Isfahan University
of Technology

Soil erosion hazard prediction by SWAT model and fuzzy logic in a highly mountainous watershed

Introduction

✓ Challenges

✓ Soil erosion

➢ A major environmental threat to the sustainability and productive capacity of agriculture (Bakker et al., 2004; Metternicht and Gonzalez, 2005; Yang et al., 2009).

➢ Reduction of soil fertility and loss of nutrients and thus, declines of crop yields in farmlands (Yang et al., 2009).

➢ Degradation of the quality of surface and ground water (Mitra et al., 1998; Kim and Gilley, 2008).

Introduction

✓ Challenges

- Iran is one of the worst affected countries by land degradation and soil erosion in Asia (FAO, 1991).

- Mean annual soil erosion rate in Iran: **about 25 tons/ha/year, 4.3 times more than the mean annual soil erosion rate in the world** (Ahmadi Ilkhchi, 2003; Rostamian et al., 2008).

Introduction

✓ Challenges

Many parts of Iran are subjected to a high and very high soil erosion hazard

Introduction

✓ Challenges

- A few areas of a large watershed might be critical and more responsible for high amount of soil and nutrient losses (Tripathi et al., 2003)
- Implementation of the best management practices in those critical erosion prone areas
- Identification of these critical areas is essential for the effective and efficient implementation of watershed management programs.

Introduction

✓ Challenges

- Using physically based distributed parameter models, RS, and GIS techniques may assist management agencies for identifying the most vulnerable erosion-prone areas of watersheds and selecting appropriate management practices.

➢Objectives

✓Main Objective

Identification and prioritization of critical sub-basins in a highly mountainous watershed

➢Objectives

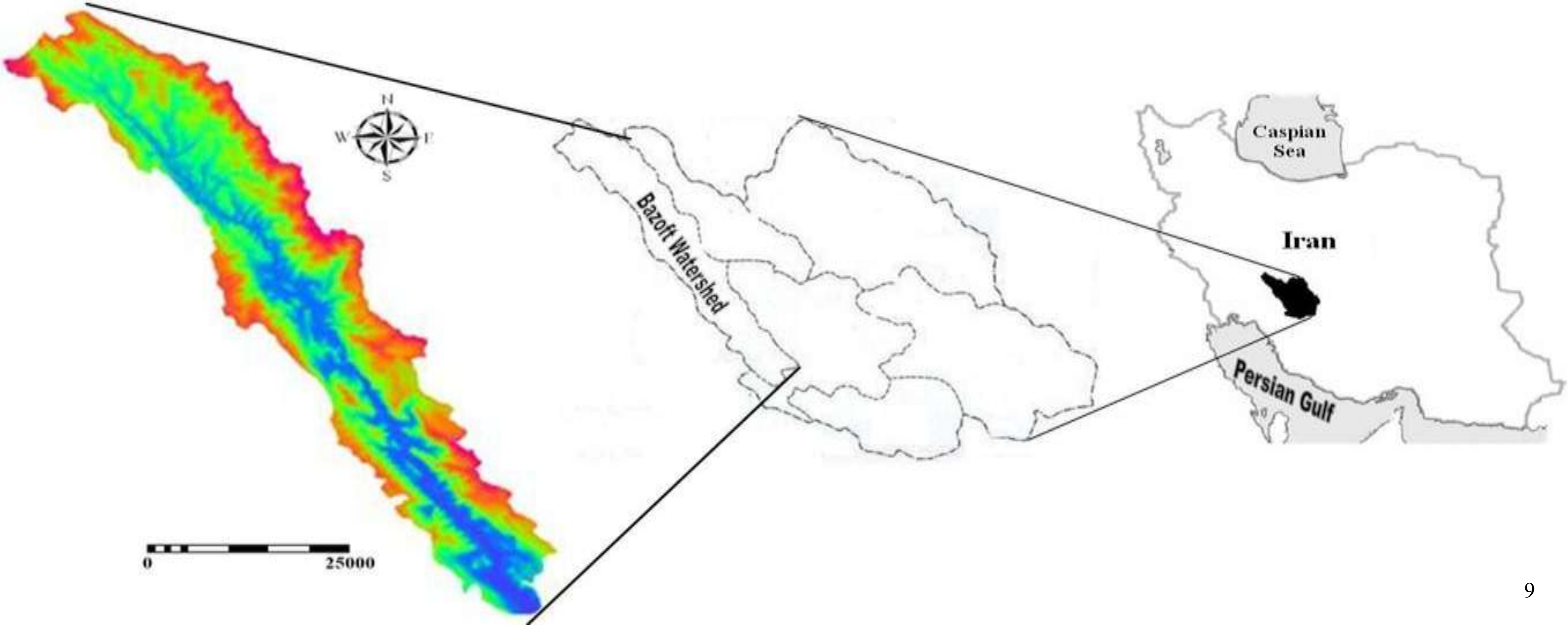
✓Estimation of runoff and sediment load in a highly mountainous watershed with imprecise and uncertain data using soil and water assessment tool (SWAT) model

✓ Developing a GIS-based fuzzy logic map for predicting soil erosion hazard in a very large watershed

Study area

- ✓ Bazoft Watershed

One of the main sub-basins in Iran where the land degradation and soil erosion have contributed to major economical, social, and environmental problems

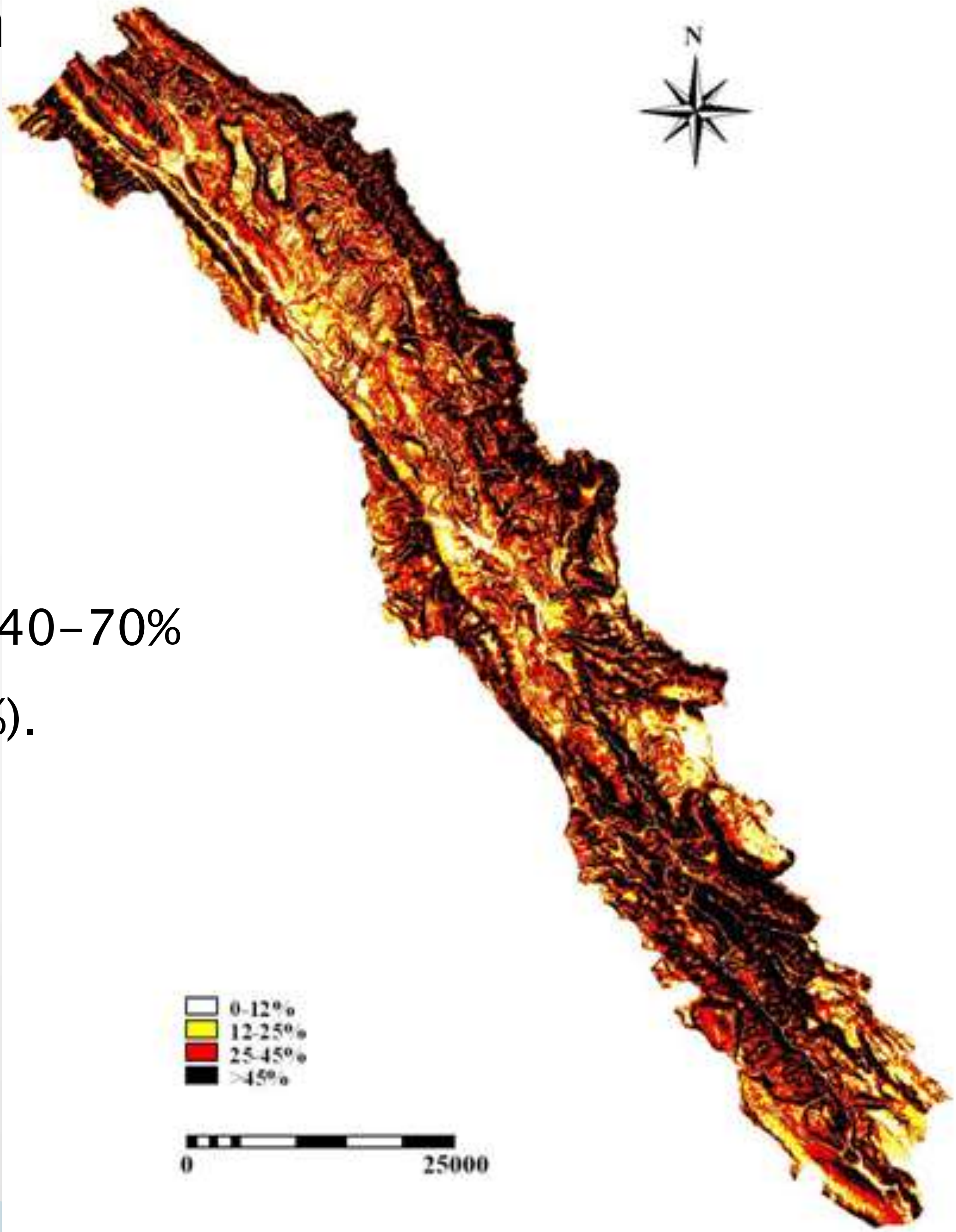


Study area description

✓ Bazoft watershed

➢ Highly mountainous

The major slope class: 40-70% (covers an area of about 46 %).



Study area description

- ✓ Bazoft watershed

The impact of human and livestock population is exacerbated the rapid depletion of the natural resource bases in the watershed.

Conversion of wood and rangelands into croplands: Severe soil erosion in many parts of the watershed






Different Types of Soil Erosion

An urgent need to perform an comprehensive study to assess the future risk of soil erosion in this watershed for an appropriate conservation and sustainable rehabilitation of the land

Different parts of the study:

Soil Erosion Hazard Prediction Using:

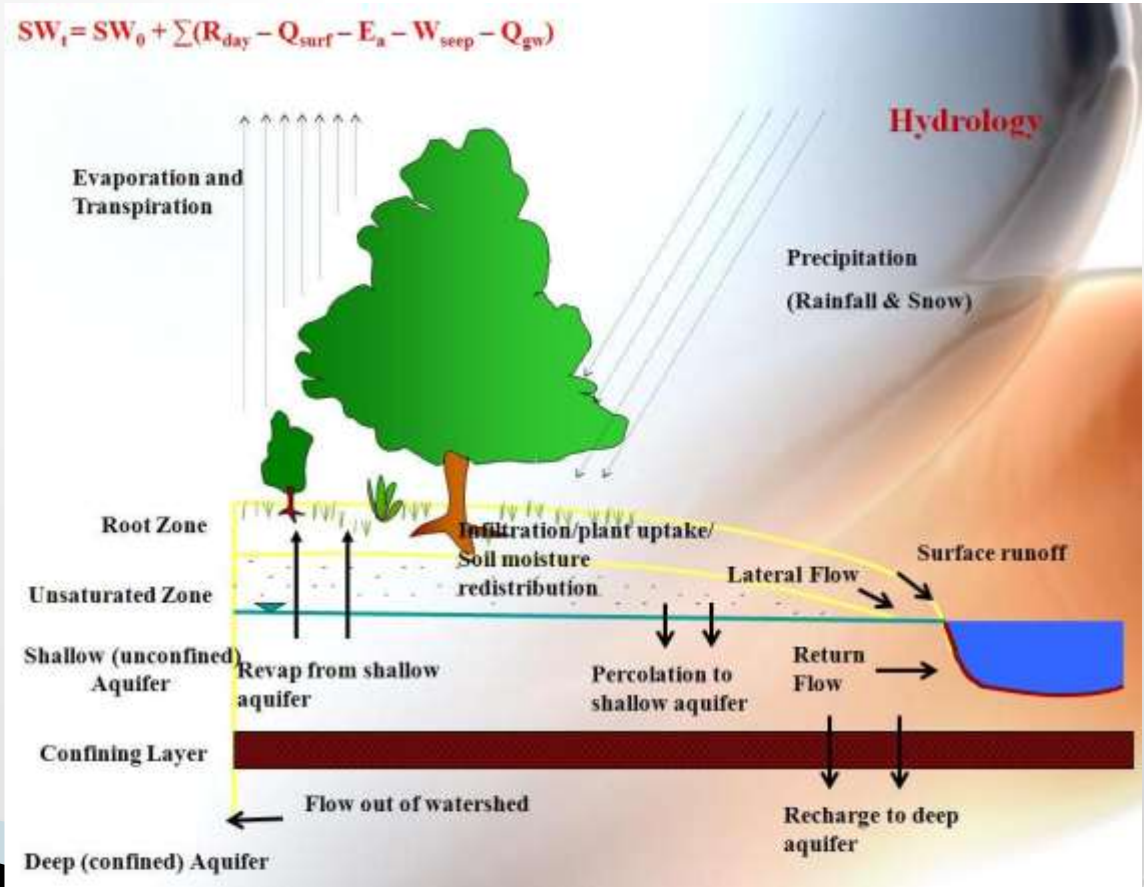
- SAWT Model
- Fuzzy Logic Algorithm

Part 1

Soil Erosion Hazard Prediction using SWAT model

Part 1
SWAT model

➢ Continuous time, spatially semi-distributed model, developed to simulate the impact of management decisions on water, sediment and agricultural chemical yields in river basins in relation to soil, land use and management practices (Arnold et al.,1998).



Problems:

- Hydrometric stations are quite limited in the Bazoft watershed.

- Management plans are difficult to develop due to the lack of measured data.

- Imprecise and uncertain data

Part 1
SWAT model

- The SWAT model has been used globally as well as in Iran to assess water quality, runoff and sediment load, and soil erosion predictions.

- A useful tool for runoff and sediment simulation in watersheds with imprecise and uncertain data

Materials and Methods

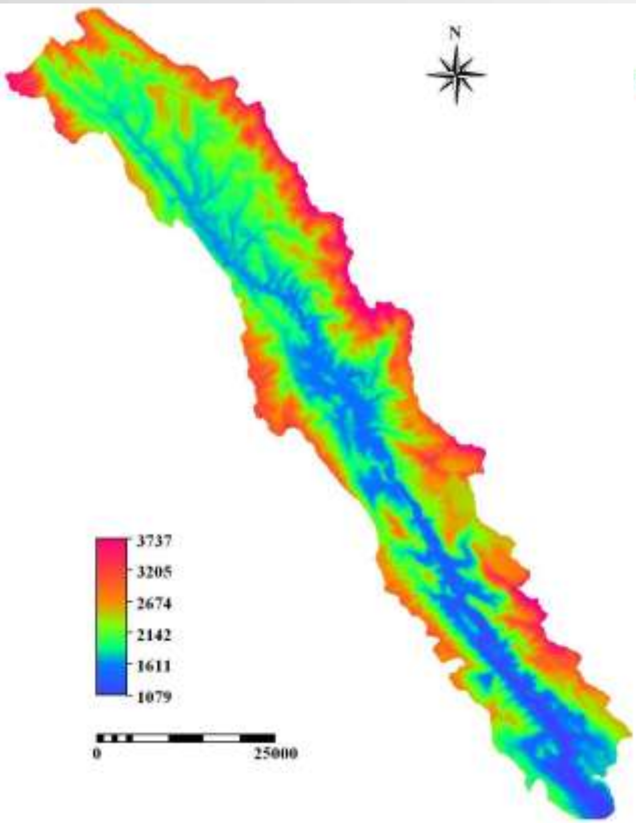
The basic input data to the SWAT:

- digital elevation model (DEM)
- stream network
- land-use
- soil
- climate data

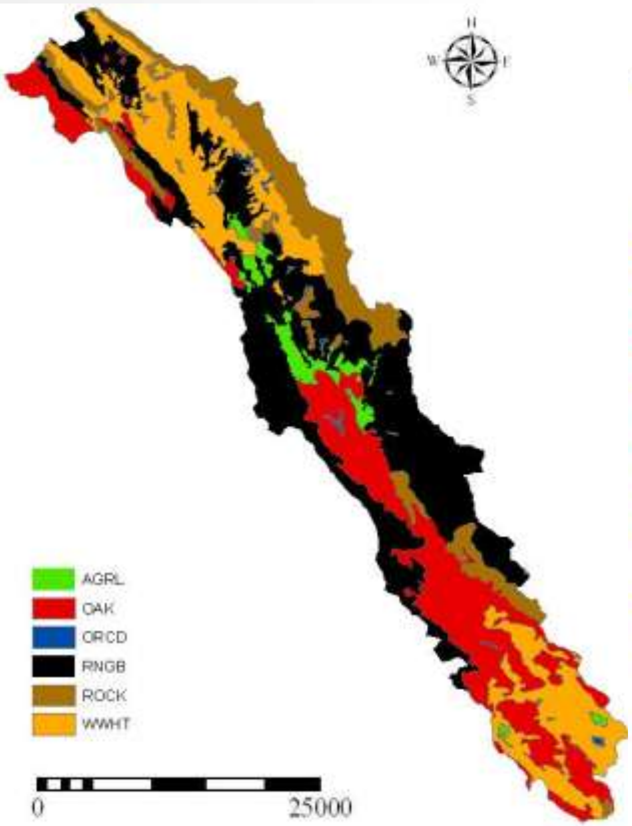
Part 1
SWAT model

- DEM

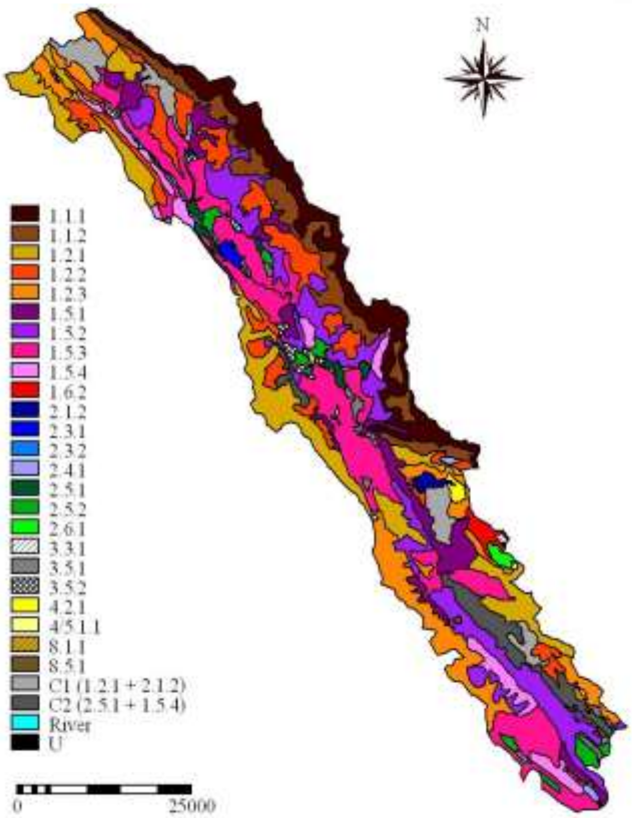
Grid size of 53m × 53m



- Land Use



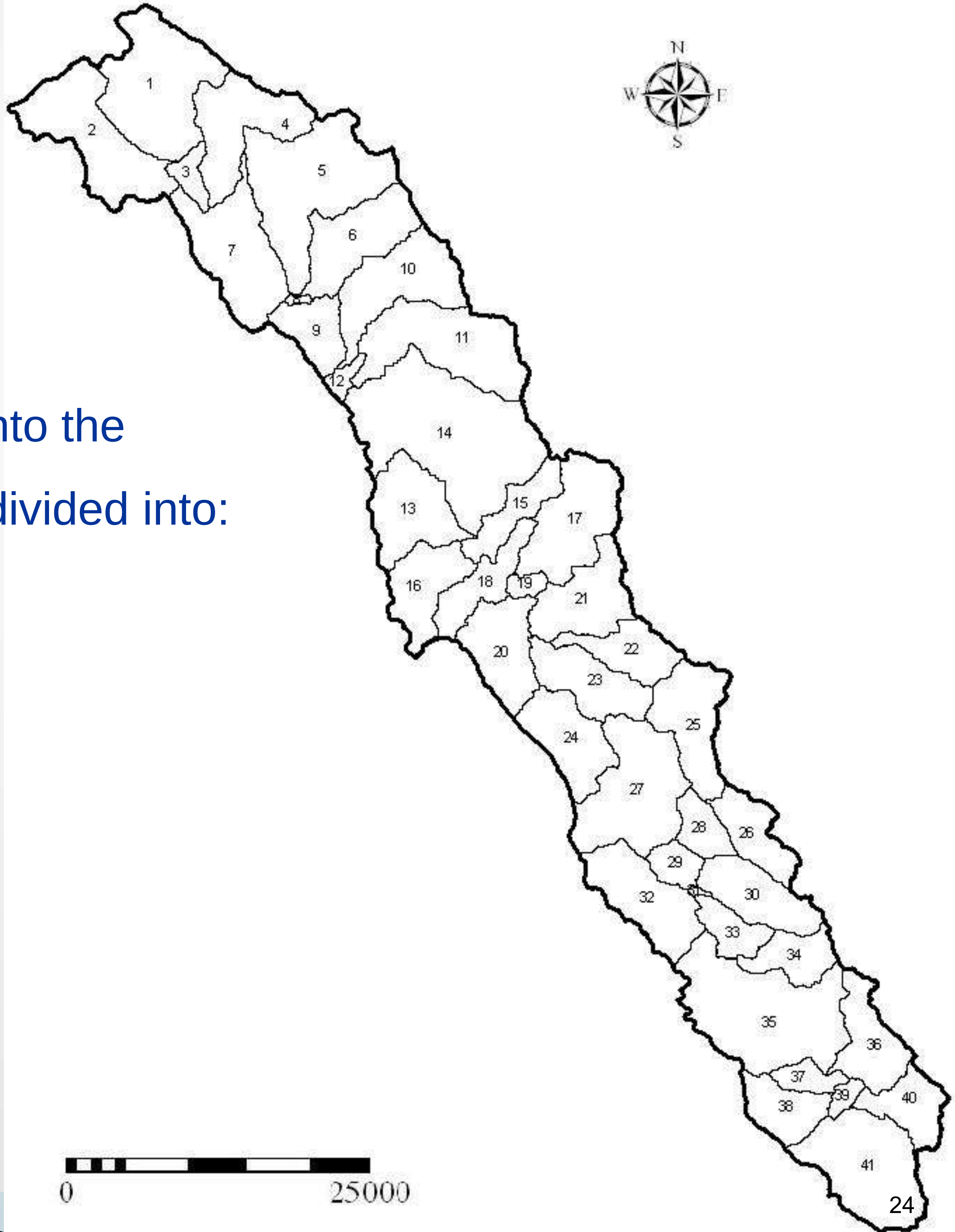
- Soil Map



Part 1
SWAT model

By entrance of different maps into the model, the watershed was subdivided into:

- 41 Sub-basins
- 406 HRUs



➢ Climate Data

- ✓ Climate data including daily precipitation, max and min air temp, were obtained from existed climatic and meteorological stations from different organizations.

- Simulation time period: 1989 – 2008

- Calibration and Validation

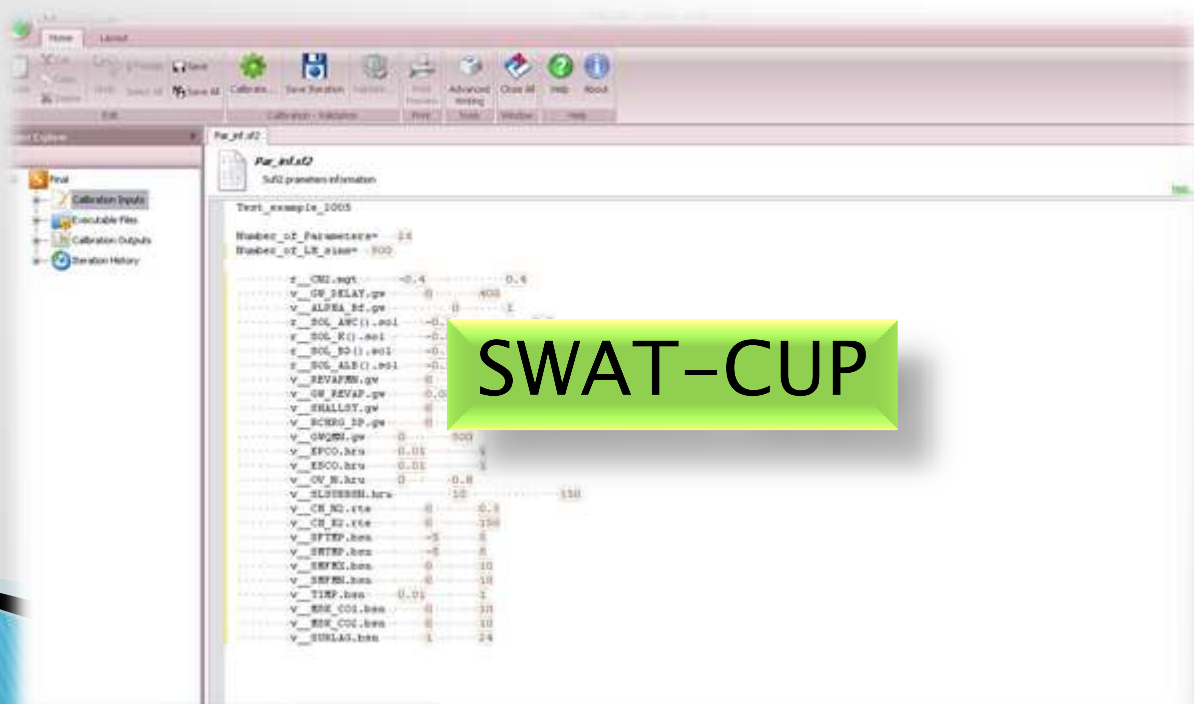
✓ Runoff
✓ Sediment

Calibration: 1995–2008
Validation: 1989–1994

- Calibration and Validation

✓ SWAT-CUP

Model calibration and uncertainty analysis:
SUFI-2, the programs interfaced with SWAT, in the package SWAT-CUP

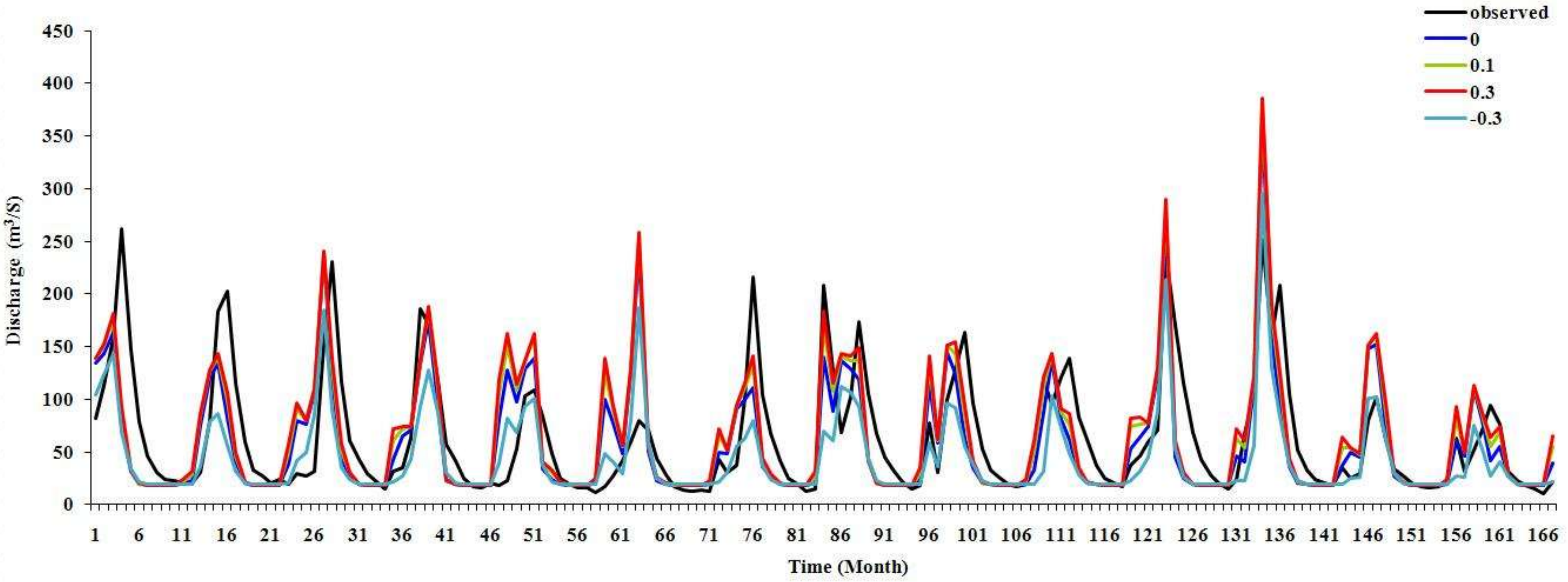


Part 1
SWAT model

Results and Discussion

➢ Sensitivity Analysis

An initial sensitivity analysis were performed for choosing the sensitive parameters



Part 1
SWAT model

- Sensitivity Analysis

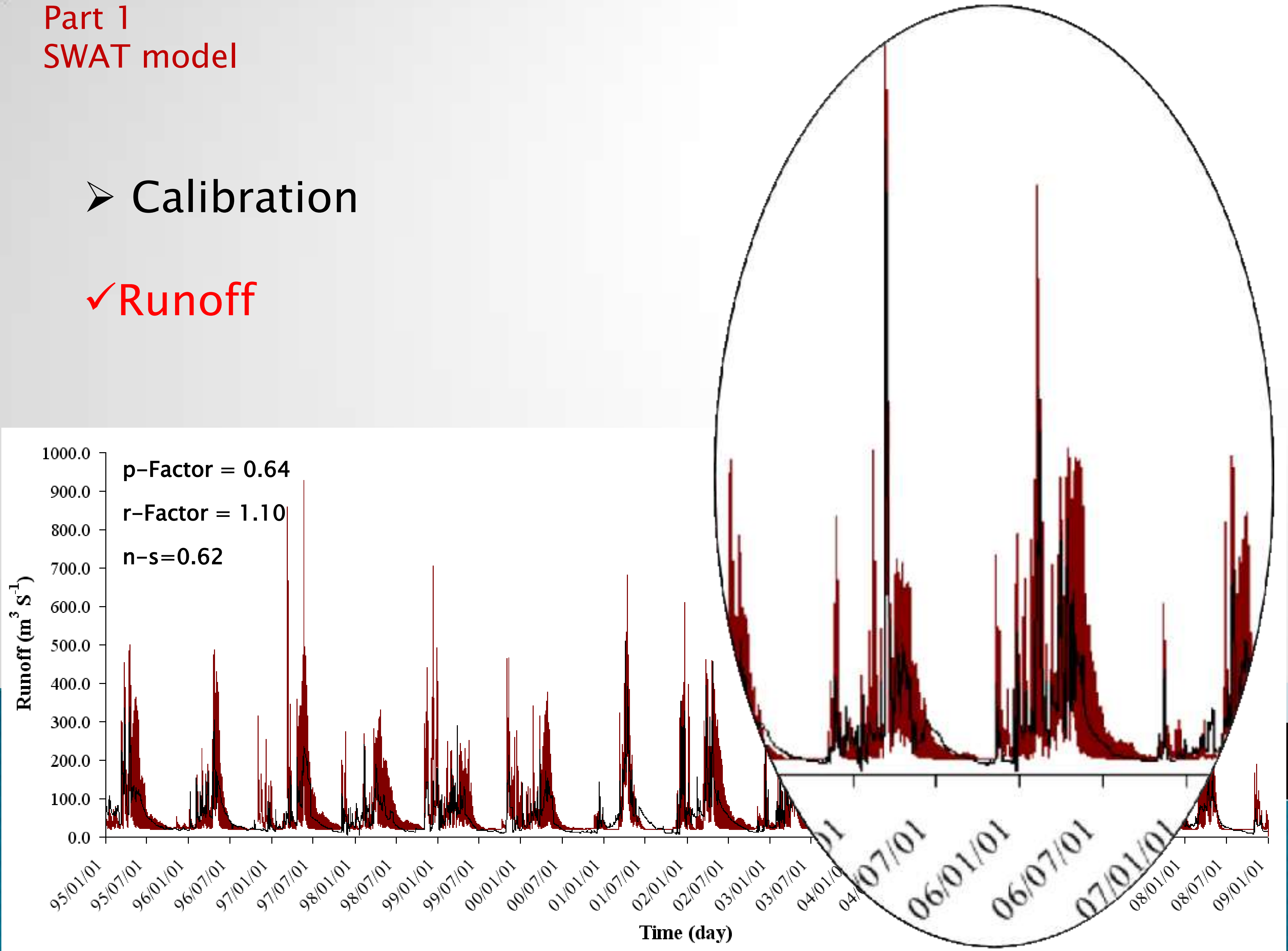
Runoff
r_CN2.mgt
r_SOL_BD.sol
r_SOL_AWC.sol
r_SOL_K.sol
r_SOL_ALB.sol
v_ALPHA_BF.gw
v_GW_DELAY.gw
v_REVAPMN.gw
v_GW_REVAP.gw
v_SHALLST.gw
v_RCHRG_DP.gw
v_GWQMN.gw
v_EPCO.hru
v_ESCO.hru
v_SLSUBBSN.hru
v_OV_N.hru
v_CH_N2.rte
v_CH_K2.rte
v_SFTMP.bsn
v_SMTMP.bsn
v_SMFMX.bsn
v_SMFMN.bsn
v_TIMP.bsn
v_MSK_CO1.bsn
v_MSK_CO2.bsn
v_SURLAG.bsn

Sediment
v_ADJ_PKR.bsn
r_USLE_K.sol
v_SPCON.bsn
v_SPEXP.bsn
v_CH_EROD.rte
v_CH_COV.rte
v_USLE_P.mgt
v_LAT_SED.hru
v_HRU_SLP.hru
v_FILTERW.mgt

Part 1
SWAT model

➢ Calibration

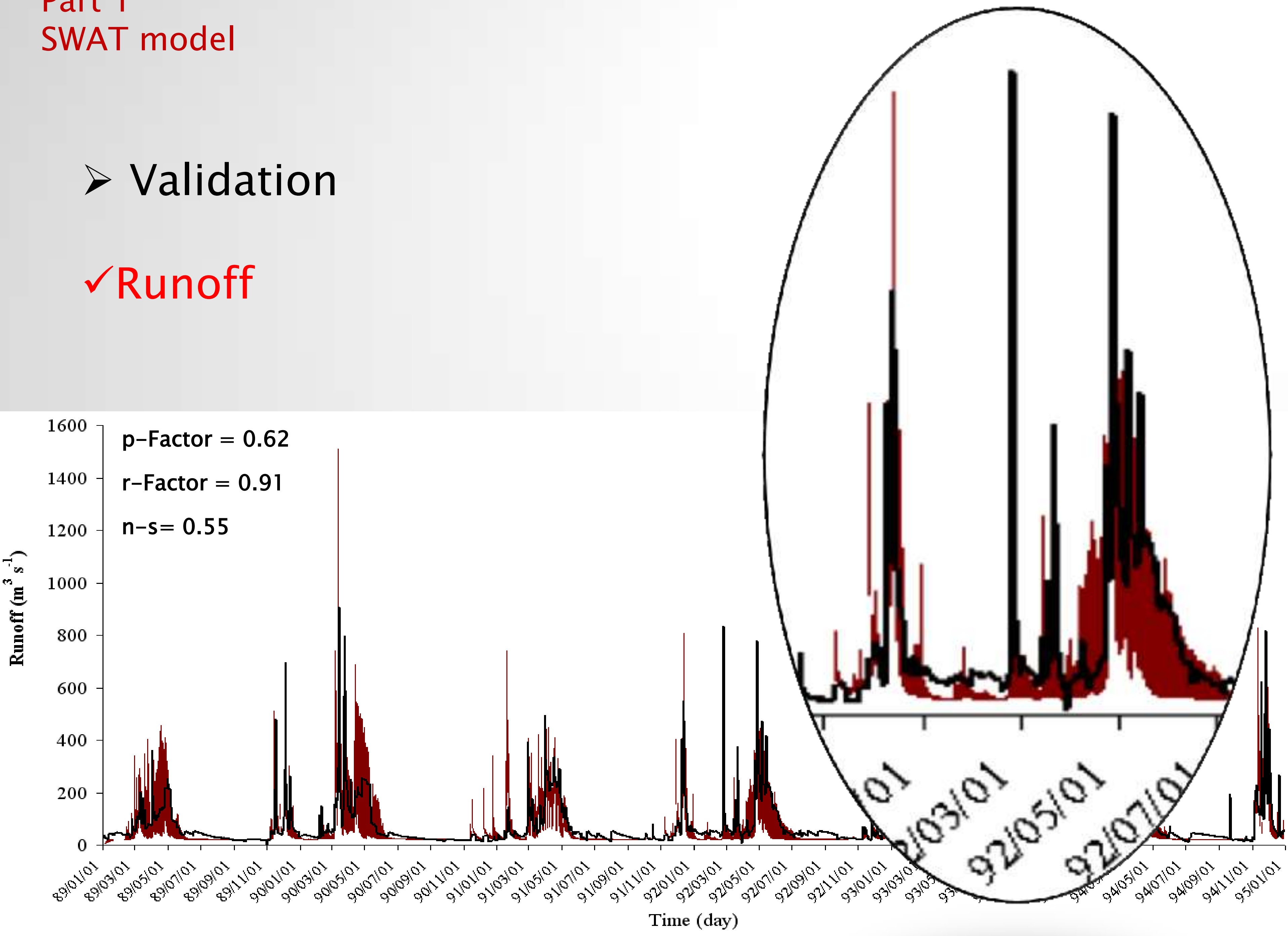
✓Runoff



Part 1
SWAT model

➢ Validation

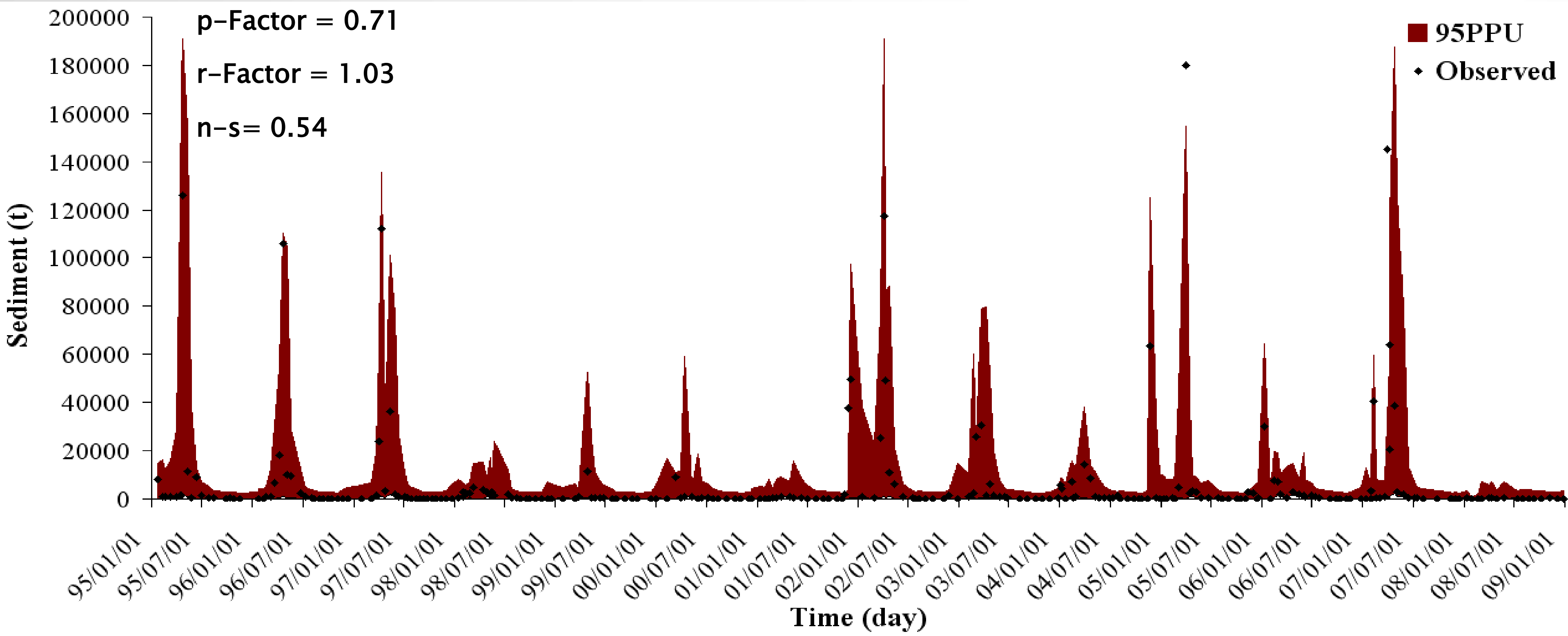
✓Runoff



Part 1
SWAT model

➢ Calibration

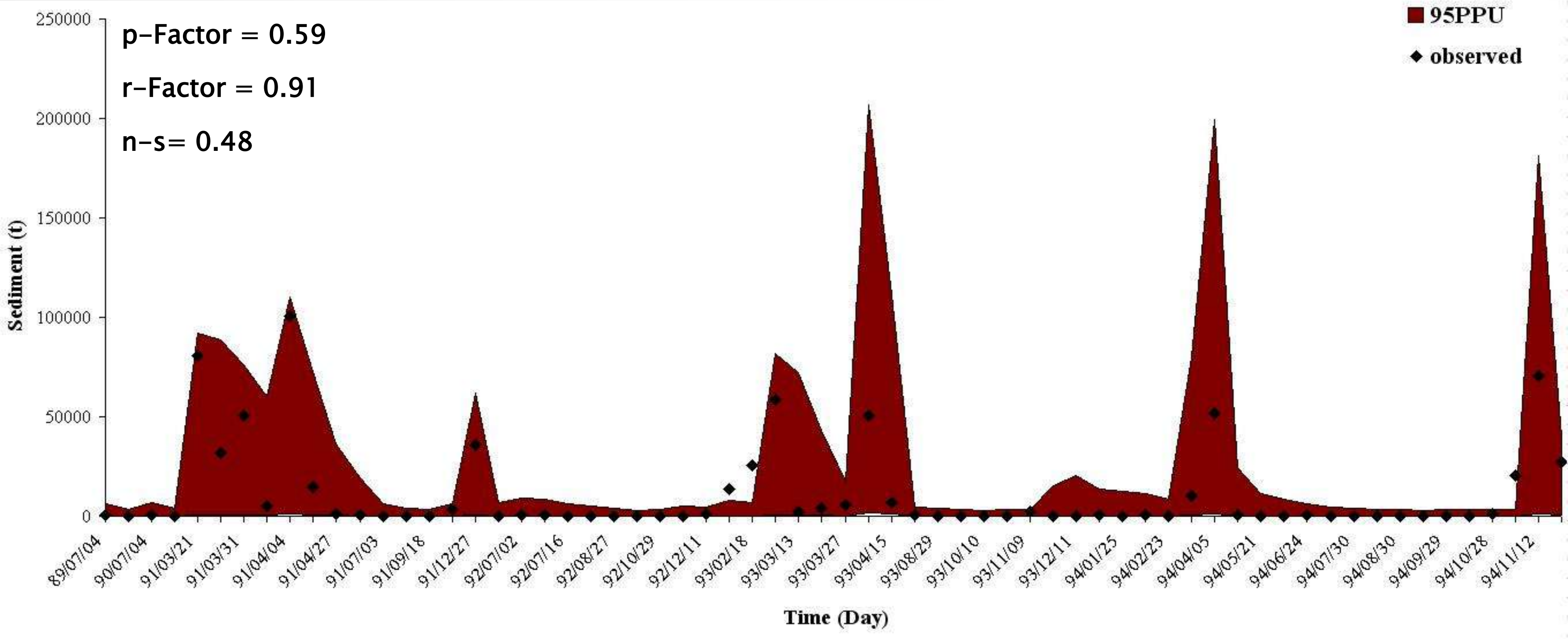
✓Sediment



Part 1
SWAT model

- Validation

✓Sediment

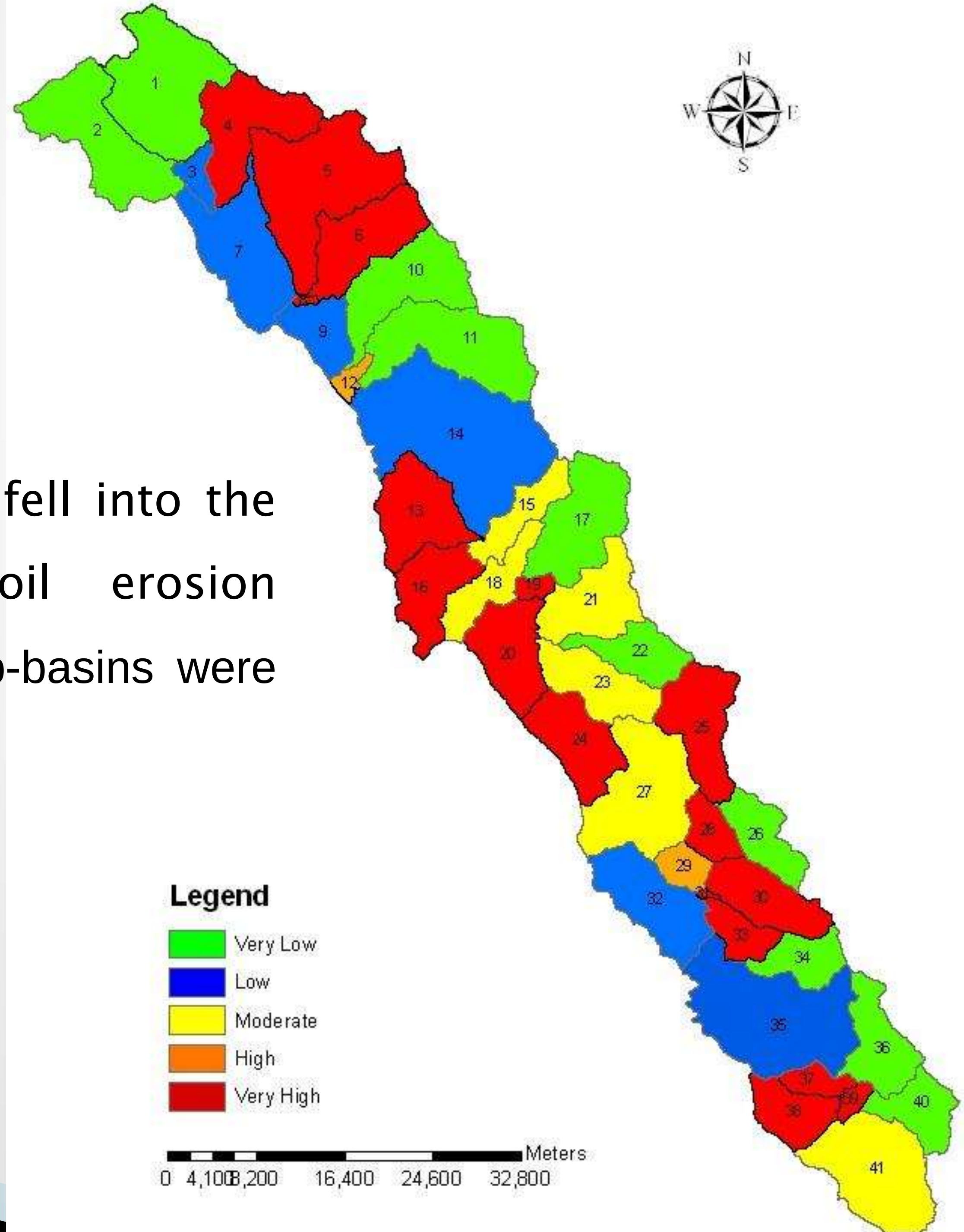


Part 1
SWAT model

Identification and prioritization of critical sub-basins in the Bazoft watershed

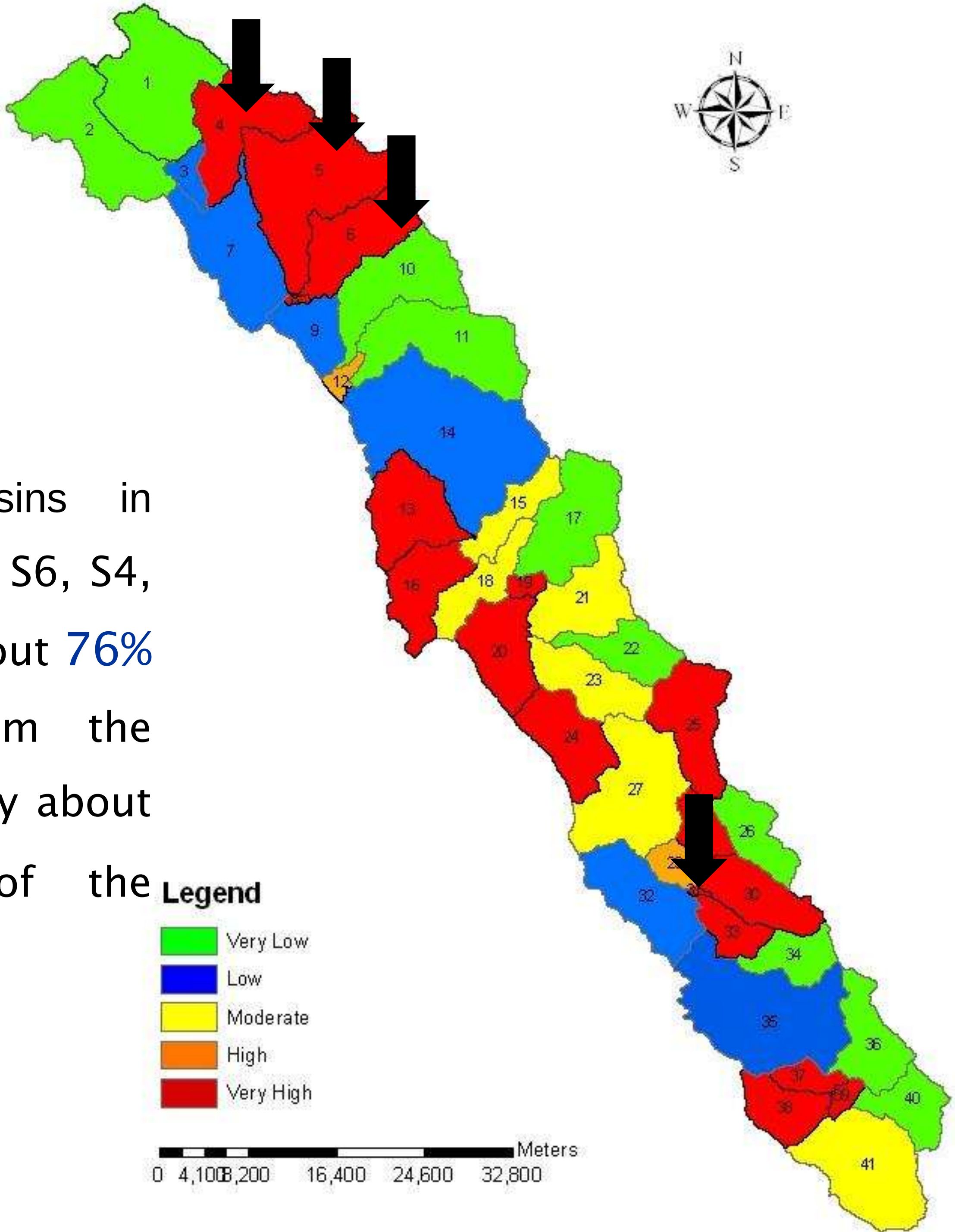
Part 1
SWAT model

- ➢19 out of 41 sub-basins fell into the high and very high soil erosion categories, of which 17 sub-basins were in the very high category



Part 1
SWAT model

➢After arranging the sub-basins in ascending order, sub-basins S5, S6, S4, and S31 were accounted for about 76% of the total soil loss from the watershed while they cover only about 11% of the total area of the watershed,.



Part 2

Soil Erosion Hazard Prediction using Fuzzy logic algorithm

Part 2
Fuzzy logic algorithm

- Fuzzy systems (fuzzy sets, membership functions, and fuzzy production rules) provide a rich and meaningful improvement extension of conventional logic, introduced by Zadeh (1965).

- A generalization of classic (Boolean) set theory (McBratney and Odeh, 1997).

- In traditional set theory, an element either belongs to a set, or it does not (0 or 1, black or white…).

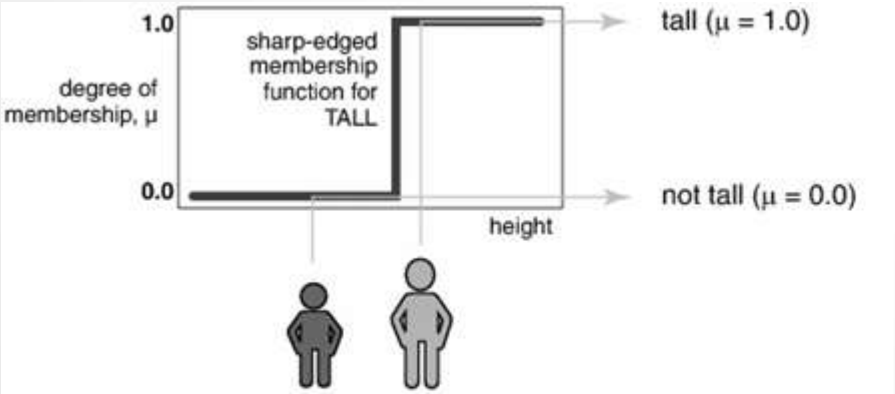
Part 2
Fuzzy logic algorithm

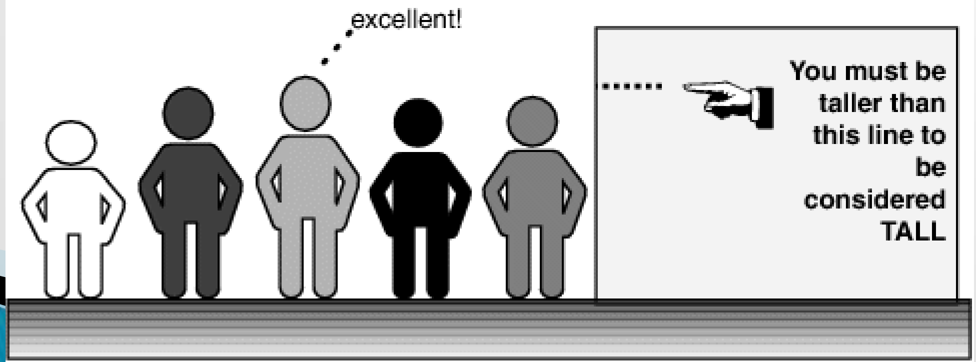
Example: Height

Tall people: say taller than or equal to 1.8m

1.8m , 1.9m, 2m etc member of this set

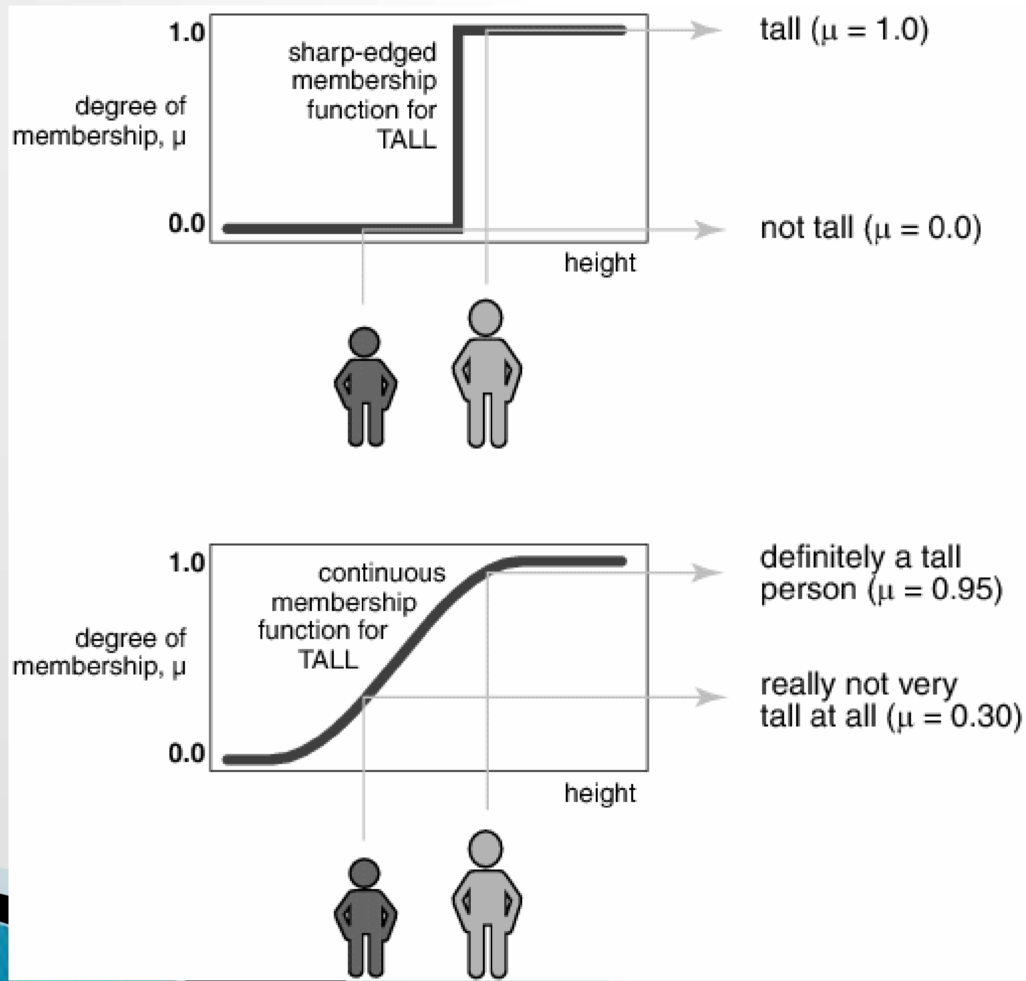
1.5 m, 1.6 m or even 1.79999m not a member

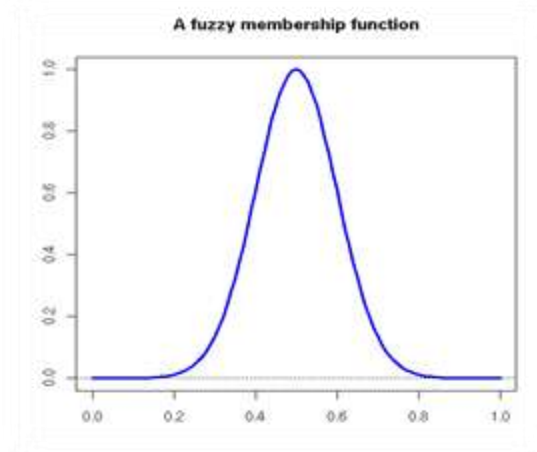




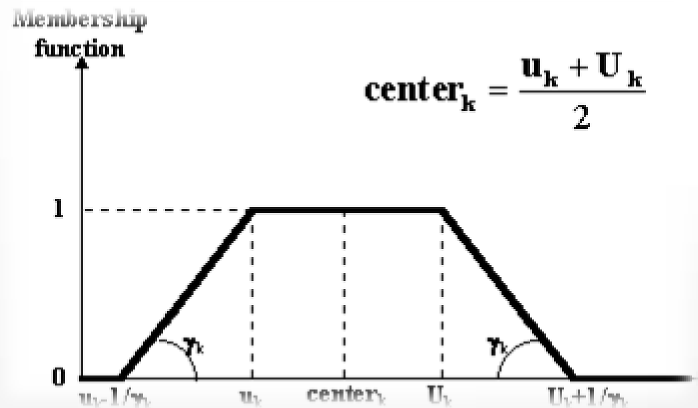
Example: Height

By the help of Fuzzy logic: you are now a member of this set

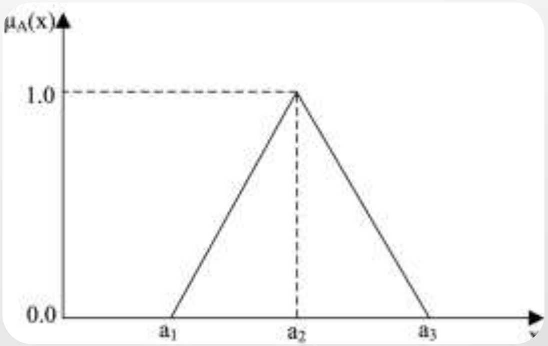




➢Membership functions



Membership functions classify elements in the range [0,1], with 0 and 1 being no and full inclusion, the other values being partial membership



➢ Fuzzy rules

✓ Fuzzy production rules represent human knowledge in the form of ‘IF-THEN’ logical statements.

IF temperature IS very cold THEN stop fan.

IF temperature IS cold THEN turn down fan.

IF temperature IS comfortable THEN maintain fan speed.

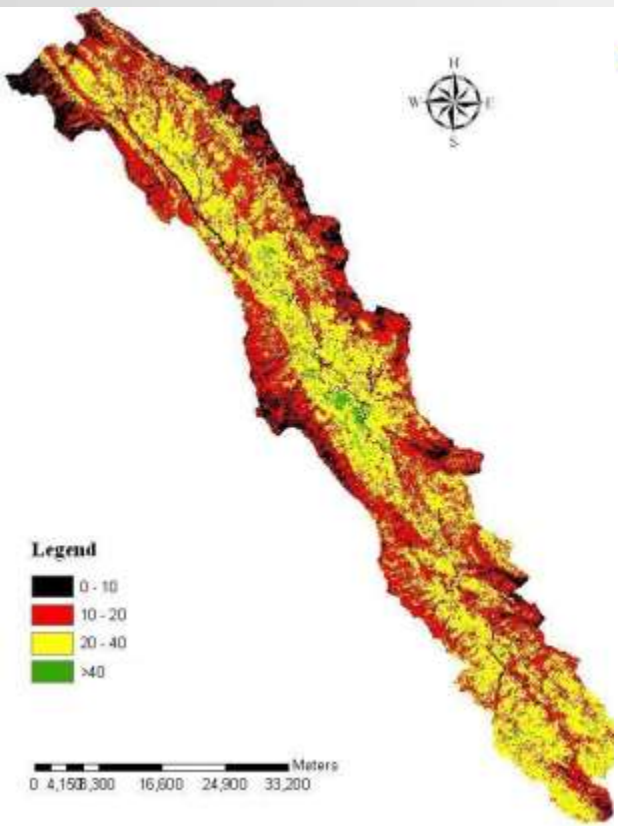
IF temperature IS hot THEN speed up fan.

Materials and Methods

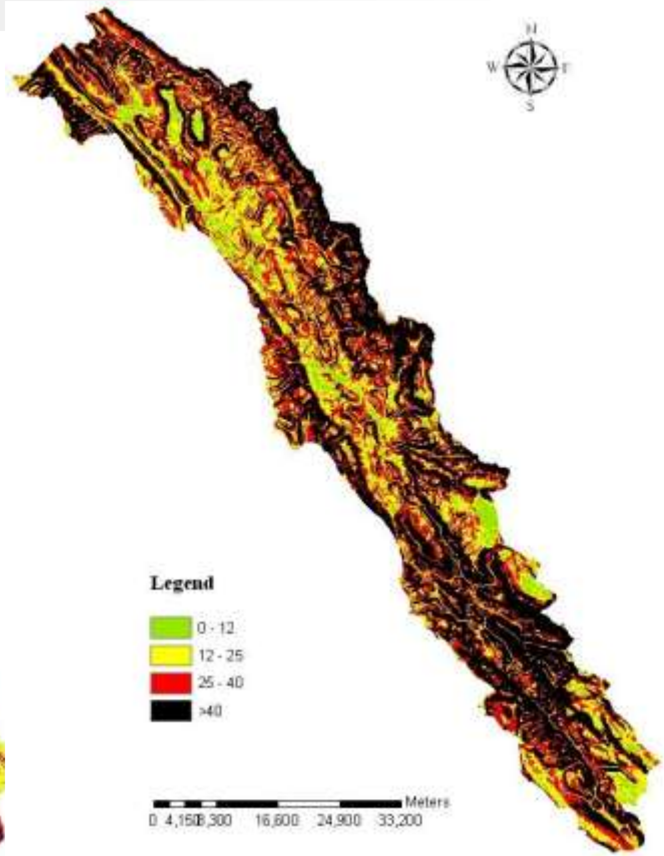
Part 2
Fuzzy logic algorithm

Three main landscape elements related to soil erosion in the study area for predicting soil erosion hazard using fuzzy logic approach:

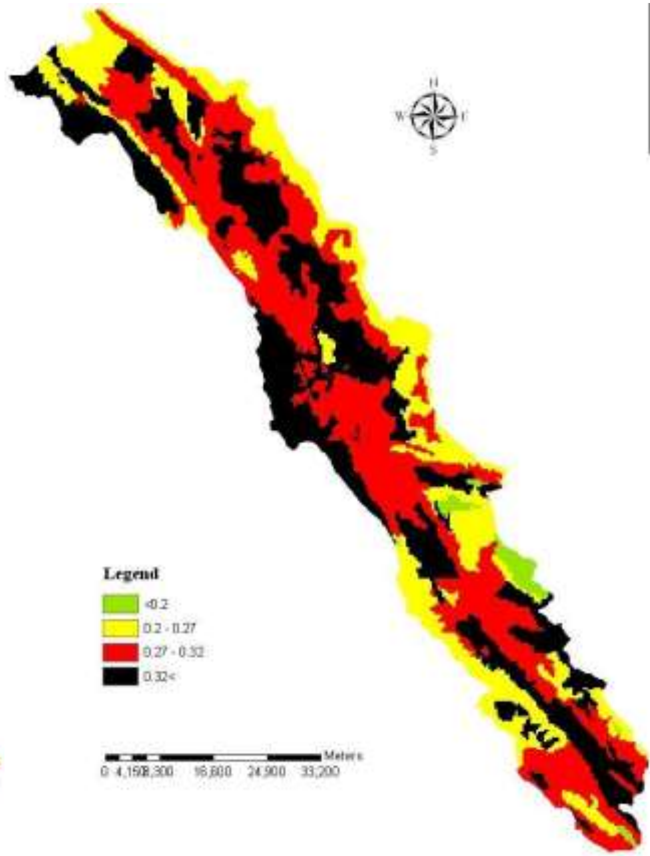
- Vegetation cover



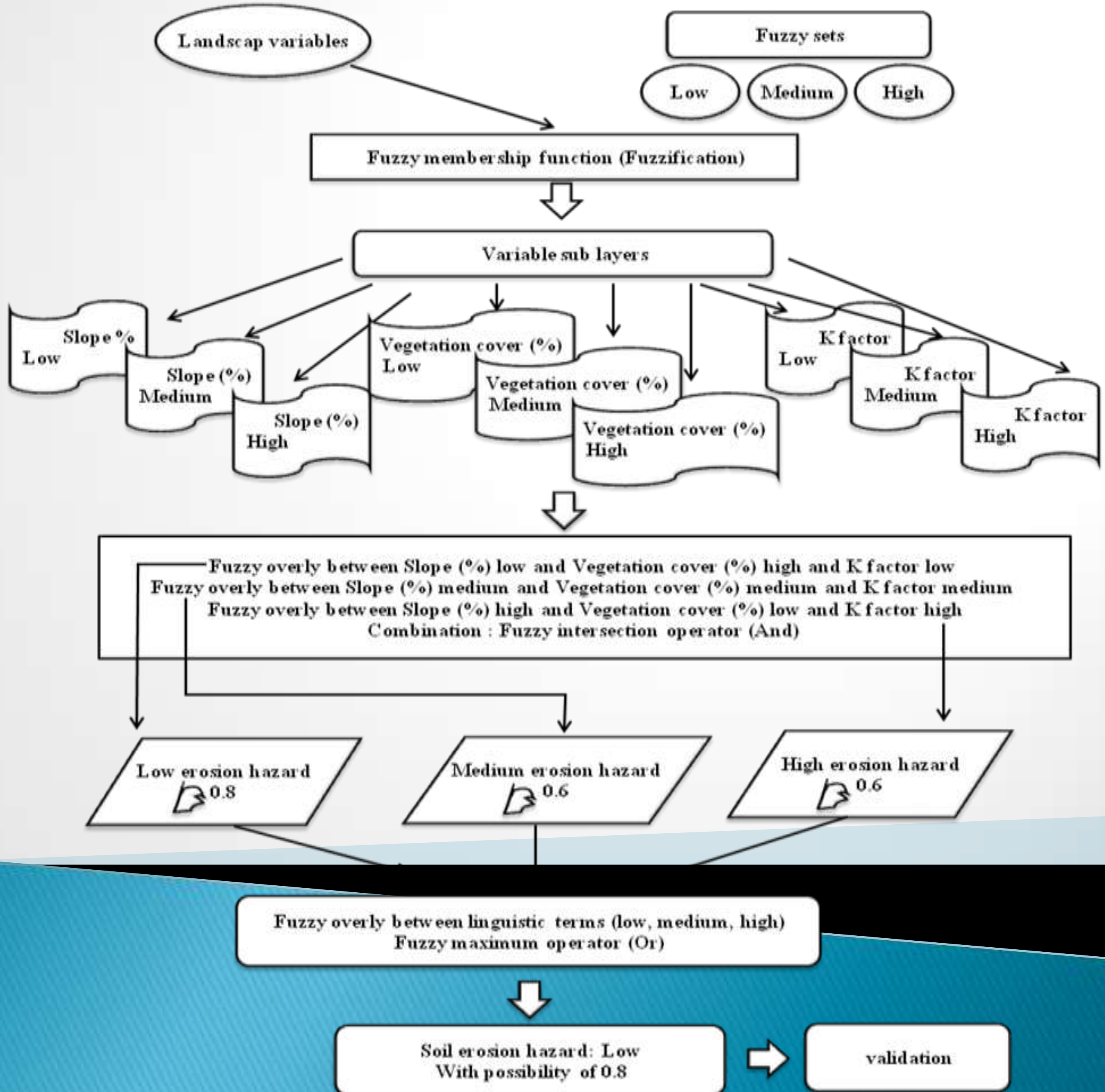
- Slope



- Soil erodibility

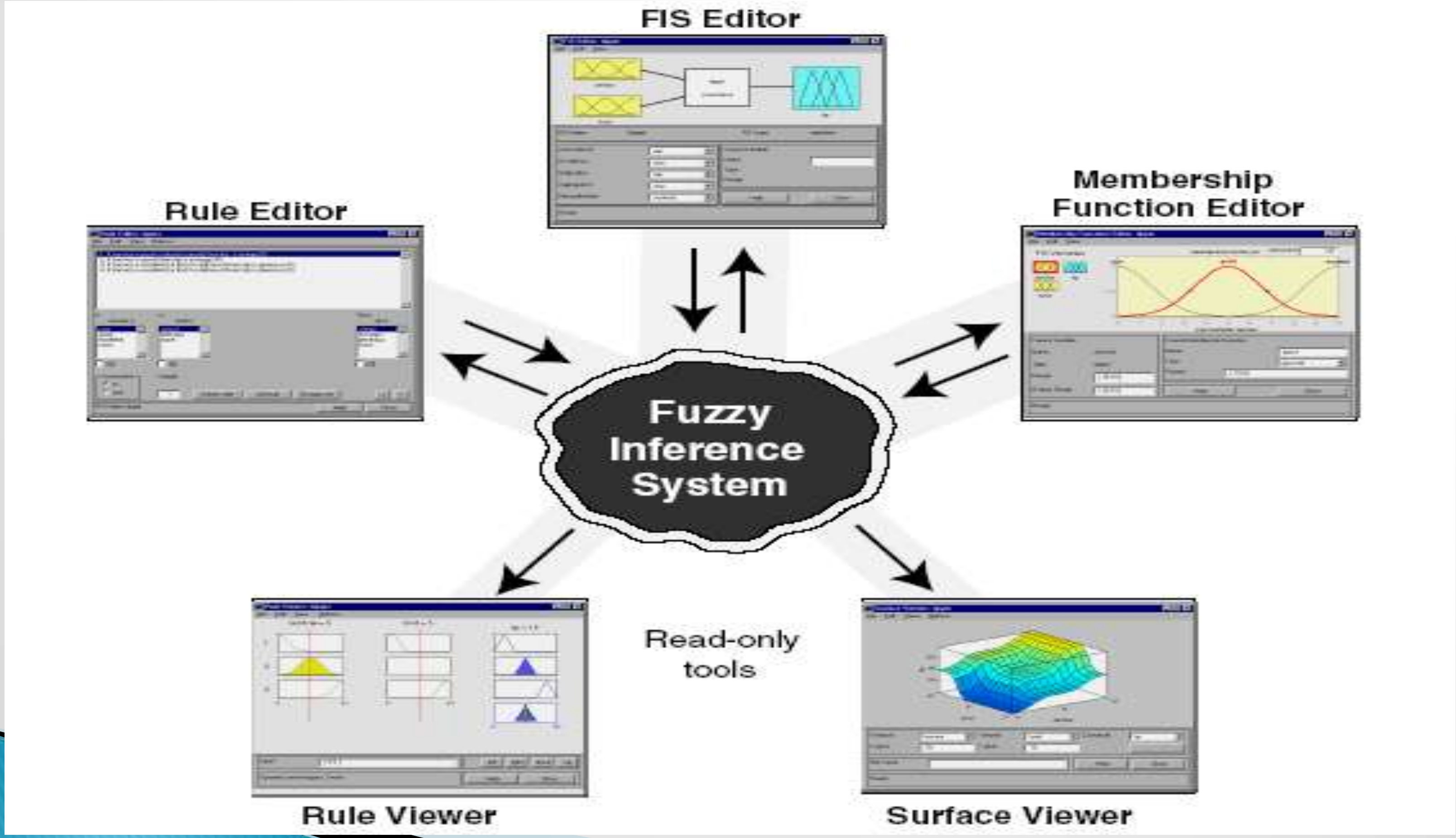


Part 2
Fuzzy logic algorithm



Part 2
Fuzzy logic algorithm

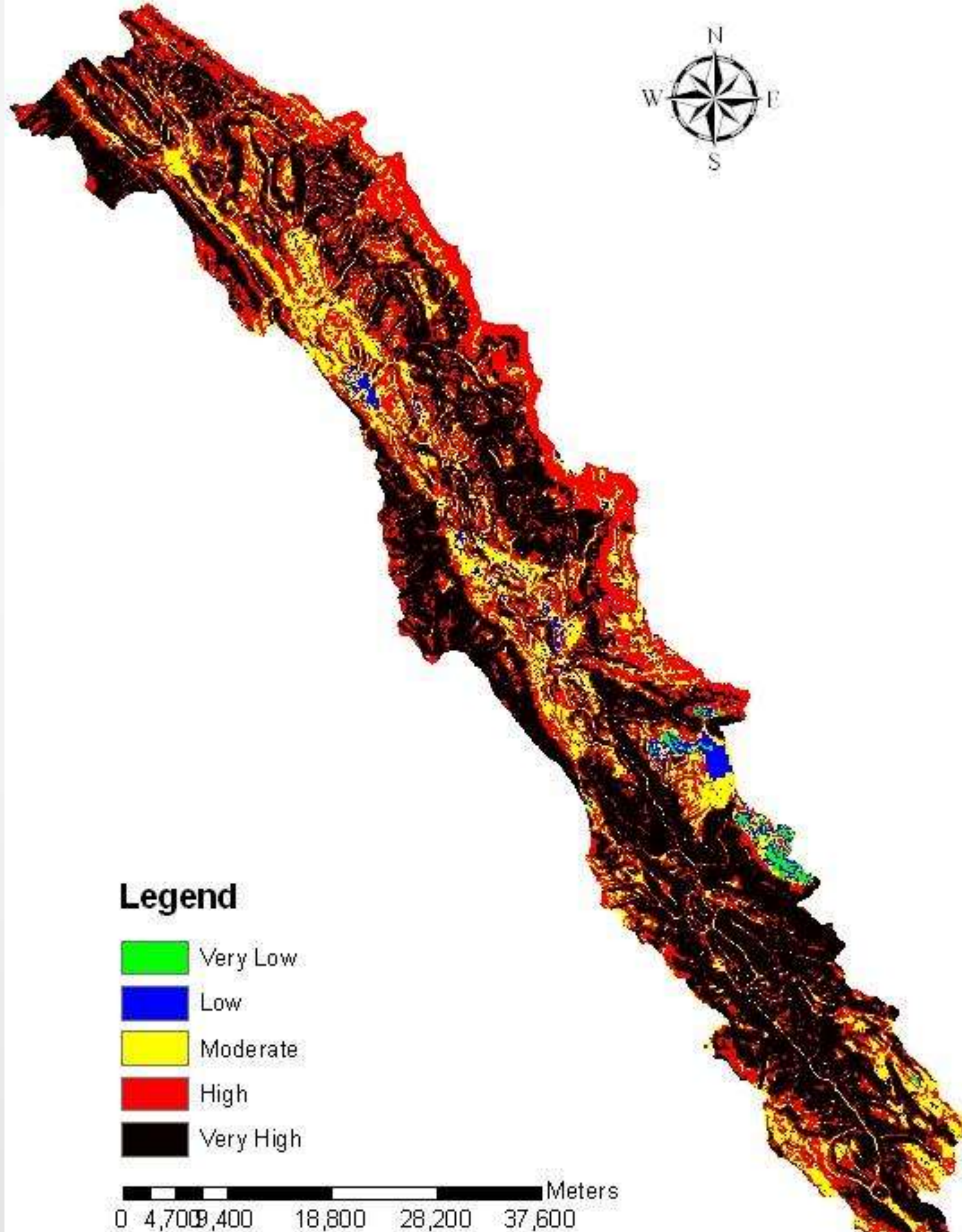
The algorithm for fuzzy logic model development provided in :



Results and Discussion

Part 2
Fuzzy logic algorithm

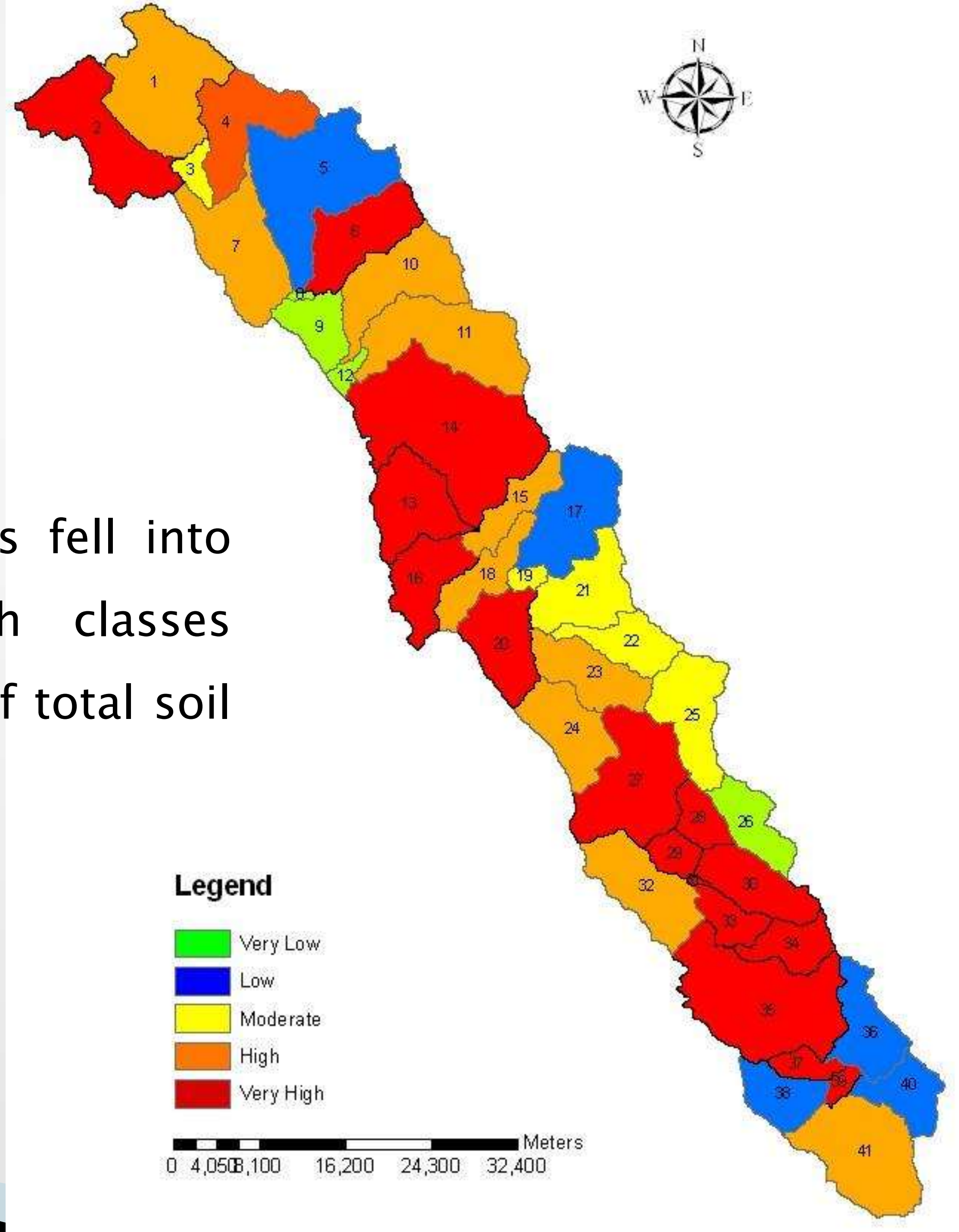
- A large part of the watershed was predicted to be endangered from a high or very high erosion risk



Identification and prioritization of critical sub-basins in the watershed

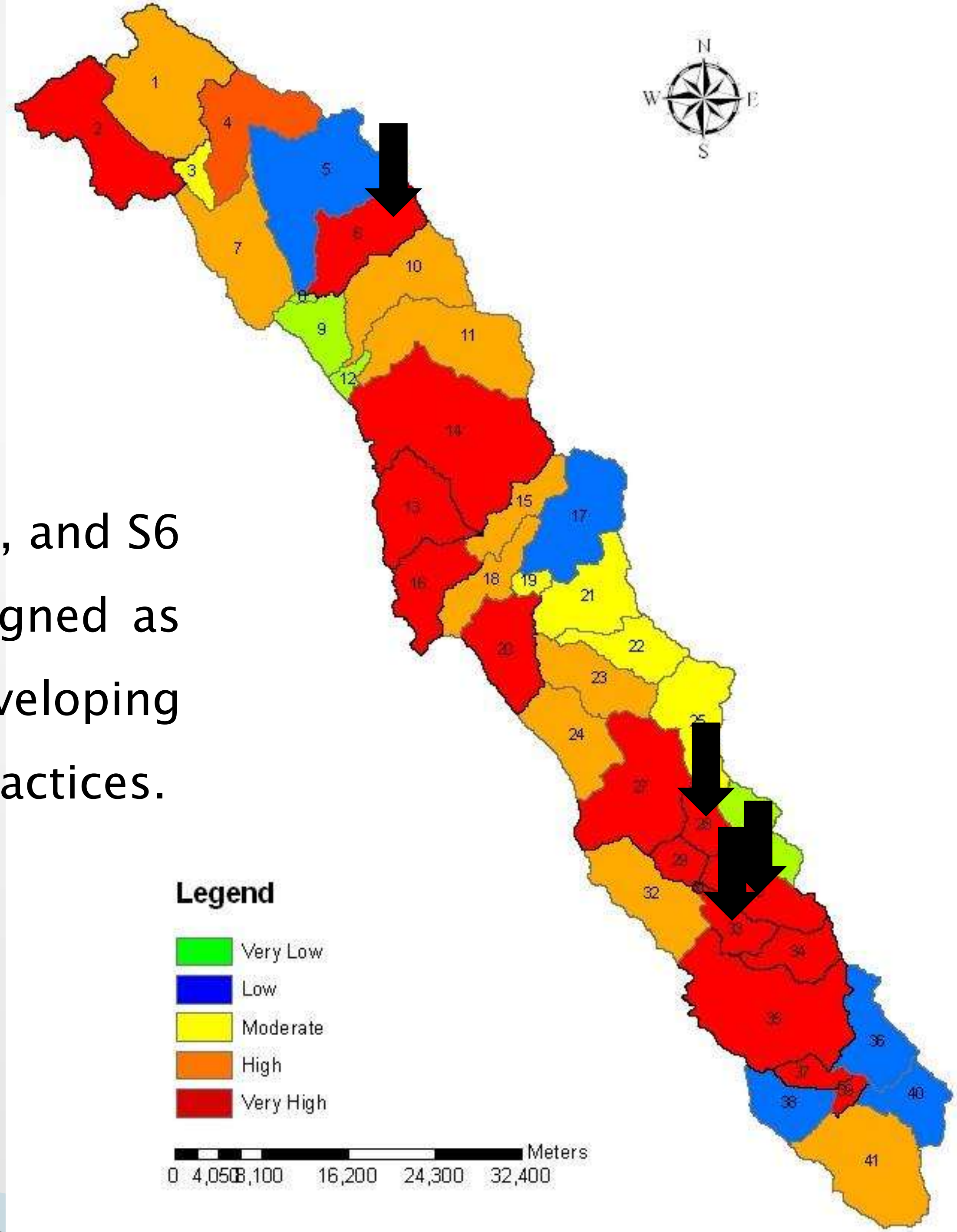
Part 2
Fuzzy logic algorithm

- 27 out of 41 sub-basins fell into the high and very high classes (accounted for about 74% of total soil loss from the watershed)



Part 2
Fuzzy logic algorithm

- Sub-basins S30, S28, S33, and S6 were more critical and assigned as the top priorities for developing appropriate management practices.

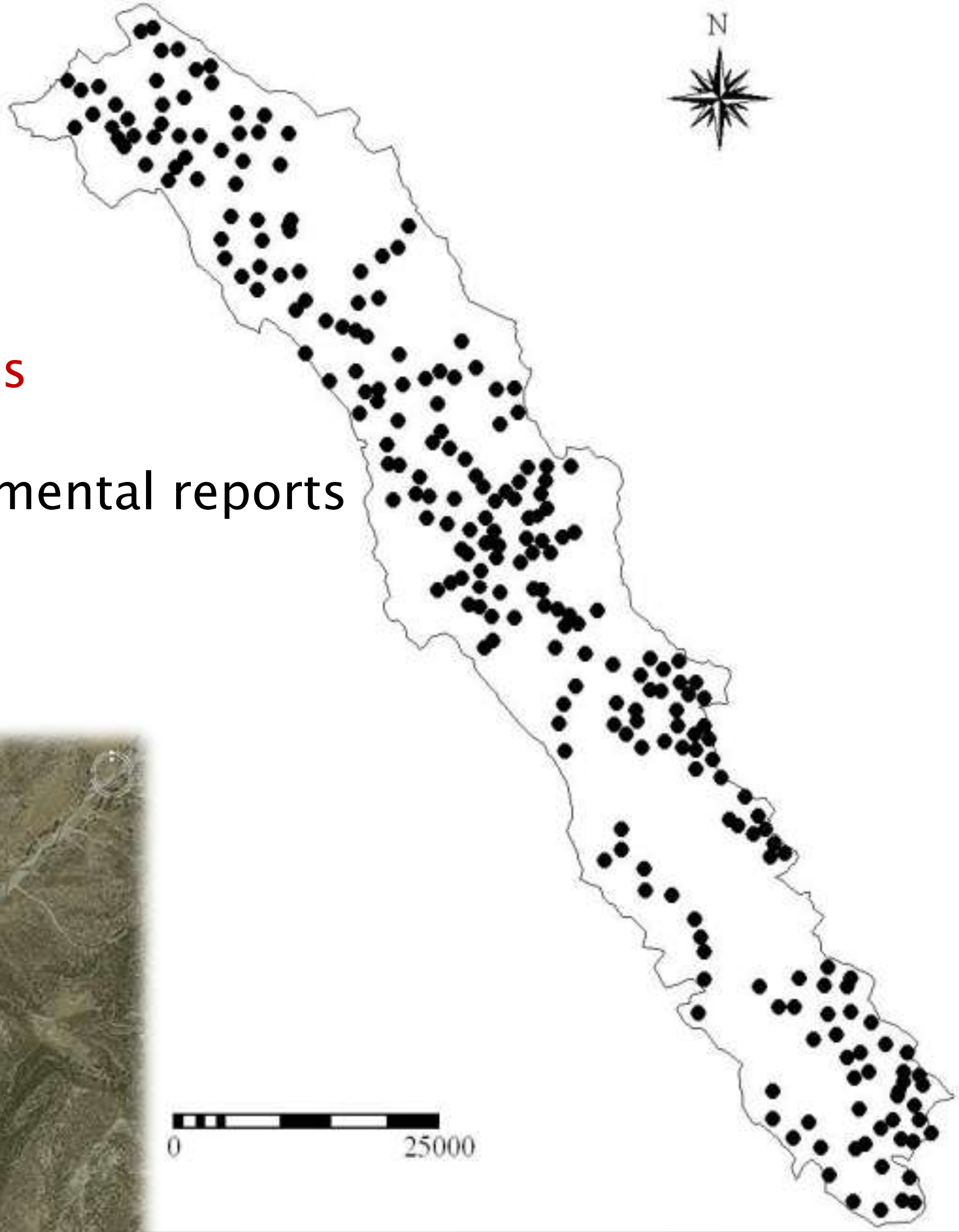


Evaluating the obtained results for identifying and prioritizating of critical sub-basins in the watershed

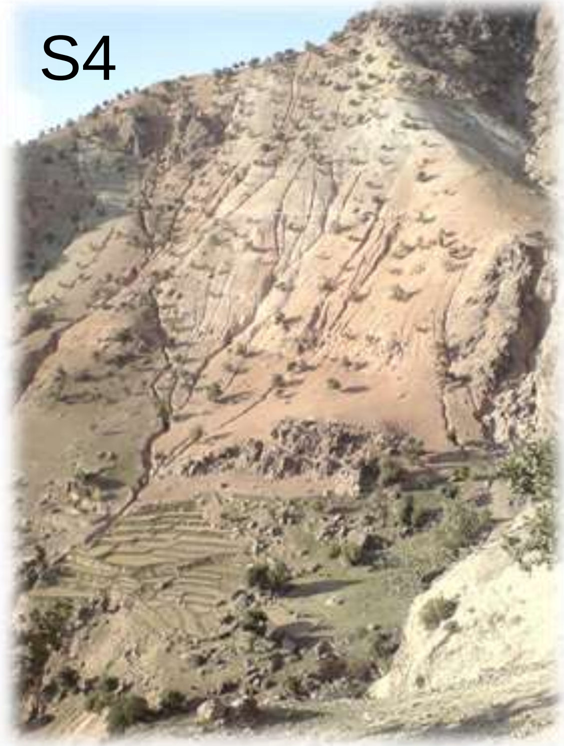
✓Field Surveys

✓Interpretation of satellite photos

✓Governmental and non-governmental reports



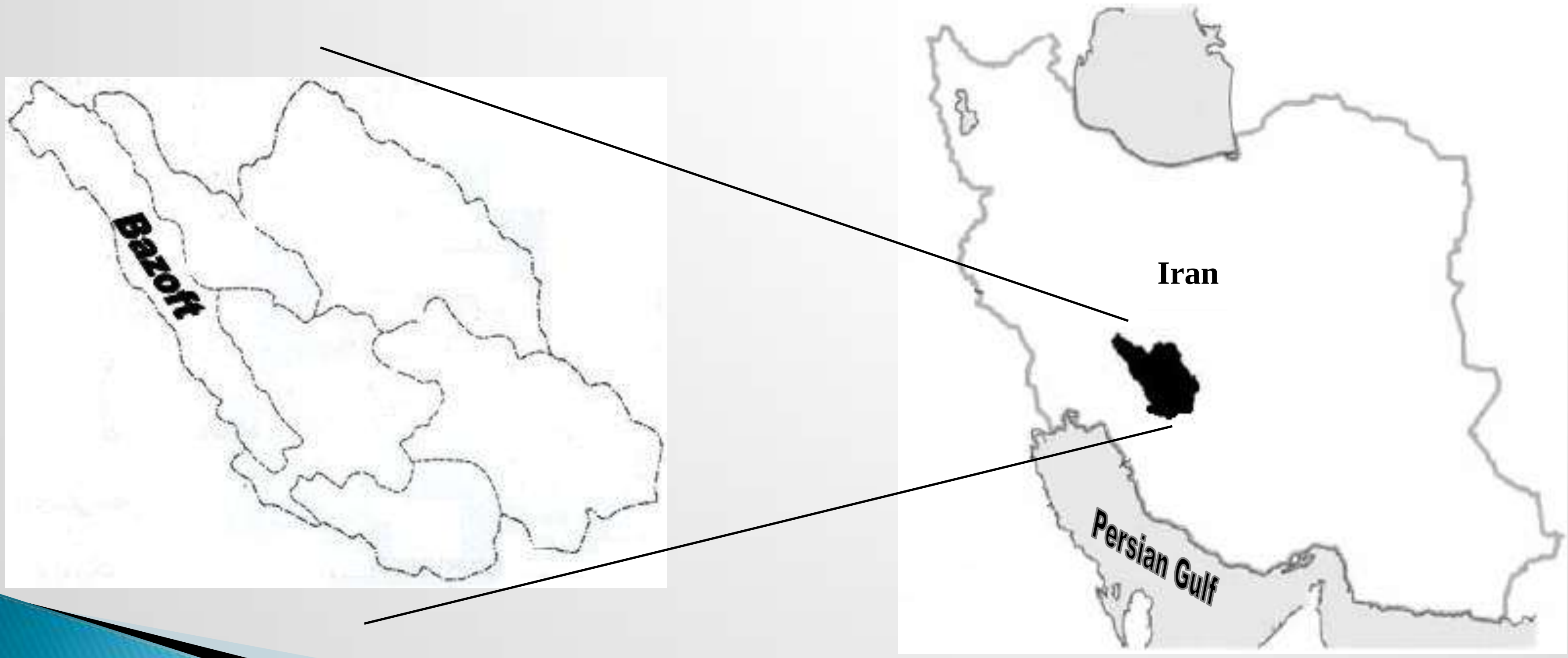

S6


S4


S31

✓ For the future

The SWAT model is recommended for identifying and prioritizing the critical sub-basins for management purposes in the Karun catchment.



Conclusions

✓ A large part of the watershed was predicted to be endangered of a high or very high erosion risk.

✓ The SWAT model may be more reliable in identifying and prioritizing the critical sub-basins for management purposes in the study area than the Fuzzy logic model.

Conclusions

- Limited data available in the study area: the method developed herein may help us to find more critical sub-basins

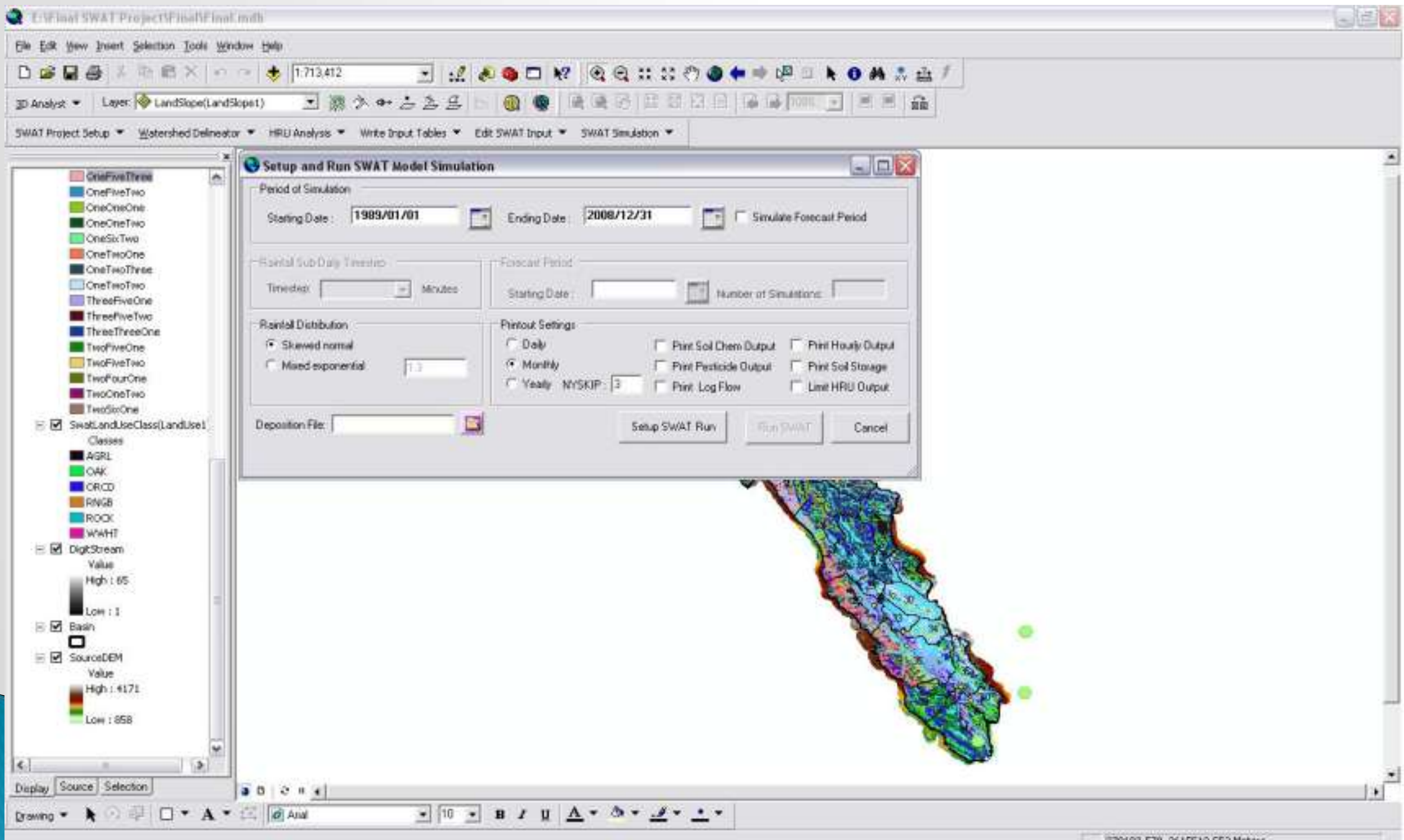
- The method can be applied in other watersheds

- Many developing countries: measured data are unavailable in each sub-basin of a watershed.

Khaju Bridge, Isfahan, Iran

Part 1
SWAT model

The simulation time period: 1989 – 2008



Karun 4 dam at the outlet of the watershed