universidade de aveiro

TECHNISCHE UNIVERSITÄT DRESDEN

Combining digital soil mapping and hydrological modeling in a data scarce watershed in north-central Portugal.

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FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

COMPETE

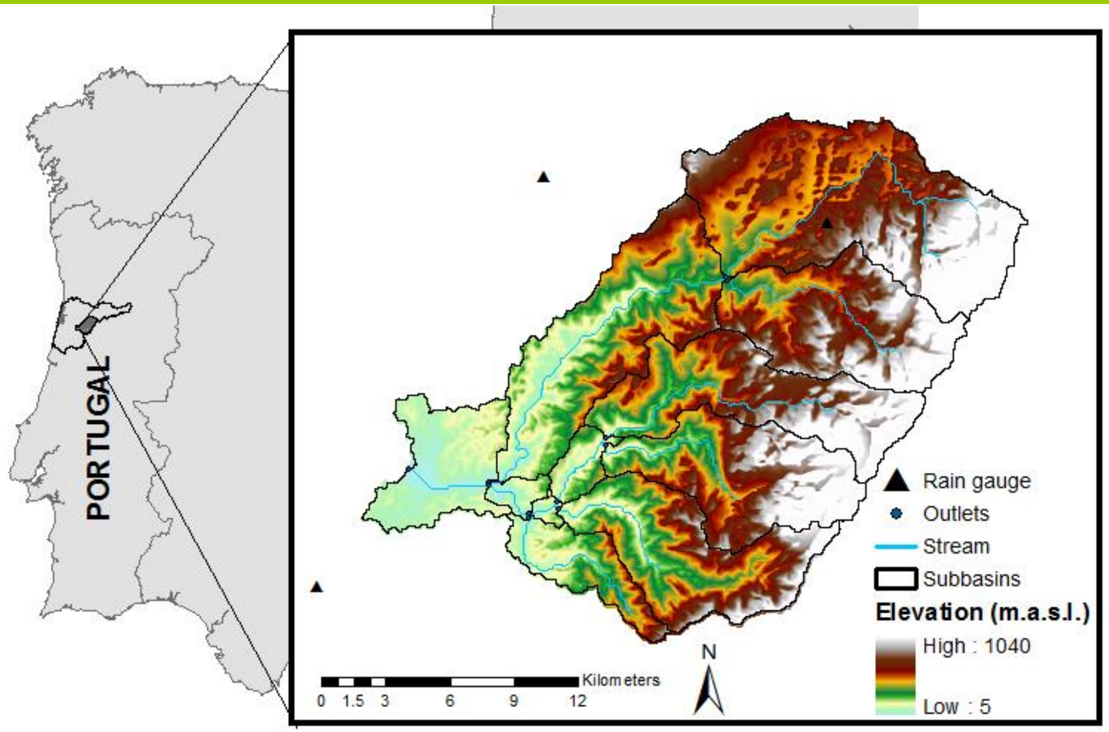
QREN QUADRO DE REFERÊNCIA ESTRATÉGICO NACIONAL PORTUGAL 2007.2013

EUROPEAN UNION
European Regional

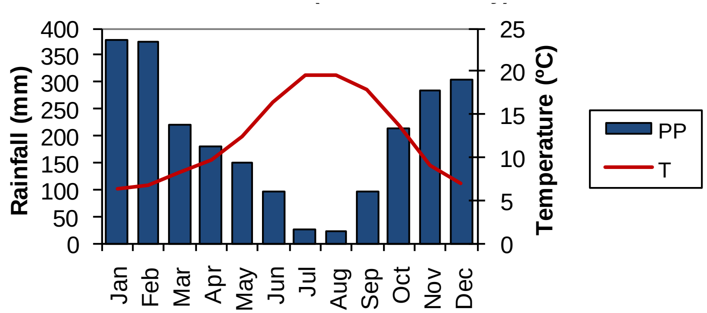
DAAD Deutscher Akademischer Austauschdienst German Academic Exchange Service

CRUP CONSELHO DE REITORES DAS UNIVERSIDADES PORTUGUESAS

Águeda river basin



Watershed area c. 400 km²
humid Mediterranean climate
c. 1400 - 2000 mm/Y pcp



- Some eco-hydrological research interests:

  – Subbasin of the Vouga river

  – Source of freshwater and nutrients for the Ria de Aveiro coastal lagoon

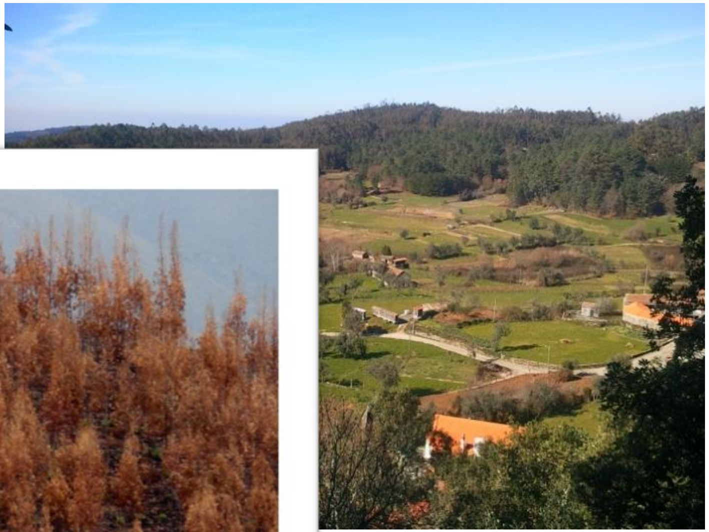
  – Forest cover, prone to recurring wildfires with consequences for streamflow and soil quality

  – Some reaches are prone to floods

Landcover

Commercial forest plantations in recent decades – eucalypt and maritime pines

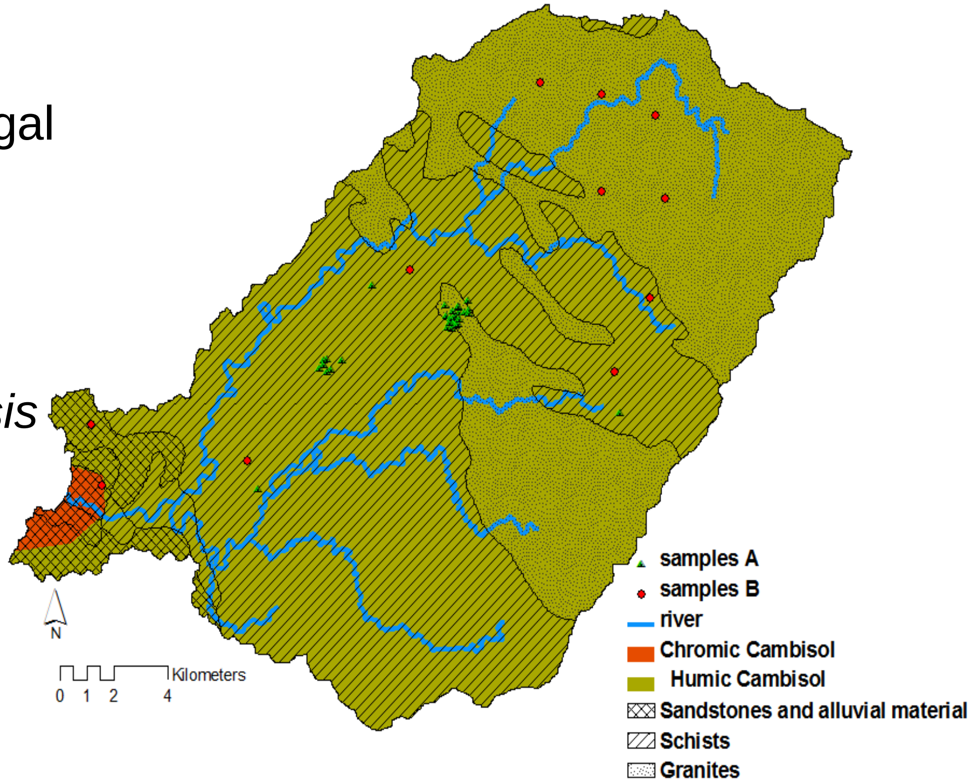
Complex agriculture in mountain catchments



Soils

Available Soil Map:
Cardoso et al. (1973) - Soil Map of Portugal
scale of 1:1,000,000

Physical characterization:
Cardoso (1965) - *Portuguese soils, their classification, characterization and genesis*
(title translated)

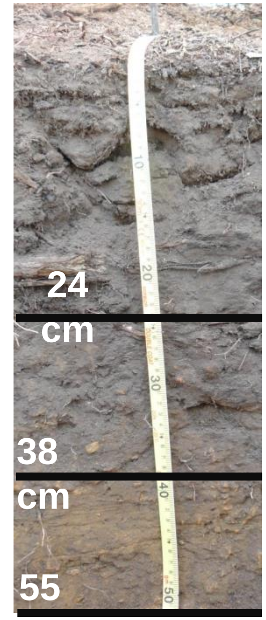


	Horizon Name	Sand (%)	Silt (%)	Clay (%)	Max. Depth (cm)
Humic Cambisols	A1	59	28	12	45
	B	70	22	8	90
	Cv	52	38	10	140
Chromic Cambisol	A	70	21	9	22
	B	63	25	12	65
	C	73	15	12	150

Soils

Many studies at plot to micro-catchment scale

e.g. Pereira and FitzPatrick, (1995); Doerr et al., (1996); Shakesby et al., (1996); Ferreira et al., (2008); Keizer et al., 2008; Santos et al., (2014)



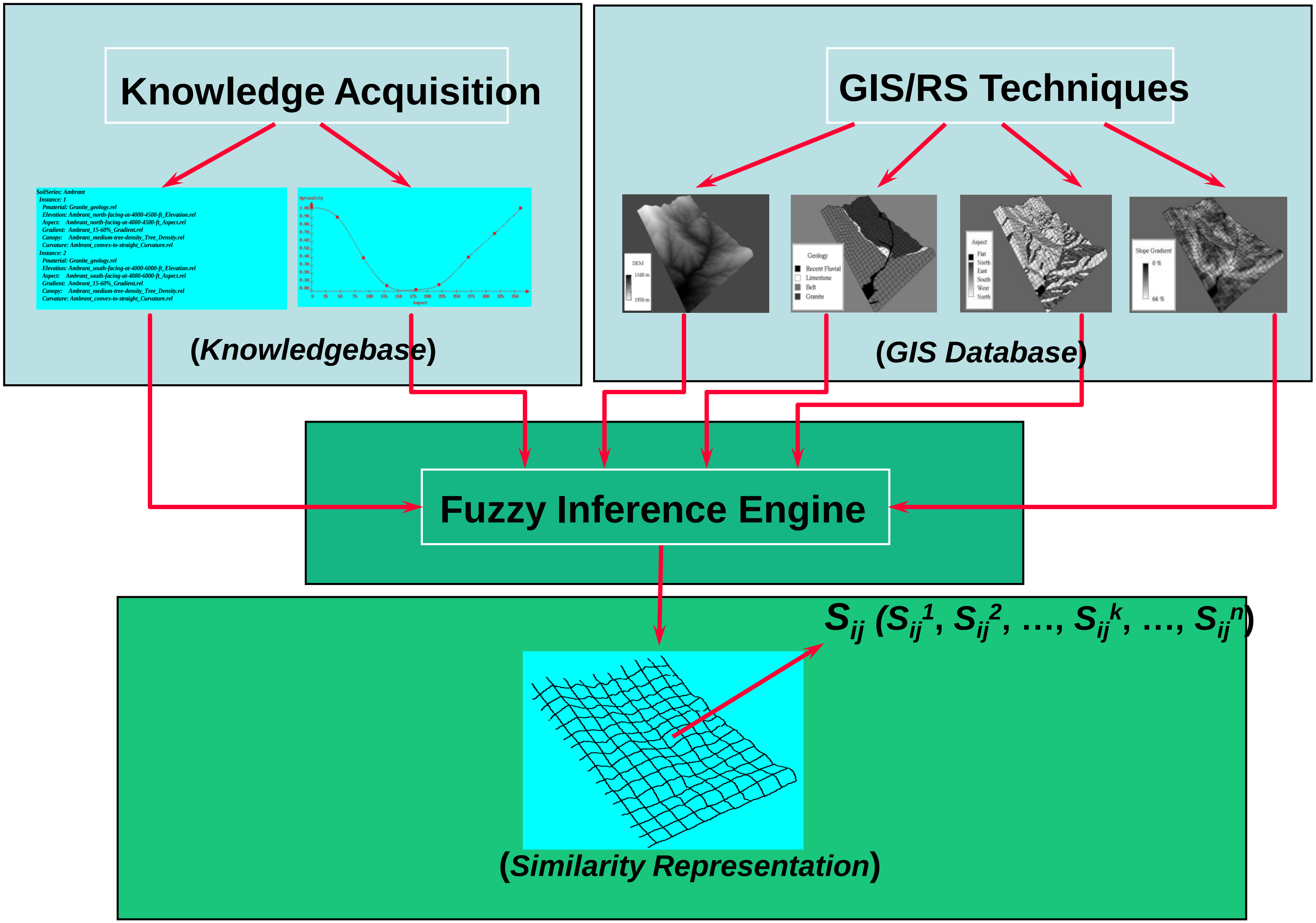
Often reported:

-High variability of effective soil depth

- Texture variation with parent material

Digital soil mapping

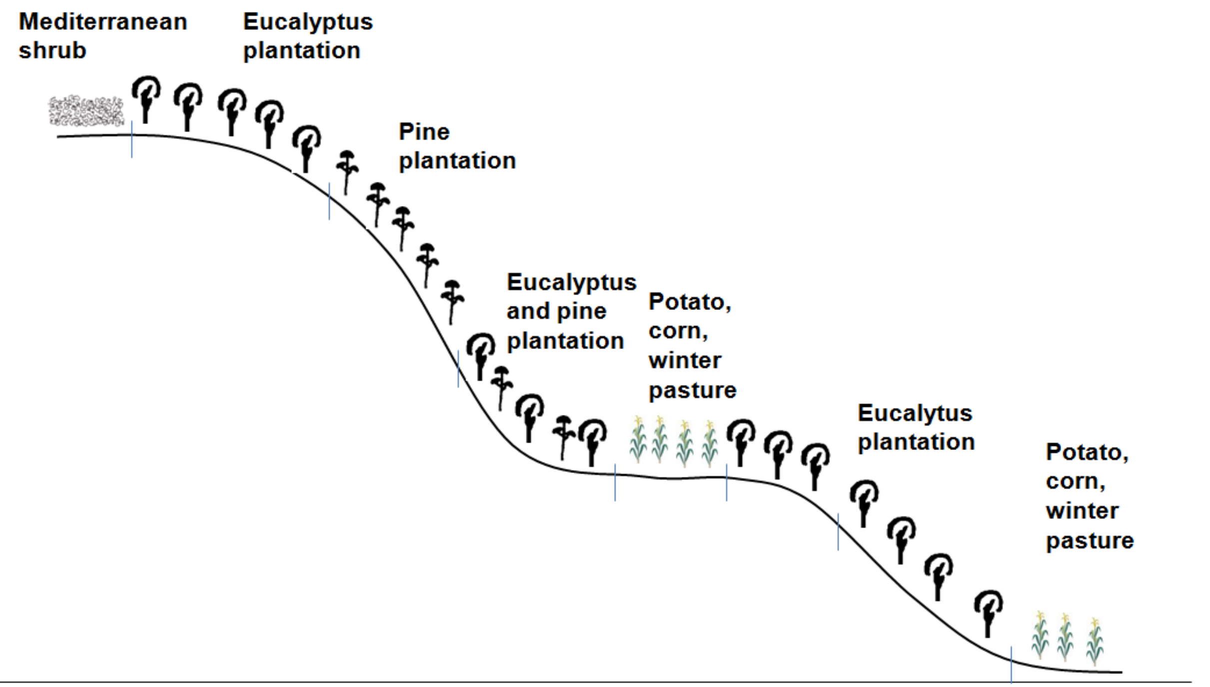
Soil Land Inference Model (SoLim) (Zhu, 1997, 1999; Zhu and Mackay 2001)



Digital soil mapping

Conceptual toposequence

• 3 conceptual effective soil depths were assumed



Depth class	Intermediate	Intermediate	Shallow	Intermediate	Deep	Intermediate	Shallow	Deep
Landscape position	Summits	Slope shoulders	Steep backslopes	Intermediate footslopes	Flat terraces	Nose slopes	Backslopes	Footslopes to drainage ways
Geology	Schists, granites	Schists, granites	Schists, granites	Schists, granites	Schists, granites	Schists, granites	Schists, granites	Schists, granites, alluvial deposits

→location (elevation, slope, curvature, parent material)

→ land-use, management (terracing)

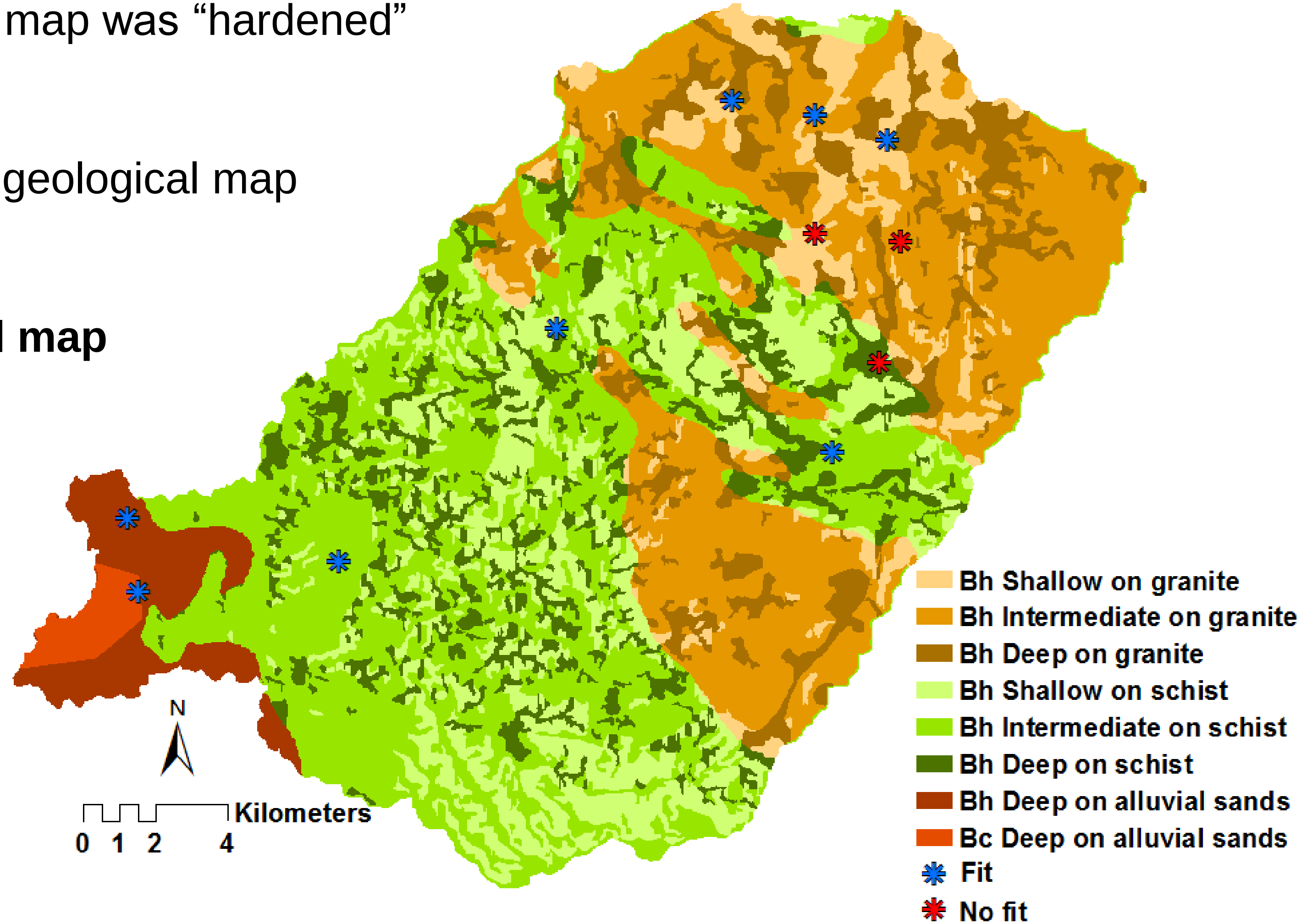
→ disturbances e.g fire (not included..)

Digital soil mapping

- fuzzy membership map was “hardened”

- combined with the geological map

➢**SoLIM-based soil map**



– verified for at 11 randomly selected locations

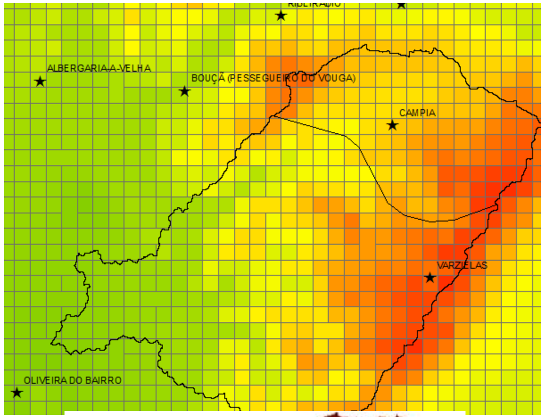
SWAT

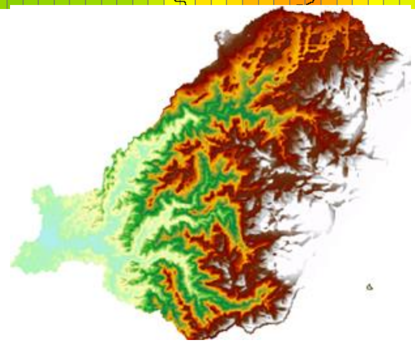
2 SWAT Projects – a) SWAT-BASE; b) SWAT-SOLIM

CLIMATE

SNIRH - Sistema Nacional de Informação de Recursos Hídricos

National Water Resources Information System



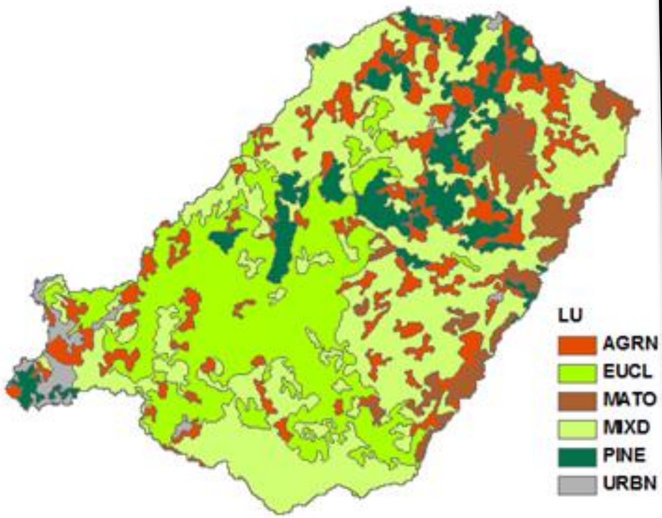


Elevation
GDEM 30 ASTER

LANDUSE

European Environment Agency

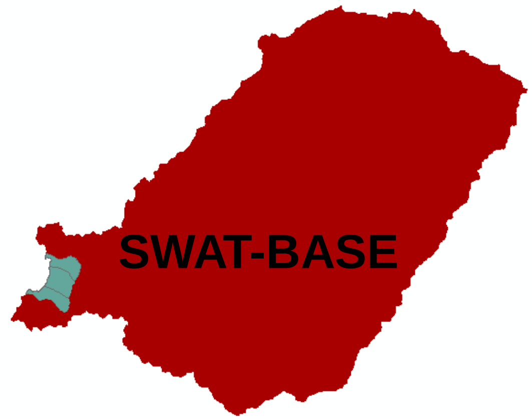
Corine Land Cover 2006 (1:100.000)

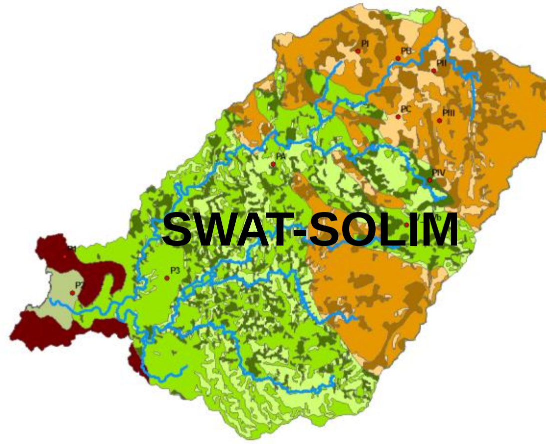


SOIL

AGÊNCIA PORTUGUESA DO AMBIENTE
Ministério do Ambiente, do Ordenamento do Território e do Desenvolvimento Regional

Environmental Atlas (1:1.000.000)





SWAT Auto-calibration

	Lower Bound	Upper Bound	Parameter Definition
SURLAG	0	3	Surface runoff lag coefficient
sol_awc	-0.15	0.15	Available water capacity of the soil layer (mm/mm)
sol_k_norock	-0.15	0.15	Saturated hydraulic conductivity (mm/hr)
sol_k_rock	100	1000	Saturated hydraulic conductivity (mm/hr)
CH_N1	0.01	0.3	Roughness coefficient n
CH_K1	0	100	Effective hydraulic conductivity (mm/hr)
ALPHA_BF1	0.001	0.99	Baseflow alpha factor (days)
GW_DELAY1	0	31	Groundwater delay time (days)
GW_REVAP1	0.02	R	Revap coefficient
GW_QMN1	0	200	Threshold depth of water in shallow aquifer for return flow to the deep aquifer to occur (mm)
Rchrg_dp1	0	0.25	Deep aquifer percolation fraction

Monte Carlo based – Latin Hypercube approach (sampling n = 5000)

Eval. Criteria: NSE, LnNSE and RSR

- Analysis was done for an **Ensemble output** rather then for the best fit

- **Ensemble definition**: each project - 10 best runs

SWAT – Calibrated parameter ranges

	SWAT-BASE Ensemble		SWAT-SOLIM Ensemble	
Parameter	Minimum	Maximum	Minimum	Maximum
SURLAG	0.00	0.06	0.00	0.02
SOL_AWC	-0.10	0.14	-0.14	0.13
SOL_K (no rock)	-0.15	0.15	-0.15	0.13
SOL_K (rock)	114.16	277.44	127.69	278.22
CH_N1	0.01	0.26	0.01	0.25
CH_K1	9.37	89.36	9.37	71.83
ALPHA_BF*	0.05	0.88	0.14	0.92
ALPHA_BF**	0.04	0.98	0.20	0.98
ALPHA_BF***	0.16	0.69	0.16	0.72
GW_DELAY*	1.49	30.33	3.63	24.42
GW_DELAY**	1.06	30.09	4.90	27.16
GW_DELAY***	1.10	30.53	4.26	30.53
GW_REVAP*	0.05	0.20	0.02	0.17
GW_REVAP**	0.03	0.18	0.03	0.18
GW_REVAP***	0.02	0.17	0.02	0.17
GW_QMN*	6.00	176.05	43.58	176.05
GW_QMN**	6.30	199.04	26.38	185.86
GW_QMN***	1.16	43.58	1.16	18.15
RCHRG_DP*	0.01	0.24	0.02	0.22
RCHRG_DP**	0.02	0.24	0.03	0.25

26 % Reduction

22 % Reduction

19 % Reduction

* Granite
** Schist
*** Alluvial sands

SWAT – Major water balance components

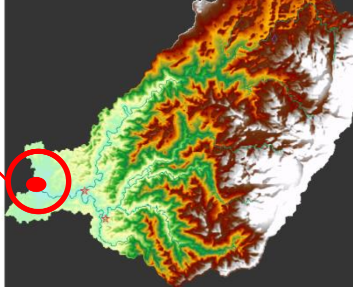
Average annual values (mm)	SWAT-BASE	SWAT-SOLIM	Observed
Precipitation	1483	1483	1483
Surface Runoff Q	131	211	
Lateral Soil Q	507	569	
Groundwater (Shal Aq) Q	29	7	
Total Discharge	667	789	760
Et	781	690	683*
Pet	1033	1033	

*- Et=Observed precipitation – Observed discharge

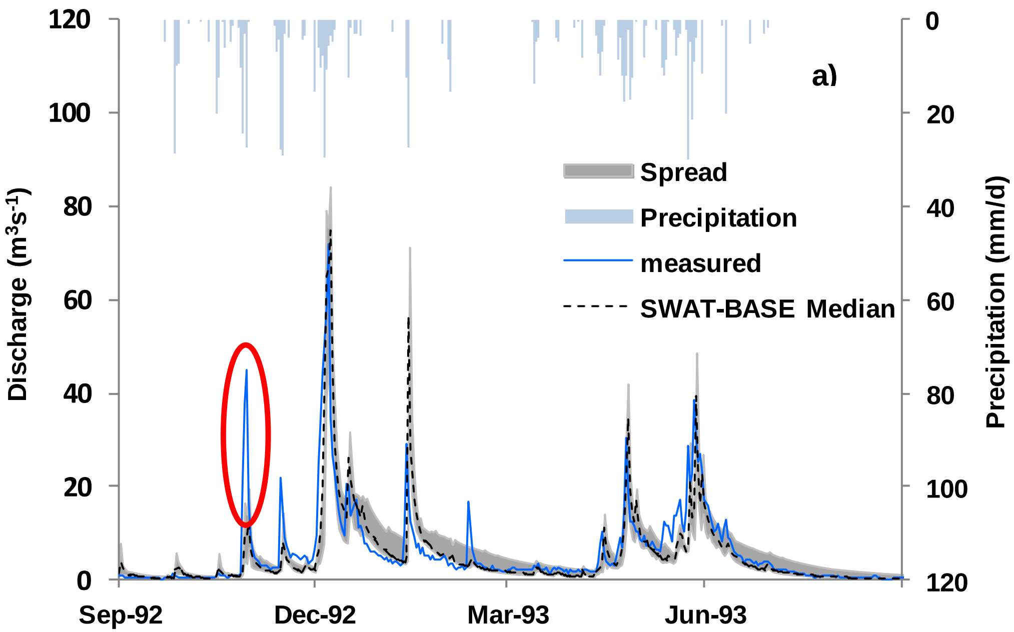
1) An increase of surface runoff was observed in SWAT-SOLIM
2) An increase in lateral flow was observed in SWAT-SOLIM
3) A reduction of actual evapotranspiration was observed in SWAT-SOLIM ⇒ in compliance with those observed from the difference between annual average precipitation and total water yield

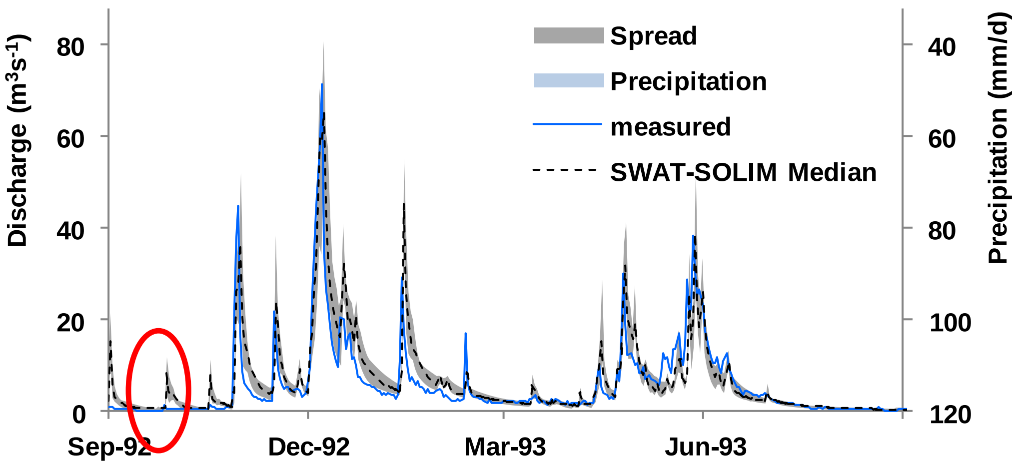
SWAT – Streamflow

Ponte de Águeda



Calibration 1/1/1991 – 31/12/1995

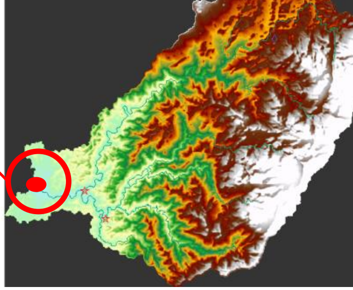




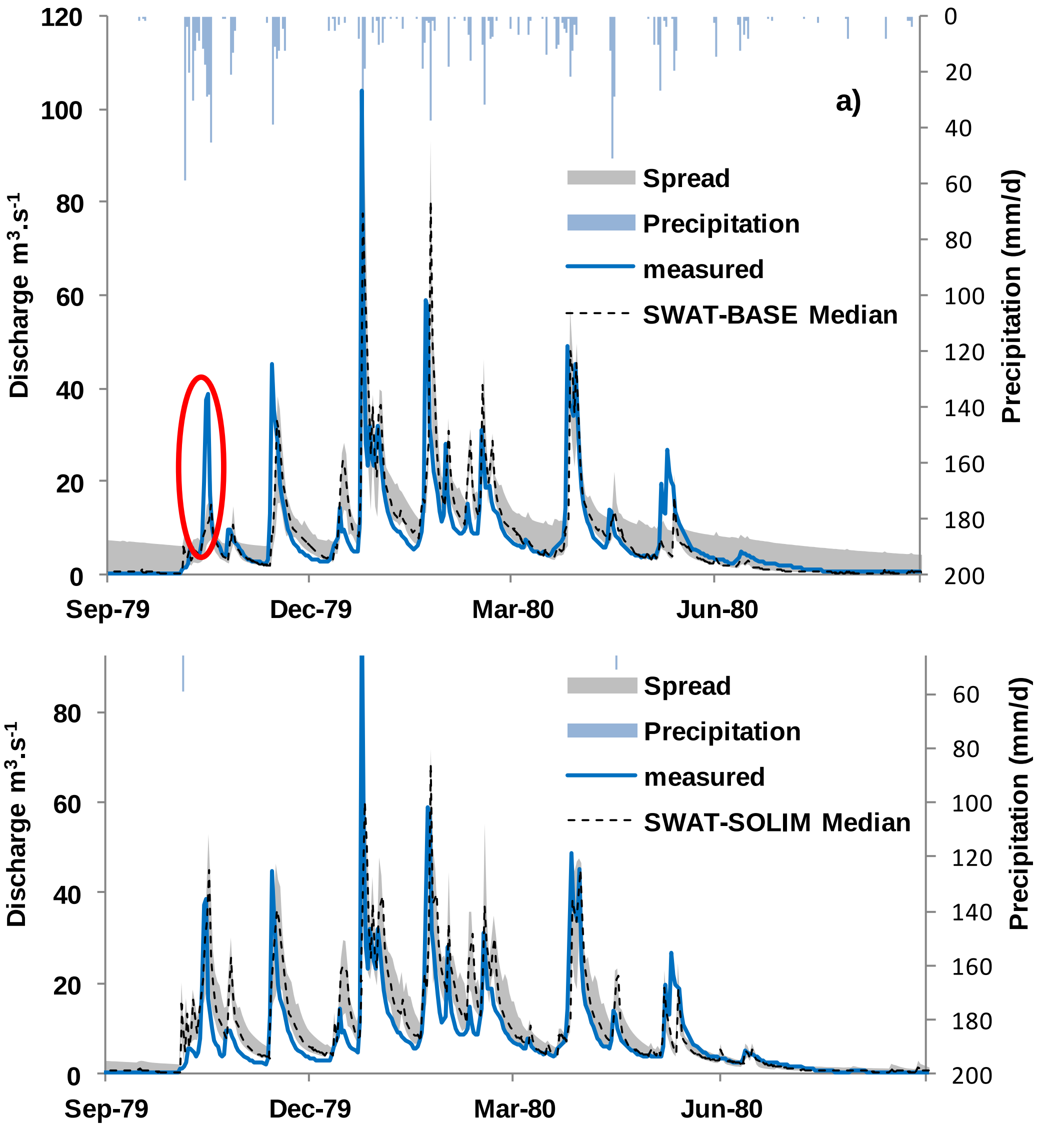
Index		SWAT-BASE	SWAT-SOLIM
NSE	Median	0.59	0.60
	Min	0.51	0.55
	Max	0.62	0.64
LnNSE	Median	0.76	0.78
	Min	0.72	0.75
	Max	0.82	0.80
RSR	Median	0.63	0.61
	Min	0.71	0.67
	Max	0.62	0.60

SWAT – Streamflow

Ponte de Águeda

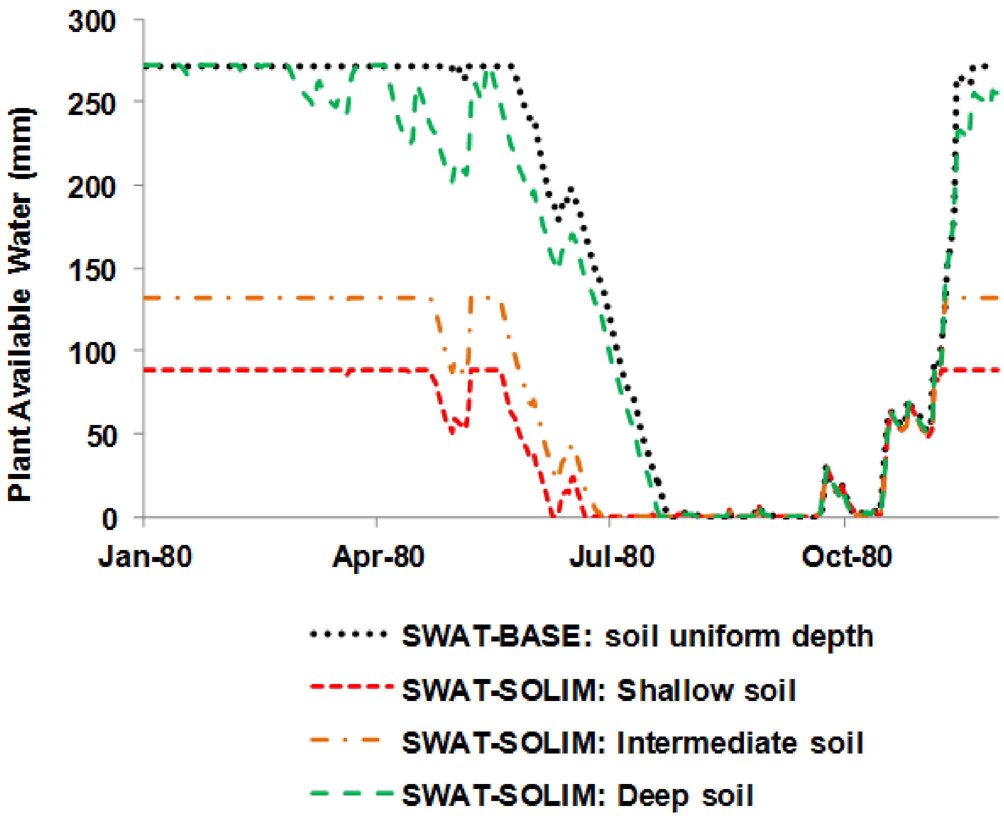


Validation 1/1/1979 – 31/12/1981



Index		SWAT-BASE	SWAT-SOLIM
	Median	0.60	0.64
NSE	Min	0.47	0.58
	Max	0.64	0.65
	Median	0.87	0.86
LnNSE	Min	0.27	0.71
	Max	0.90	0.88
	Median	0.61	0.58
RSR	Min	0.73	0.62
	Max	0.61	0.58

SWAT – HRU assessment

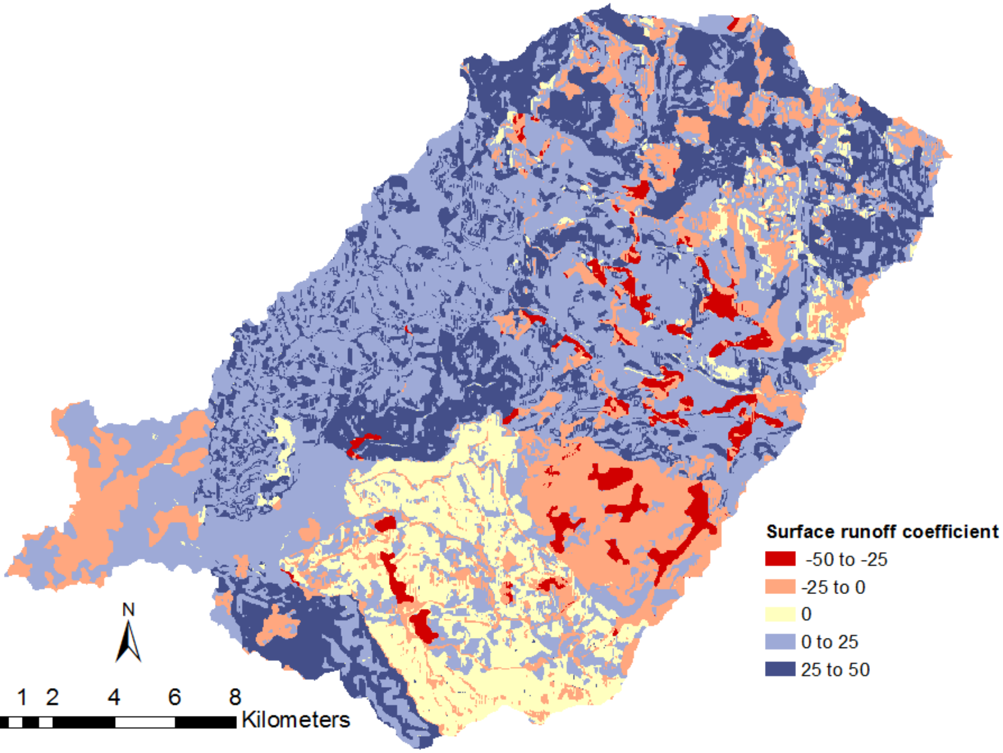


-4 representative HRU‘s (Humic Cambisol; Eucalyptus; Slope > 18°)

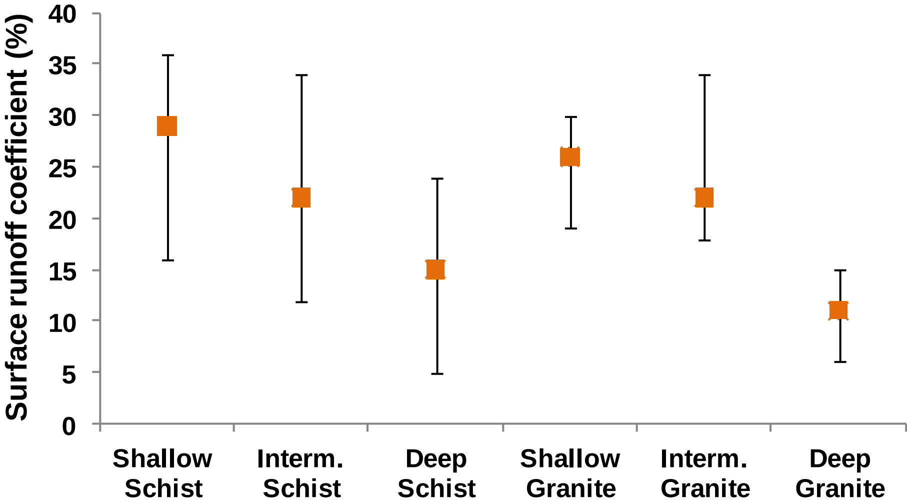
- simulation of temporal dynamics of soil water

- different dry out timing – establishment of water repellency, altered infiltration capacity etc.

SWAT – HRU assessment



➢ SWAT-SOLIM predicts larger surface runoff coefficients than SWAT-BASE for more than 67 % of the catchment



➢ The dependence of the surface runoff generation process on effective soil depth and soil texture needs to be taken into account.

Outlook

• Simple approach to overcome the lack of spatially differentiated soil information.

• SWAT – SoLIM represents better the watersheds soil variation

• SWAT-SoLIM model structure allowed a reduction of parameter ranges (particularly groundwater related)

still…Both projects were SUCCESSFULLY calibrated

• the assessment of management options may be negatively affected by a coarser model structure – implicit hydrological process misrepresentation can occur.

• in areas with data scarcity, it should be avoided focusing on discharge at the watershed's outlet.

• an assessment of runoff components that is based on a more realistic spatial differentiation needs to go along with in-stream assessments.

Thank you for your attention!!!