir due to land use changes related to alterations in agricultural practices.



NATIONAL TECHNICAL UNIVERSITY OF ATHENS
SCHOOL OF CIVIL ENGINEERING, LABORATORY OF HYDROLOGY AND WATER RESOURCES MANAGEMENT
PROFESSOR M.A. MIMIKOU

Model Inputs

Digital Elevation Model (DEM) | Land Use Map | Soil Map | Meteorological Information



Elevation
- Range 0-2400 m
- Mean 785 m

Land Uses
- Forest (30%)
- AGRR (20%)
- Orchards, Vines and Pastureland (40%)

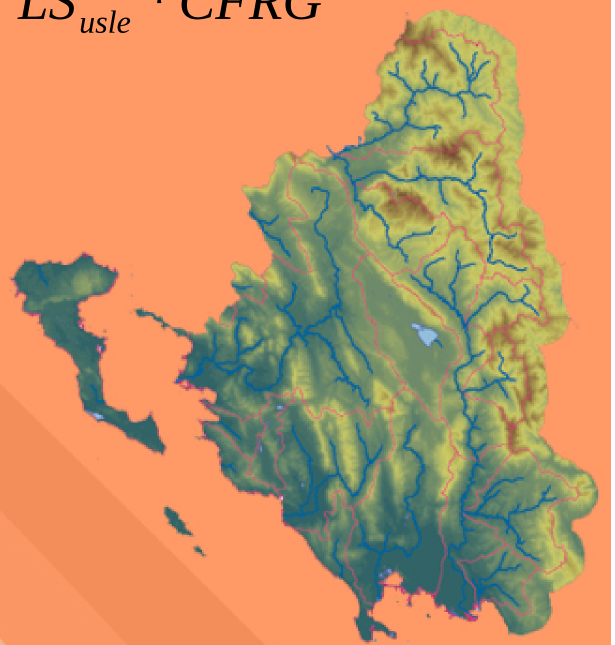
Geology
- Alluvial
- Flysch
- Sandstones
- Limestones

Meteorology
- Daily data from various stations around the catchment

Sediment Yields

Modified Universal Soil Loss Equation:

$$sed = (11{,}8 * Q_{surf} * q_{peak} * area_{hru})^{0{,}56} * K_{usle} * C_{usle} * P_{usle} * LS_{usle} * CFRG$$



sed is the sediment yield on a given day (metric tons)

Qsurf is the surface runoff volume (mm H2O/ha)

qpeak is the peak runoff rate (m3/s)

areahru is the area of the HRU (ha)

K_{USLE} is the USLE soil erodibility factor

C_{USLE} is the USLE cover and management factor

P_{USLE} is the USLE support practice factor

LS_{USLE} is the USLE topographic factor

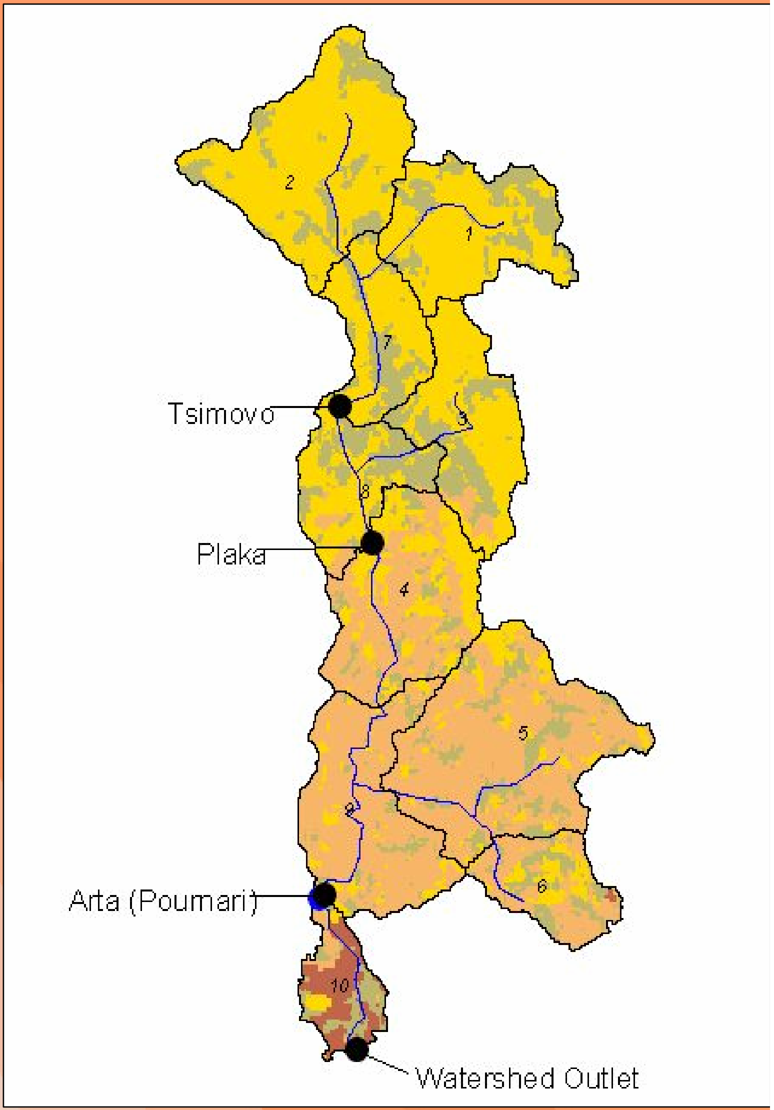
CFRG is the coarse fragment factor

Calibration - Validation

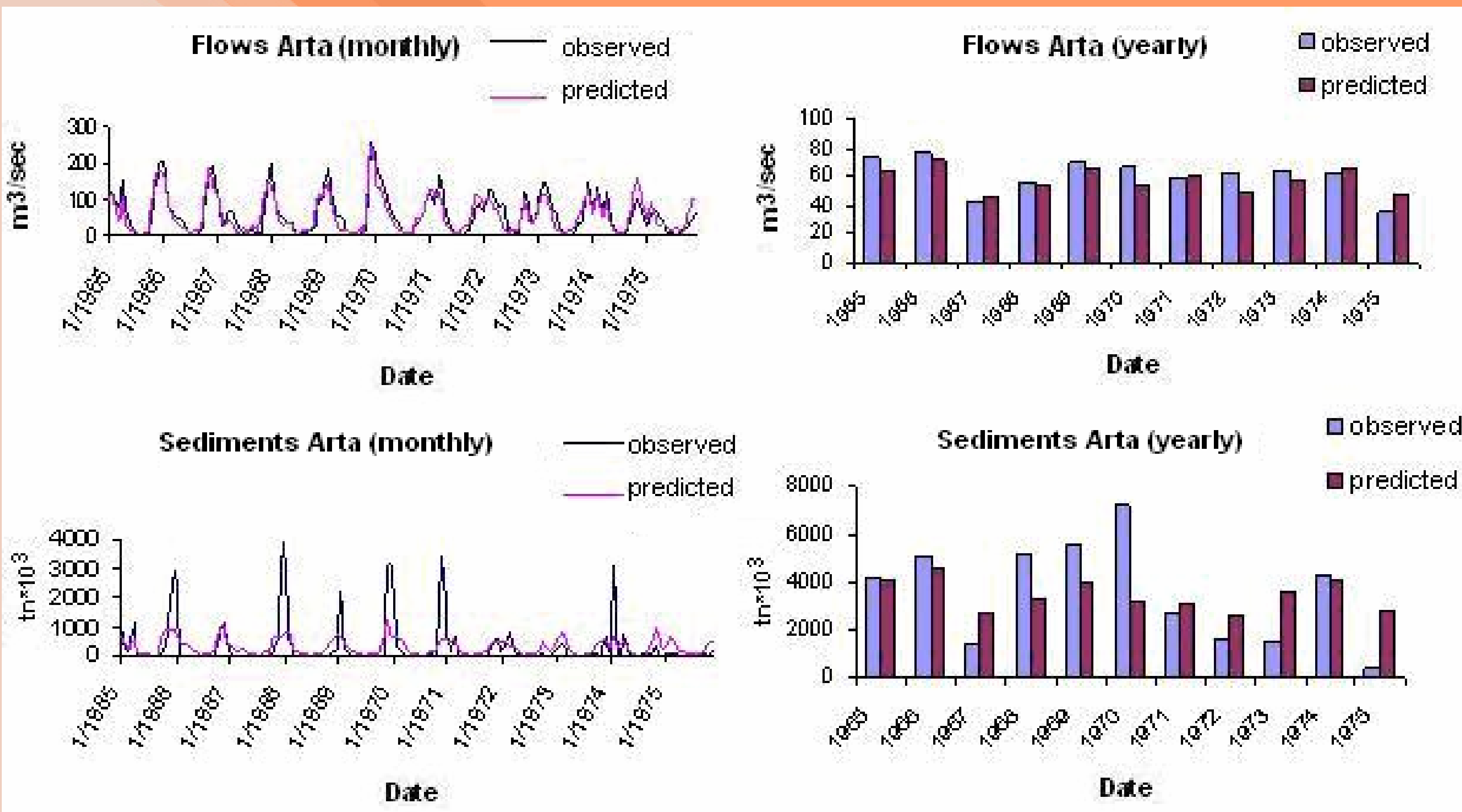
Calibration: Adjustment of parameter values for sufficient simulation
Validation: Comparison between predictions and an independent data set

Calibration and Validation were carried out:

- At 3 sites (Tsimovo, Plaka, Arta)
- In monthly and annual time step
- With the use of 10-12 years (1965-1976) of available data divided into two equal-length time series.
- Evaluation of the results using NTD-RMSE-R^2



Flow and Sediment Predictions in Arta



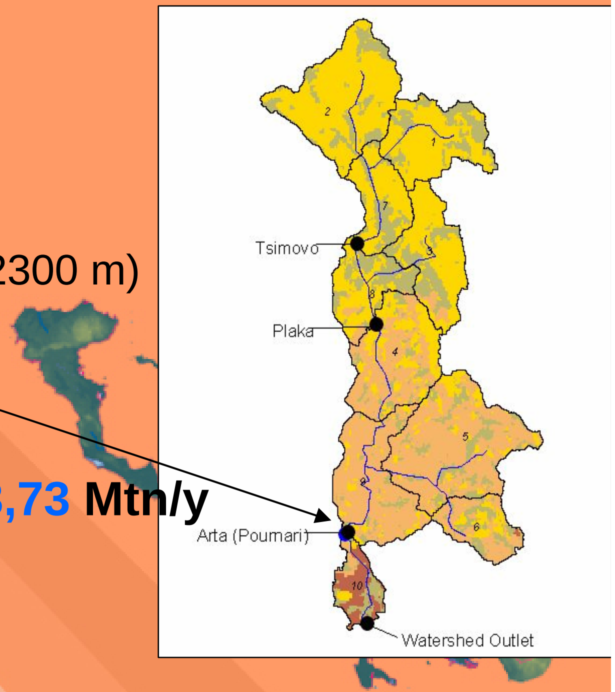
Numerical results – Comparison to Other Methodologies

Mean annual sedimentation rate at Arta predicted by SWAT - 3,8 Mtn/y

Syvitski et al, 2003 'Predicting the terrestrial flux of sediment to the global ocean: a planetary perspective' Sed. Geol. Vol 162, pp. 5-24.

$$Q_s = 1.1 \times 10^{-3}\, Q^{0.53}\, R^{1.1}\, e^{0.06T}$$

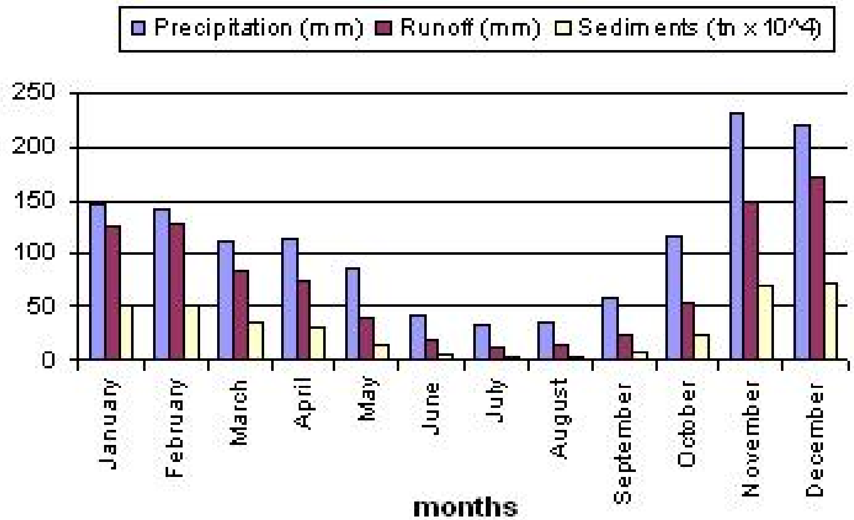
Qs is the long term sediment load (kg/s)
R is the maximum relief from catchment outlet to the mountain top (2300 m)
T is the mean annual temperature (15ºC)
Q is the average annual water discharge (60m³/s).

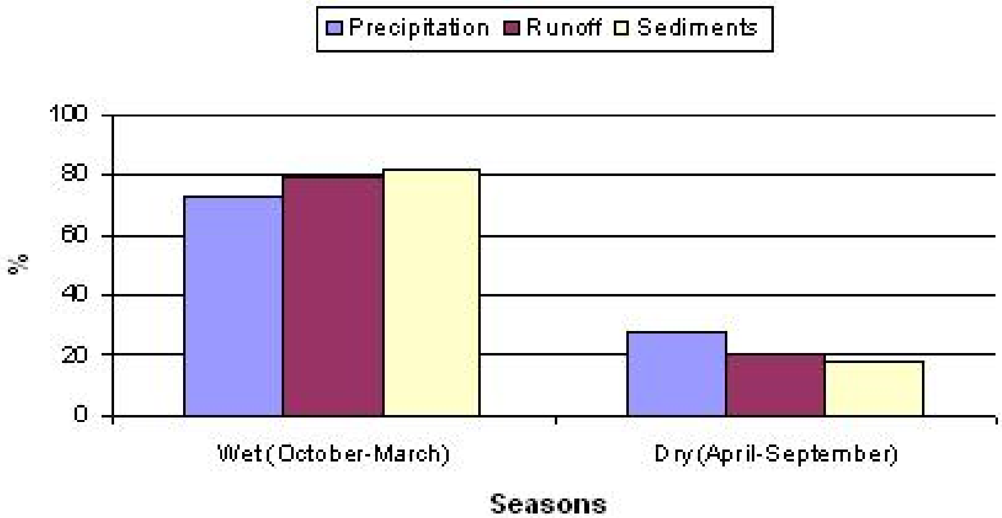


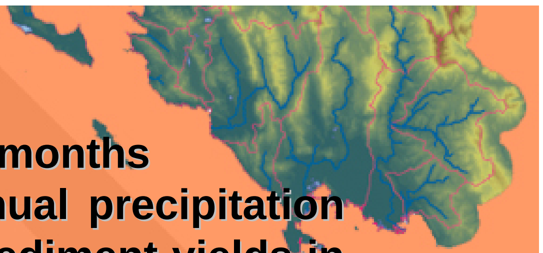
Mean annual sedimentation rate predicted by Syvitski - 3,73 Mtn/y

NATIONAL TECHNICAL UNIVERSITY OF ATHENS
SCHOOL OF CIVIL ENGINEERING, LABORATORY OF HYDROLOGY AND WATER RESOURCES MANAGEMENT
PROFESSOR M.A. MIMIKOU

Seasonal Variations of Flows and Sediments

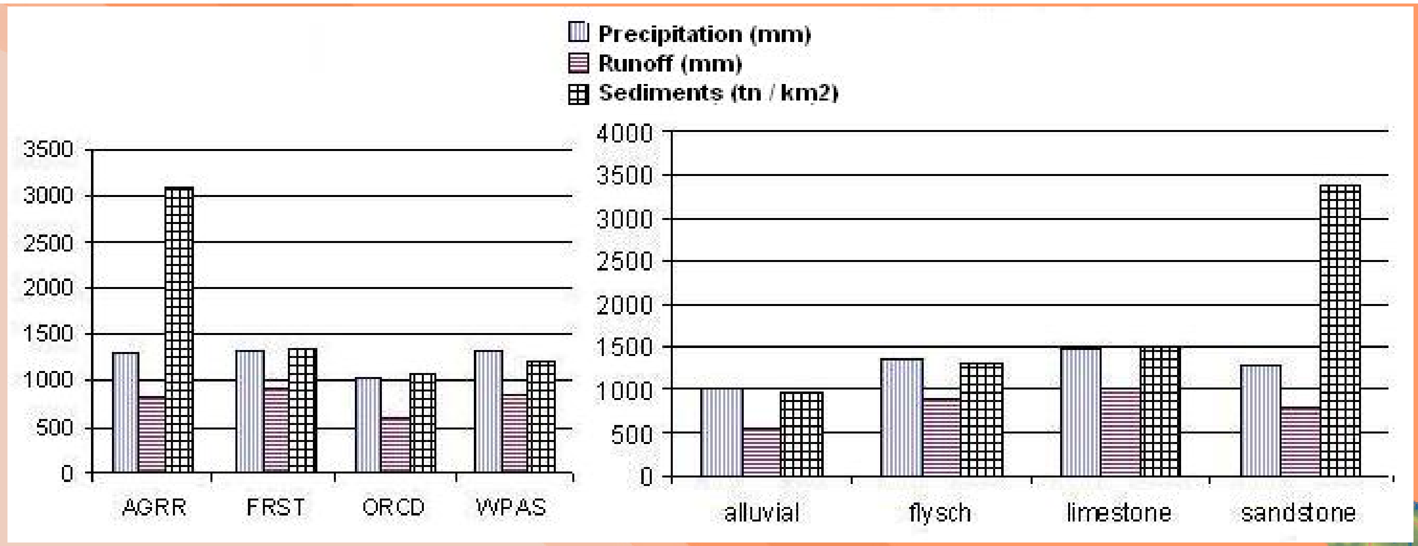






•Runoff and sedimentation rates were maximized during winter months
•During the wet period (October-March) 76% of the mean annual precipitation occured causing 80% and 82% of the mean annual water and sediment yields in Arta.

Runoff and Soil Losses Generation



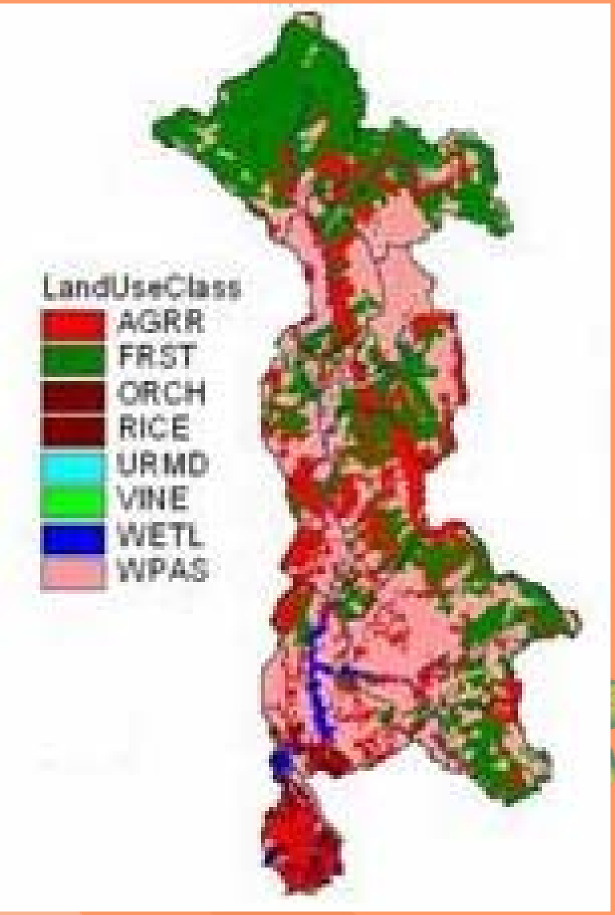
Calibration values of MUSLE factors determining soil losses

MUSLE coef / Landcover type	Forest	Arable land	Pasture	Orchard Trees
C_{USLE}	0.001	0.2	0.003	0.001
P_{USLE}	1.00	1.00	1.00	1.00
MUSLE coef / Soil type	Alluvial	Sandstones	Flysch	Limestones
K_{USLE}	0.10	0.20	0.12	0.15
CFRG	10%	10%	10%	10%

C_{USLE} and K_{USLE} are the major factors that govern the erosion susceptibility of the different landcover and soil types respectively

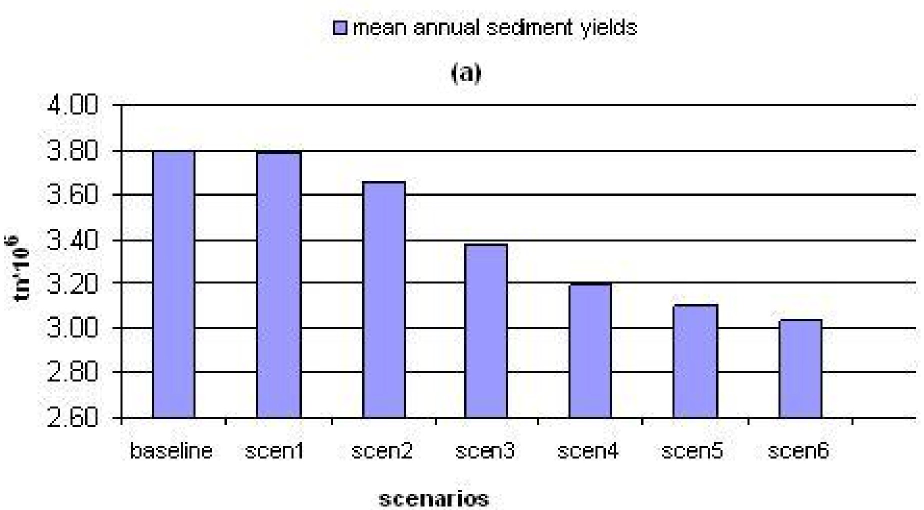
Construction of Land Use Change Scenarios

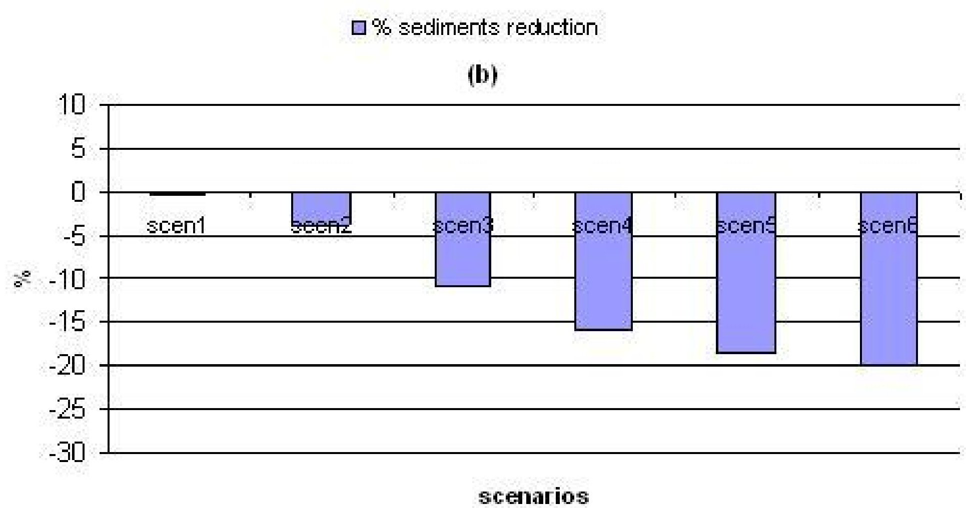
- Scenarios applied only in the agricultural land of row crops (20% of the total area, 30% of the total agricultural land)
- Crop rotations and application of support management practices (contour cultivation, strip-cropping on the contour, terrace systems)
- Alteration of the mgt files for the HRUs with AGRR as landcover type
- Change of values according to the theoretical base of SWAT (Theoretical documentation for changes in USLE_C and USLE_P factors)
- Execution of the model for the same period keeping all the other parameters of the original calibration stable



Scenarios and Results

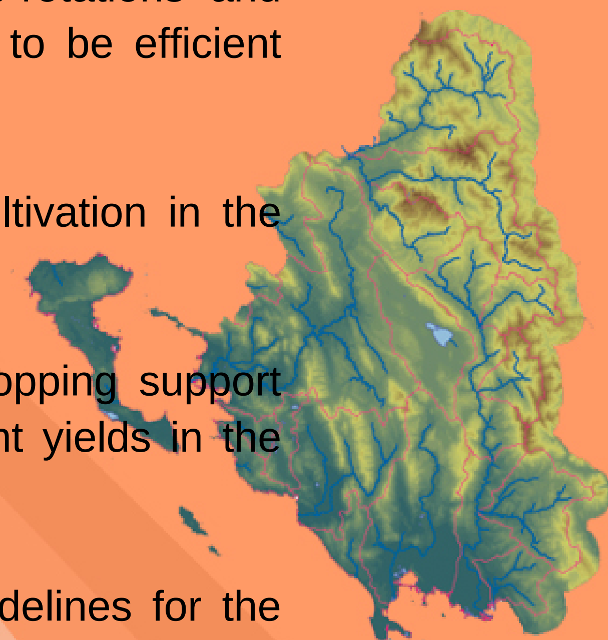
	Base run	Scen1	Scen2	Scen3	Scen4	Scen5	Scen6
Crop rotation	AGRR no rotation	corn – wwht 2 years	corn – hay (4 years)	wwht – hay (4 years)	wwht - hay	wwht	wwht - hay
Cultivation Technique	none	none	none	none	contours	terraces	strip-cropping
C_{USLE}	0.2	0.2 - 0.03	0.2 - 0.003	0.03 - 0.003	0.03 - 0.003	0.03	0.03 - 0.003
P_{USLE}	1.00	1.00	1.00	1.00	0.60	0.50	0.30





Conclusions

- Soil losses from different geographical units of the Arachtos catchment were sufficiently quantified resulting in a significant average annual sedimentation rate of 3.80 Mtn yr-1 at the Pournari I dam location
- Land use change scenarios based on application of crop-rotations and support practices on parts of the agricultural land seemed to be efficient mitigation measures against erosion
- The results strongly suggested the incorporation of hay cultivation in the arable land of the catchment
- The cultivation of hay and winter wheat under the strip-cropping support practice resulted in the highest annual reduction in sediment yields in the reservoir
- Public Institutions are stimulated to define and develop guidelines for the defence of land degradation by preferably applying non-structural and low-cost measures



NATIONAL TECHNICAL UNIVERSITY OF ATHENS
SCHOOL OF CIVIL ENGINEERING, LABORATORY OF HYDROLOGY AND WATER RESOURCES MANAGEMENT
PROFESSOR M.A. MIMIKOU

Acknowledgments

- The current study took place under the European funded project Cadsealand (http://www.cadsealand.net/) (INTERREG III B CADSES Programme).

- Catchment data provider: Public Power Corporation