Instituto de Ingeniería del Agua y Medio Ambiente

UNIVERSIDAD POLITECNICA DE VALENCIA

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A definição de caudais ambientais em sistemas fluviais: desenvolvimento do modelo RIPFLOW e as suas aplicações

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Regional and national research programmes network on iwrm-net Integrated Water Resource Management

Outline

- Introduction: RIPFLOW project description
- RIPFLOW model
- Implementation in Terde reach at upper Mijares River
- Scenarios simulation
  - Regulated
  - Minimum environmental flows
- Conclusions

The Consortium & key personnel

- **Technical University of Valencia (Spain)**
  - Research Institute of Water and Environmental Engineering : **Félix Francés** (coordinator)
  - Research Institute for Integrated Management of Coastal Zones: **Francisco Martínez-Capel**

- **Technical University of Lisbon (Portugal)**
  - Instituto Superior de Agronomia: **Teresa Ferreira**
  - Instituto Superior Técnico: **António Pinheiro**

- **Umweltbüro Klagenfurt (Austria): Gregory Egger**

Ripflow project background

- Riparian ecosystems are important by their self and for their ecological services.
- They are connected with rivers ➔ be taken into account in the rivers ecological status evaluation, in a wide sense or from the WFD point of view.
- To accomplish this evaluation in the long-term, it is necessary to have a tool capable to predict the riparian vegetation response to its driving forces, as far as these drivers will or can change in the future.

Ripflow project objectives

- Scientific objective: to develop a flexible dynamic model of riparian habitats and vegetation to be easily applied in a wide range of conditions across Europe.
- Merging two models:
  - CASIMIR, from Umweltbüro Klagenfurt (Austria)
  - RibAv, from IIAMA (Spain)

Ripflow project objectives

- Scientific objective: to develop a flexible dynamic model of riparian habitats and vegetation to be easily applied in a wide range of conditions across Europe.

- Application to some case studies of the countries involved in this project (Austria, Portugal and Spain):
  - Validate the model (present conditions)
  - Practical objective: assess the impact of future scenarios:
    - Climate change
    - Water management decisions: **reservoirs**, **environmental flows** and restoration

- Introduction: RIPFLOW project description
- **RIPFLOW model**
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Definition of a mathematical model

- Simplification of reality
  - System = reality of interest
- State variables (**Y**):
  - Defines the state of the system at each moment and place
    - Output: state variables of interest
- Input: need to be measured (**X**)
- Equations (M):
  - Mass/energy balance
  - Flows descriptions (processes)
- Parameters (**Θ**)
  - Characterize the system
  - Should be stationary

$$\mathbf{Y} = M(\mathbf{\Theta}, \mathbf{X}, \mathbf{Y})$$

Input

Set of:

- Equations
- Parameters
- State variables

Output

RIPFLOW model definition

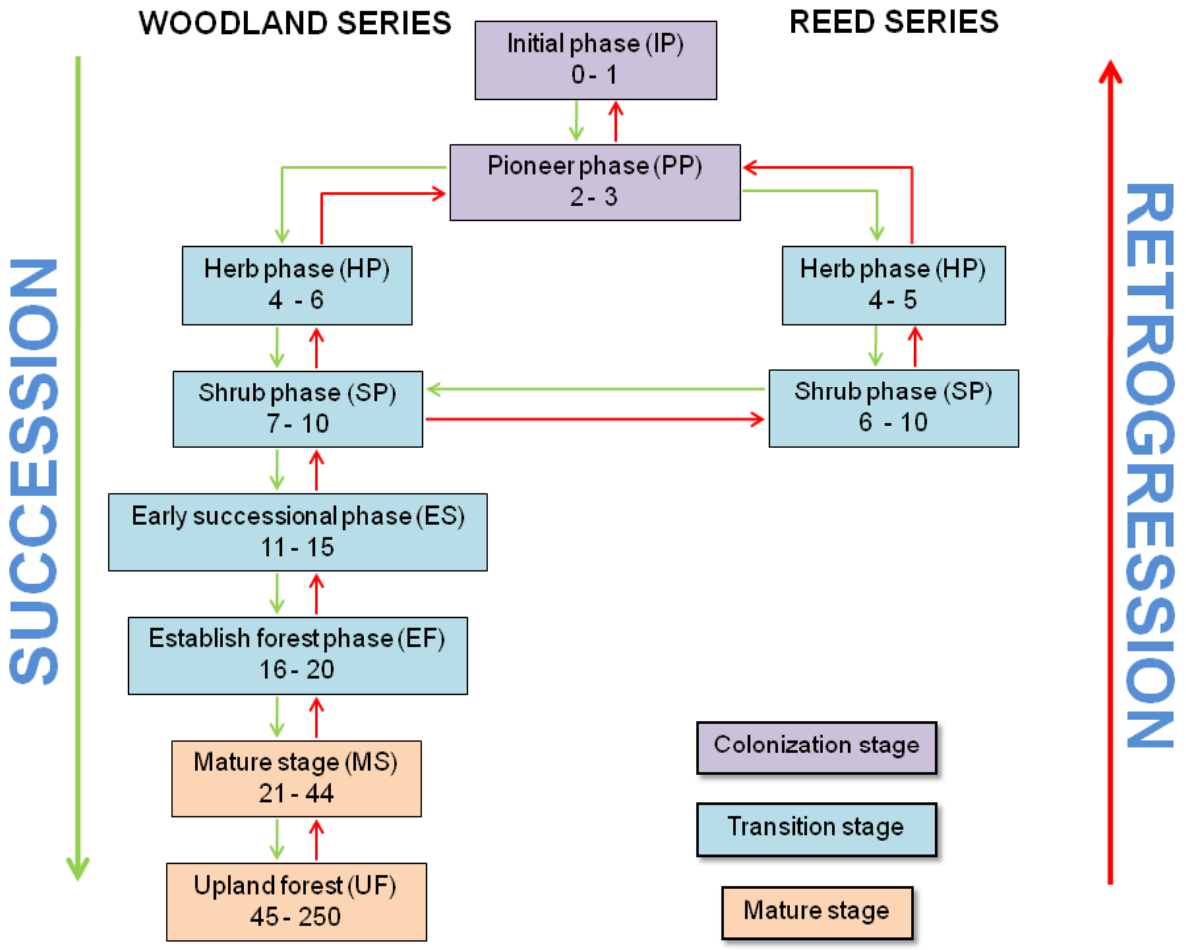
- Distributed in cells, small size (1-5m) due to height influence
- Annual time discretization (soil moisture daily)
- Main state variable: vegetation succession phase

Succession phases

- IP: initial phase
- PP: pioneer phase
- HP: herb phase
- SH: shrub phase
- ES: early successional woodland
- EF: establish forest
- MS: mature stage
- UF: upland forest

- Succession series
  - WD: woodland series
  - RE: reed series
  - WE: wetland series

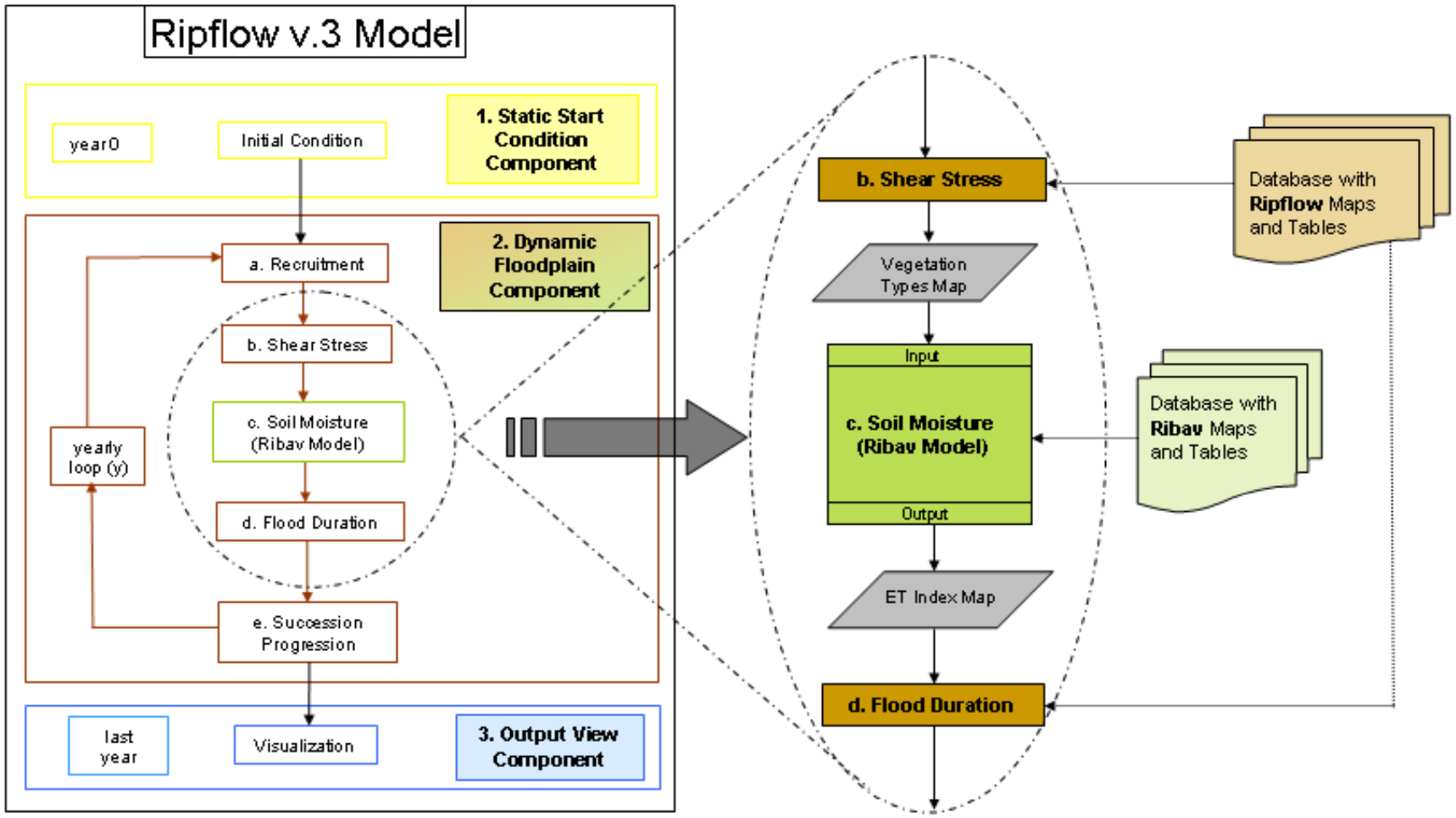
Succession and retrogression



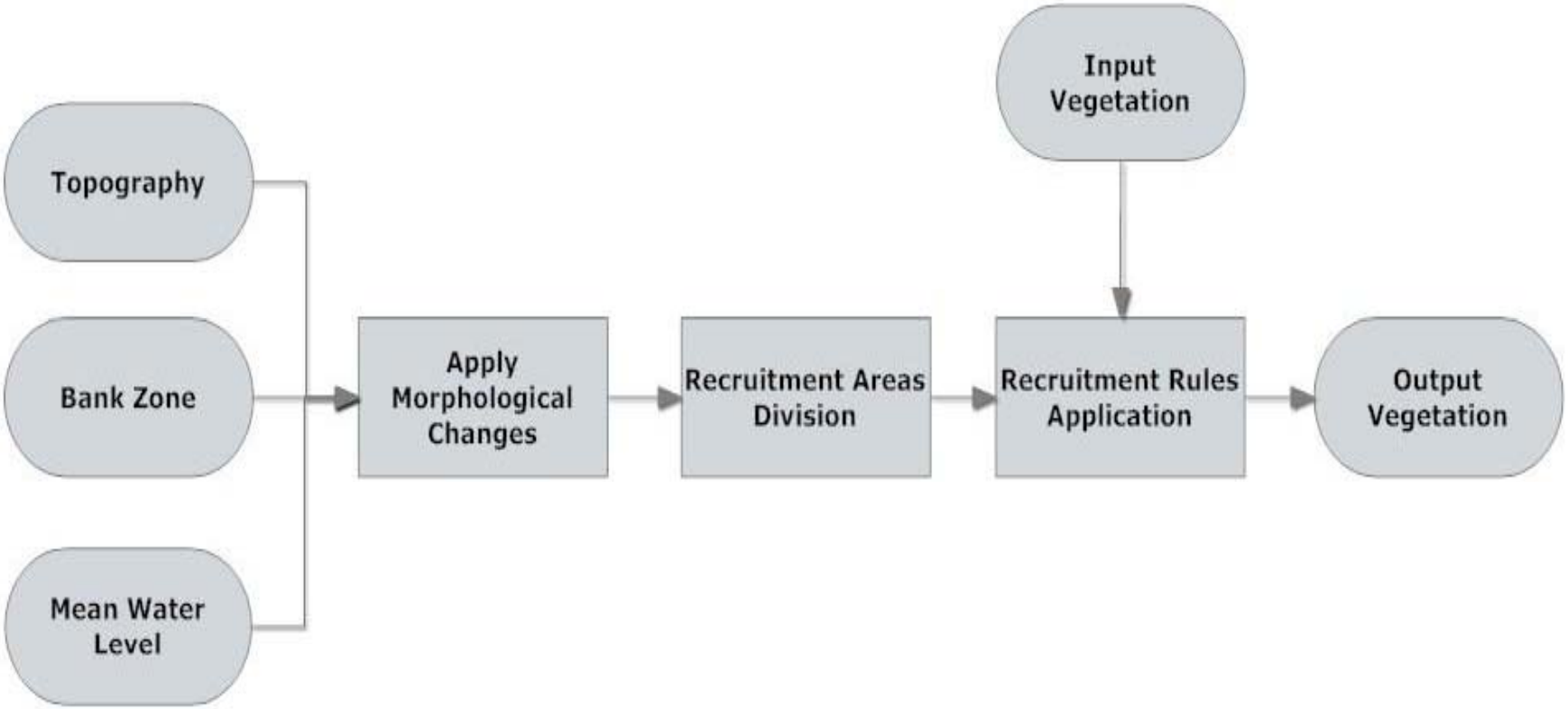
RIPFLOW model definition

- Distributed in cells
- Annual time discretization
- Main state variable: vegetation succession phase
- Main driving forces (and processes):
  - Maximum shear stress <= flood destruction
  - Flood duration <= submersion stress
  - Base flow or spring flow <= recruitment and seedling conditions
  - Annual transpiration <= water stress
- Parameters basically are thresholds

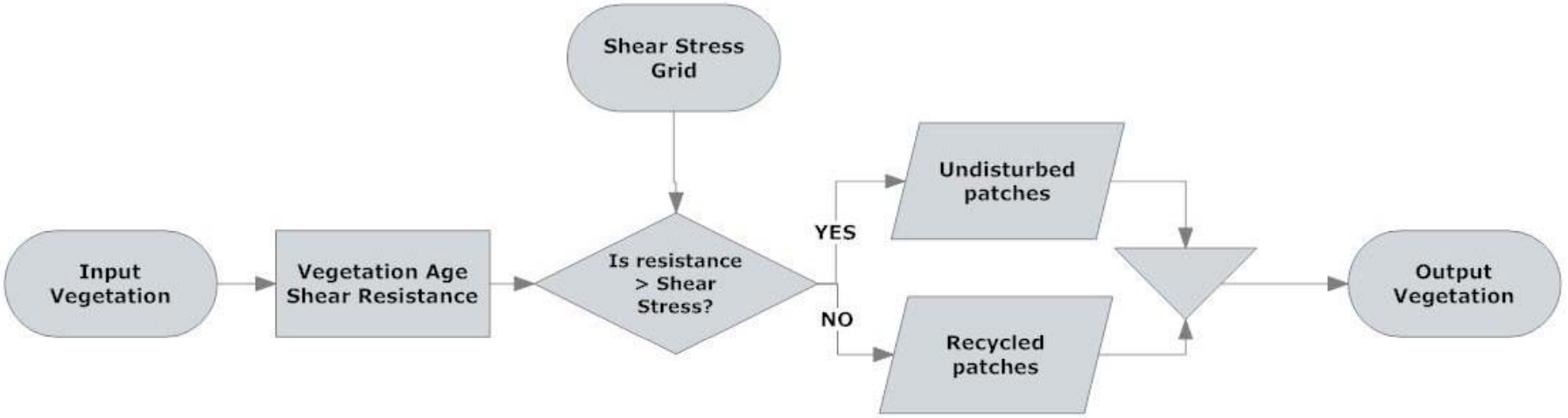
General structure



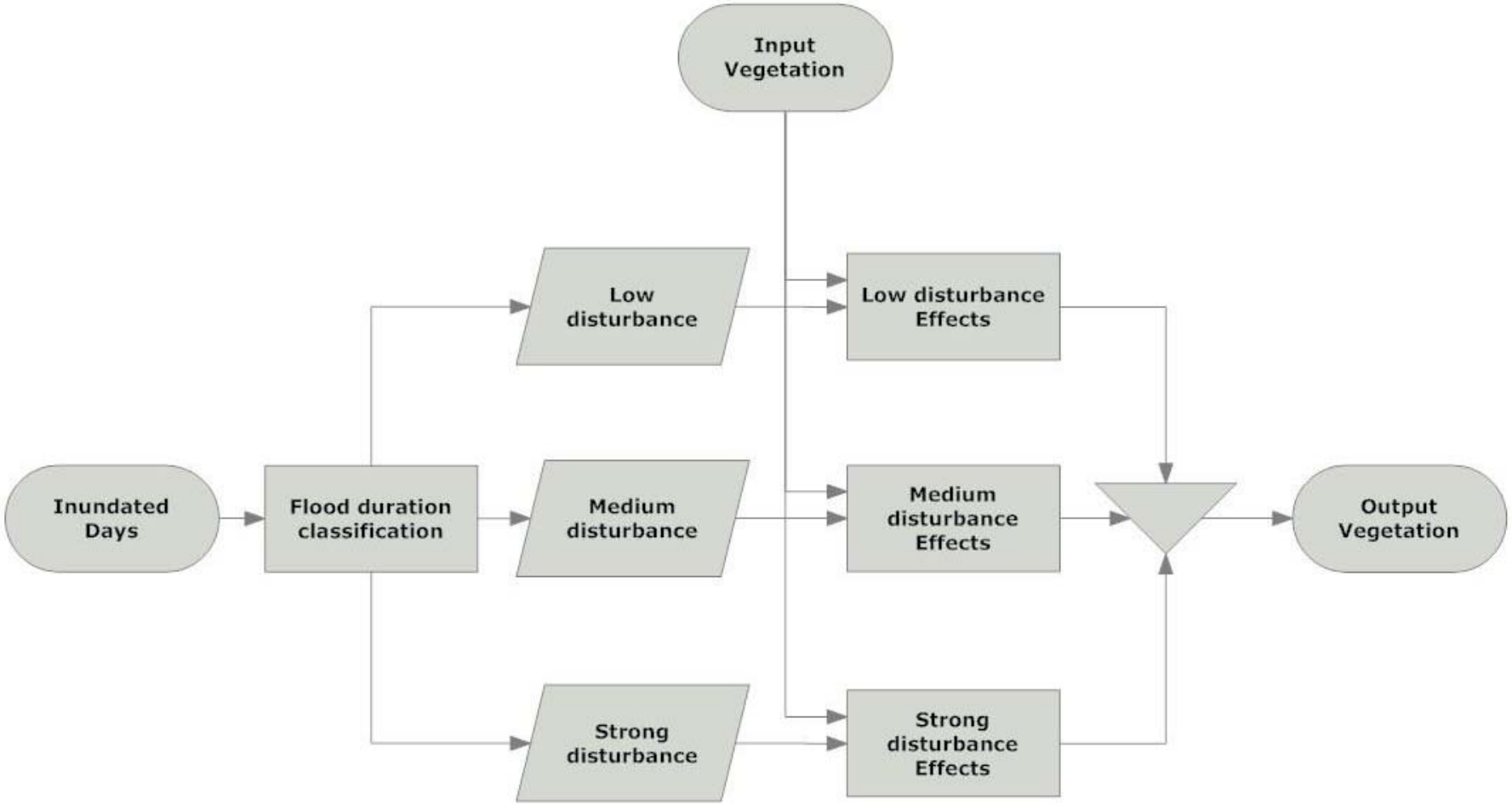
Recruitment module



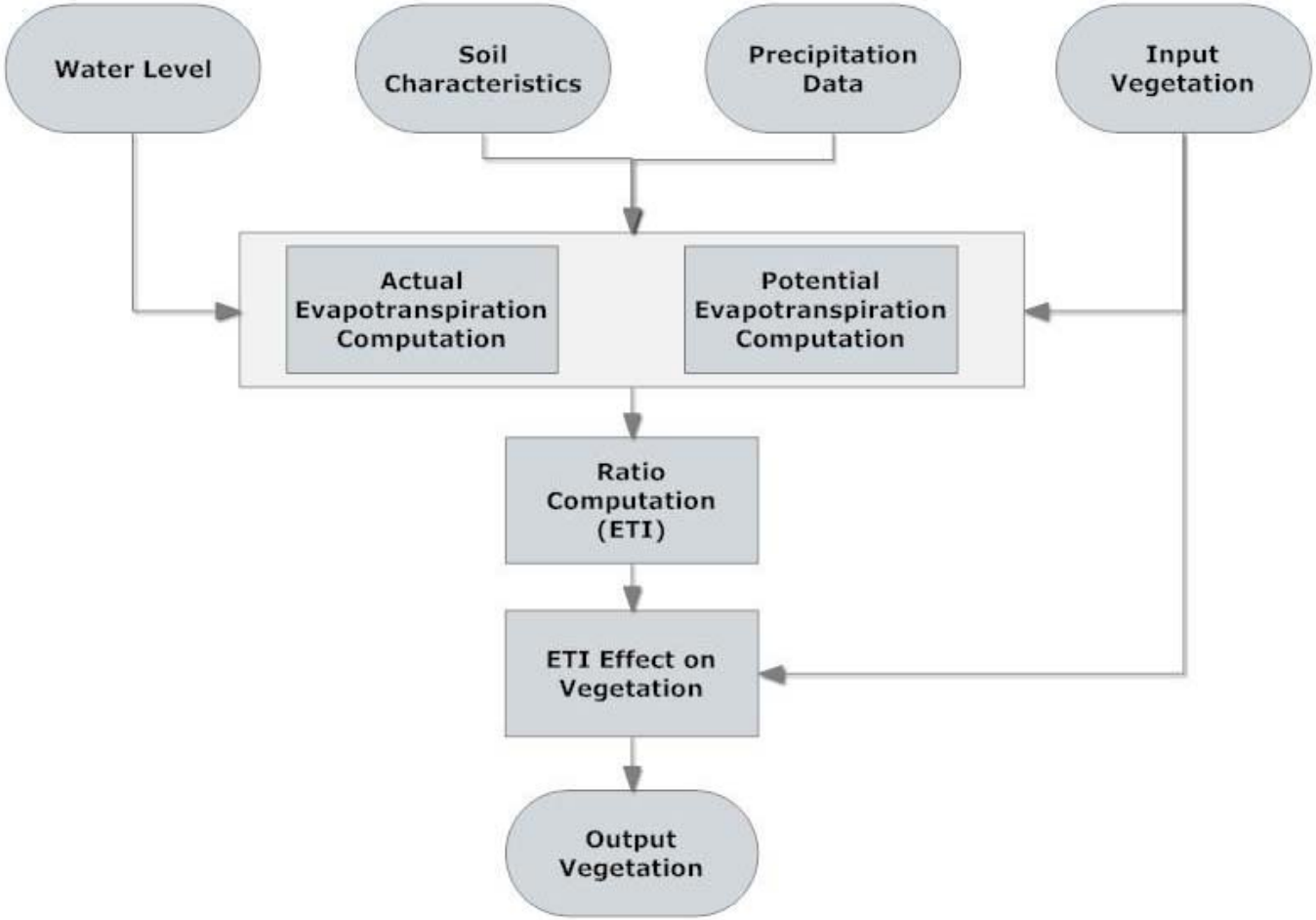
Shear stress module



Flood duration module



Soil moisture module

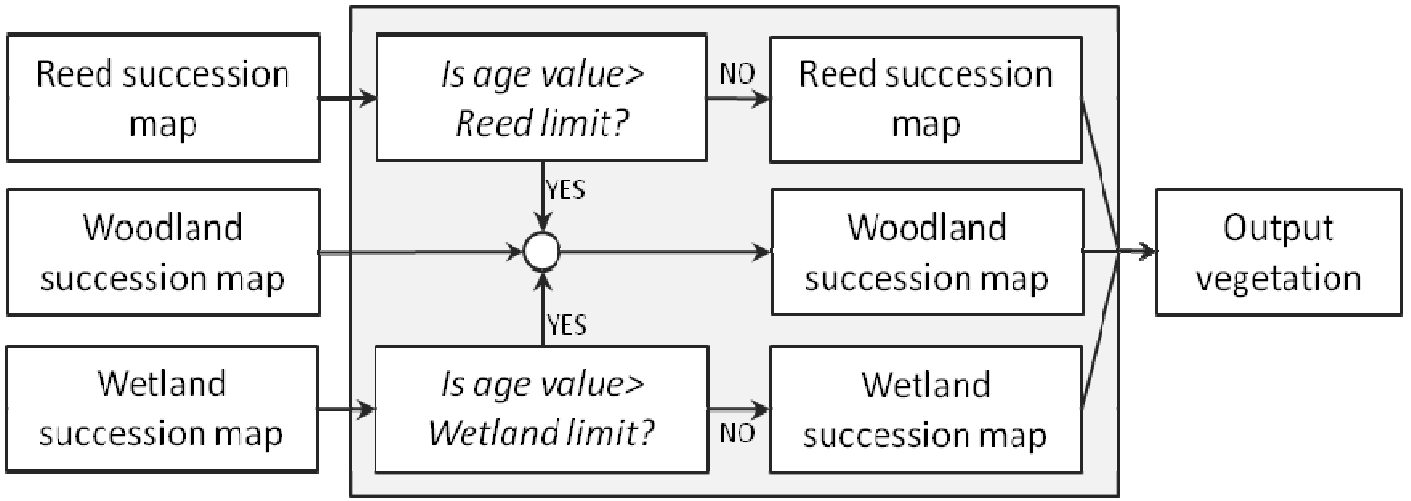


Soil moisture module

- Plant Functional Types:
  - BS: bare soil
  - RH: riparian herbs
  - RJ: riparian juveniles and small shrubs
  - RA: riparian adults trees and big shrubs
  - TV: terrestrial vegetation

Succession progression module

- Determine a series change



Succession progression sub-model

- Introduction: RIPFLOW project description
- RIPFLOW model
- **Implementation in Terde reach at upper Mijares River**
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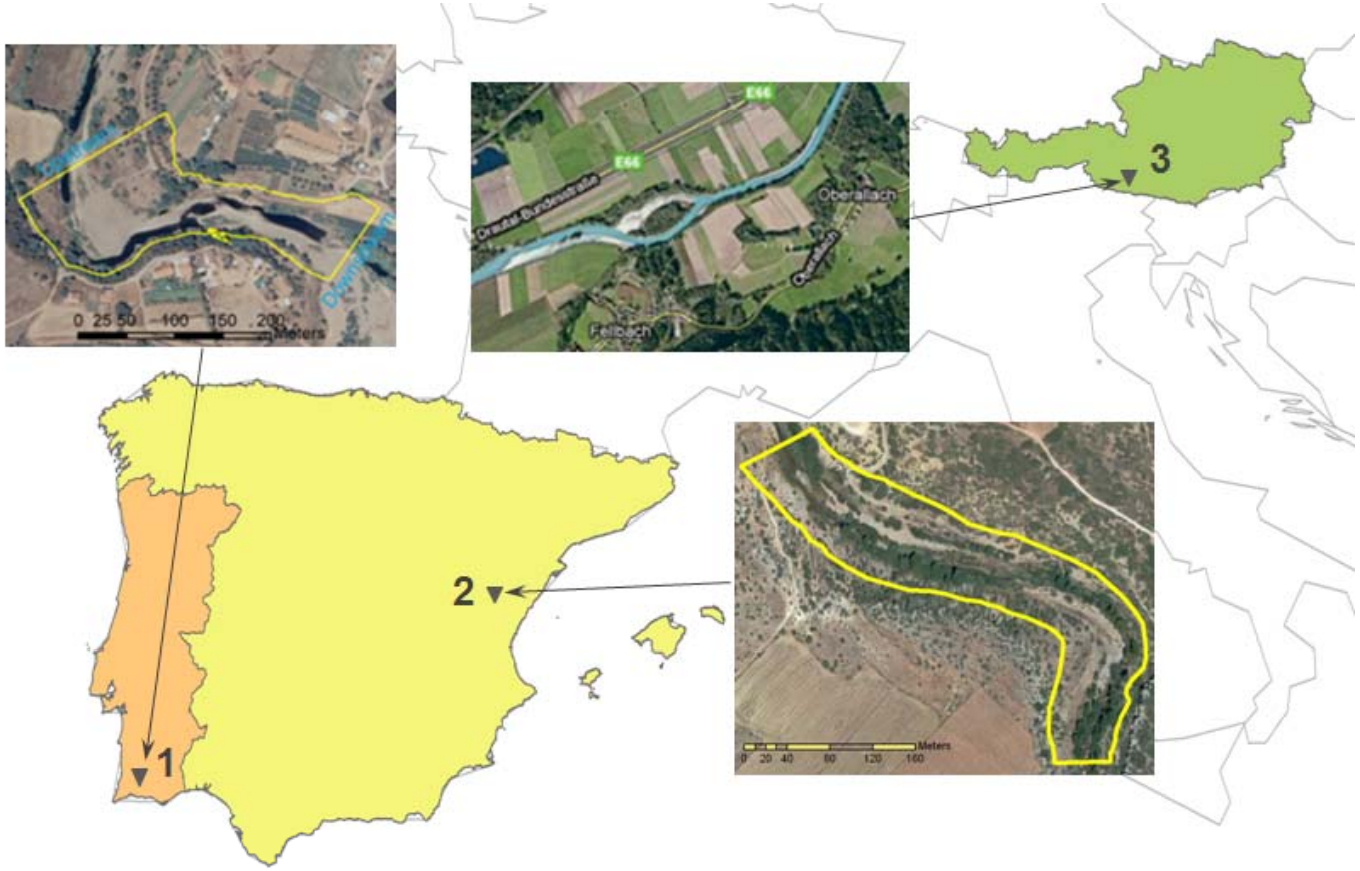
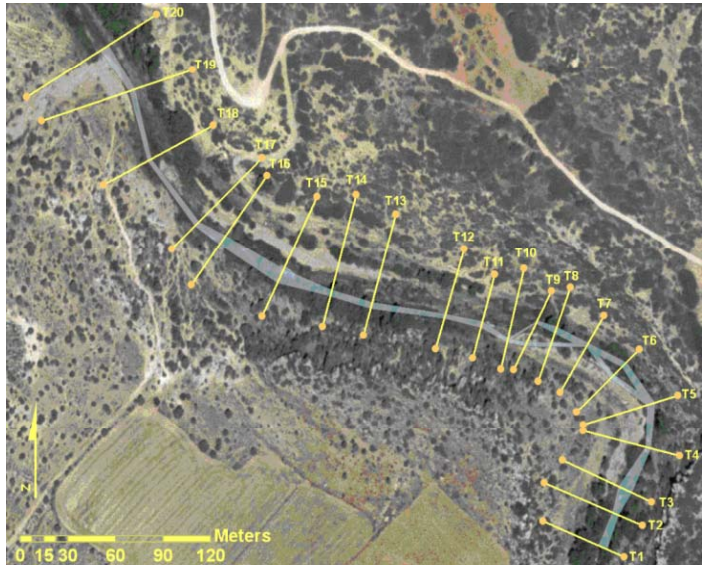
Case studies

- Odelouca, Upper Drau and Mijares



Terde reach at the Mijares River

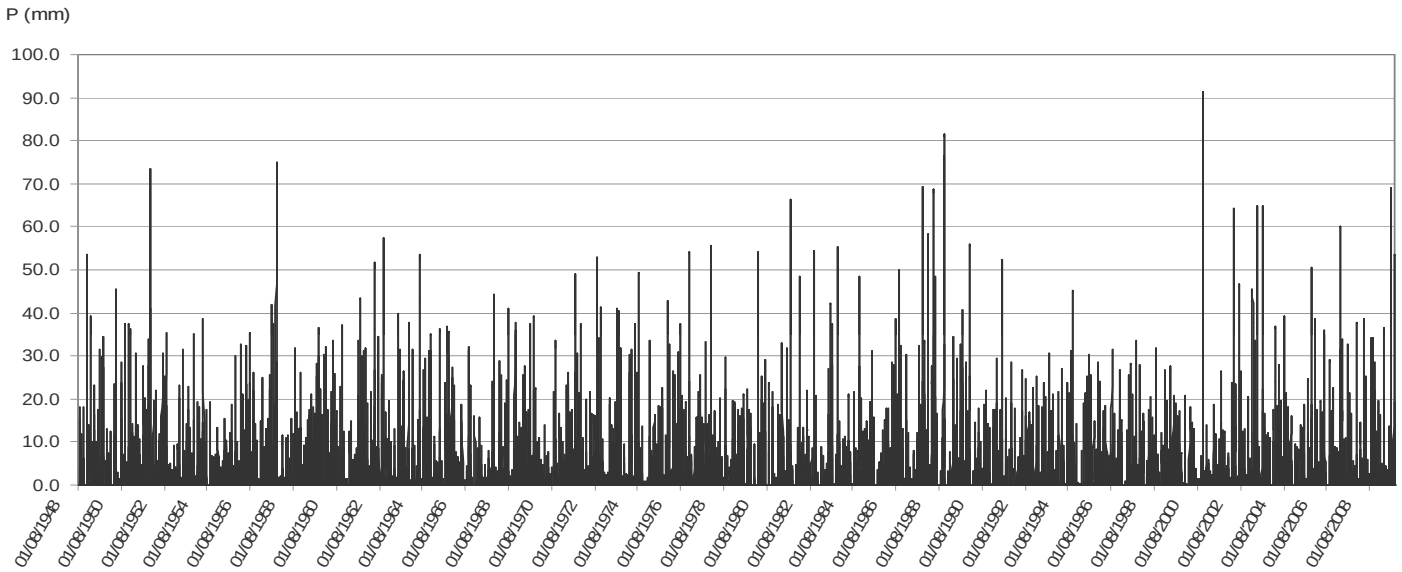
- **Permanent** flow regime
- **No flow regulation** upstream
- Near natural conditions
- Basin area: 665 km2
- Bankfull Q= 5 m3/s



- Riparian vegetation: *Salix eleagnos*, *Salix purpurea* and *Populus nigra*
- Upland forest: *Pinus* and *querqus*

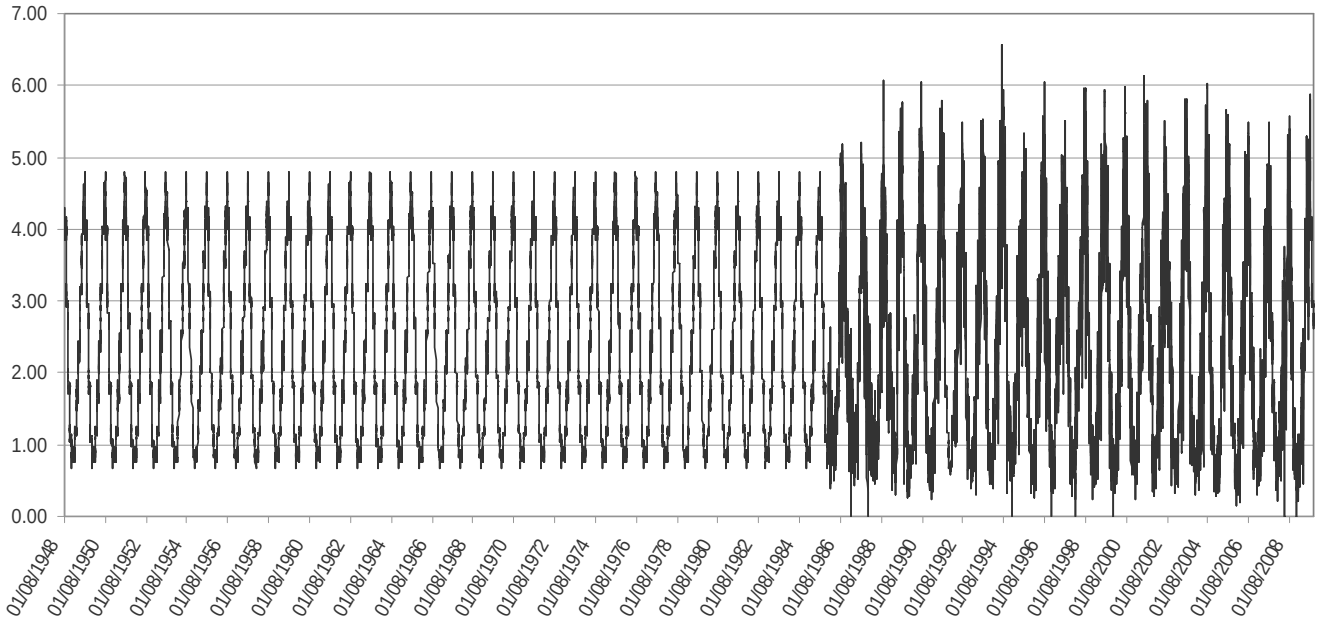
Hidrometeorological info.

- Daily precipitation (mm/day) period 1948 – 2009
  - 1988-2009: **P= 514 mm/year**



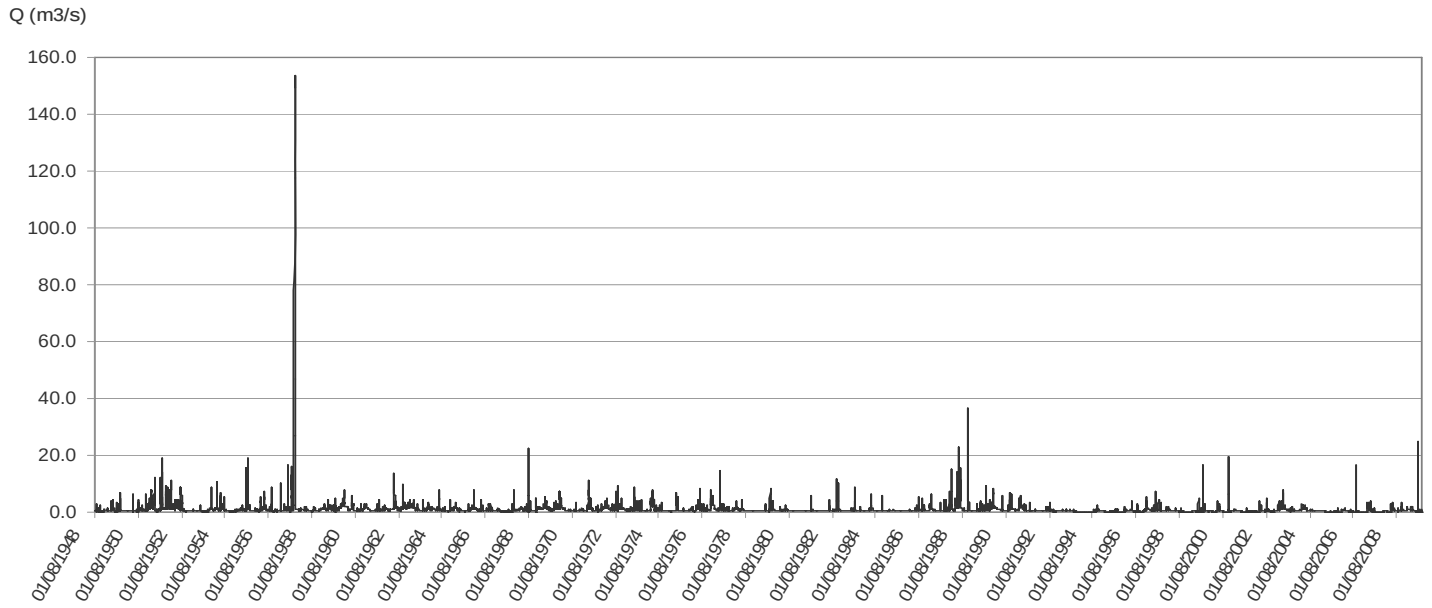
Hidrometeorological info.

- ET0 (mm/day) period 1948 – 2009
  - 1988-2009: **ET0= 860 mm/year** >P **=> semiarid**

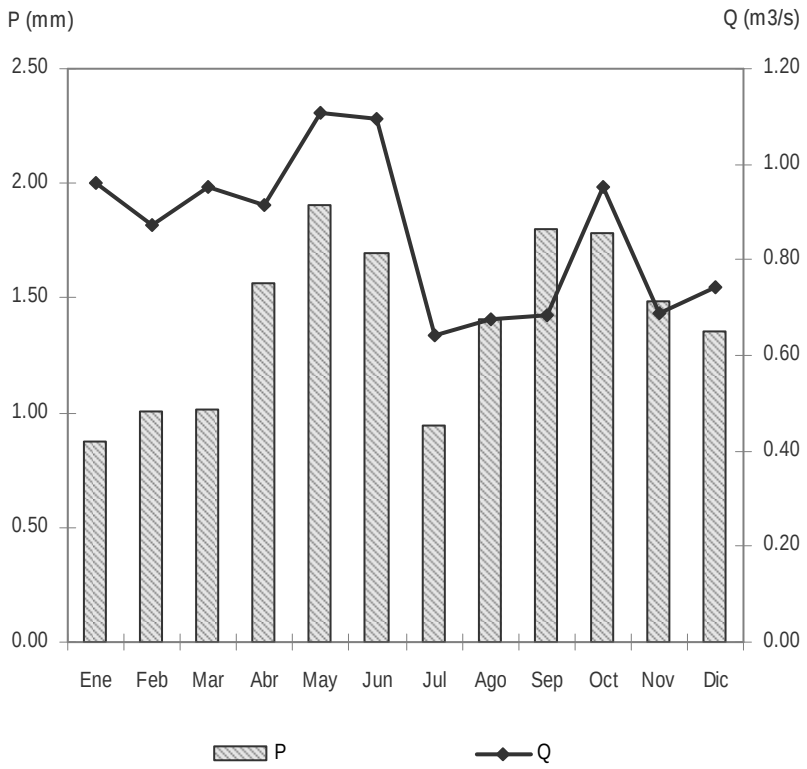


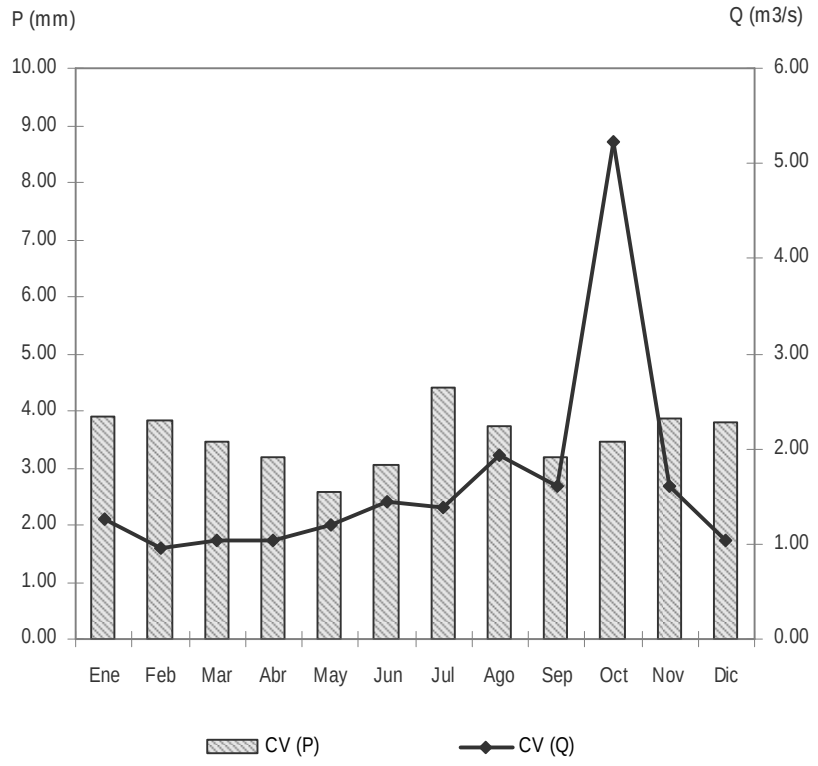
Hidrometeorological info.

- Daily river discharge (m3/s) period 1948 - 2009
  - 1988-2009: **Q= 0,640 m3/s**

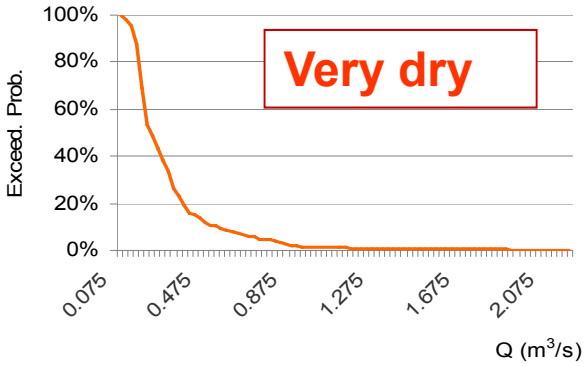


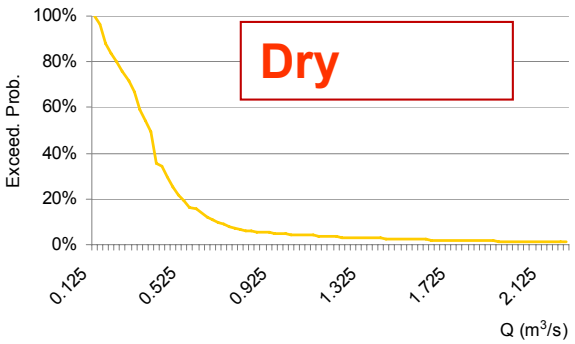
Hidrometeorological info.

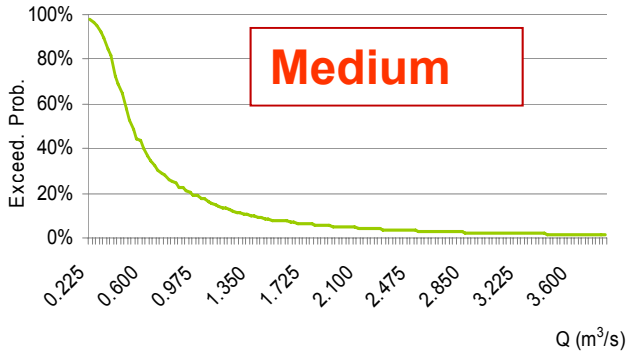


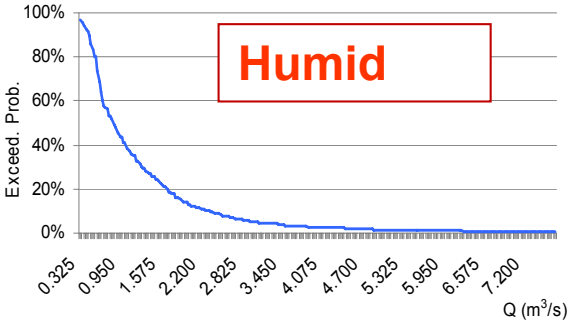


Year type classification

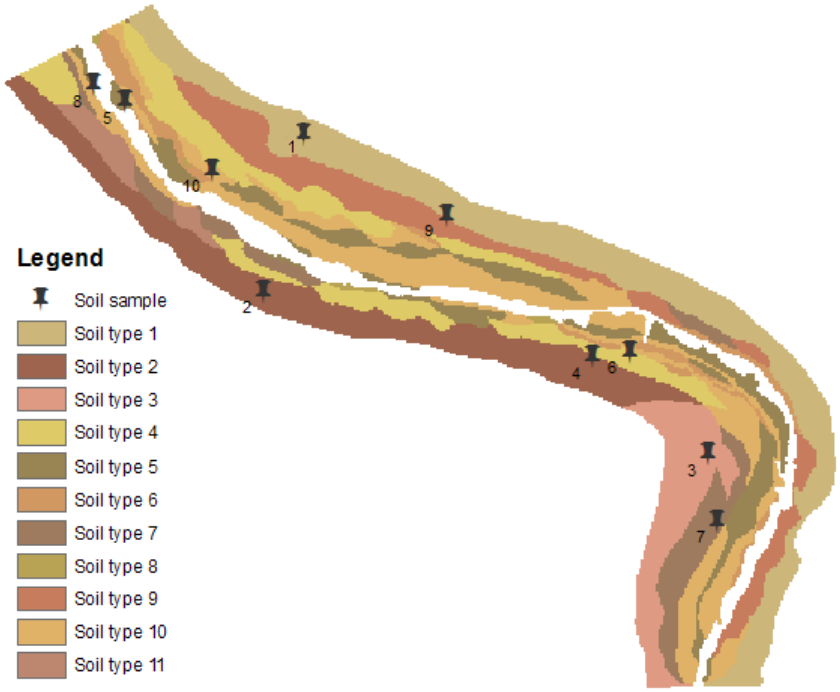


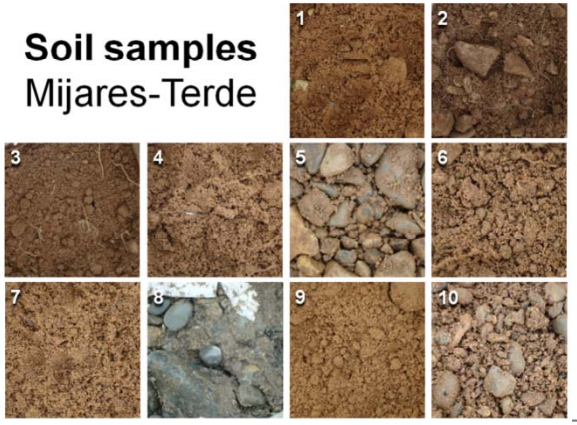


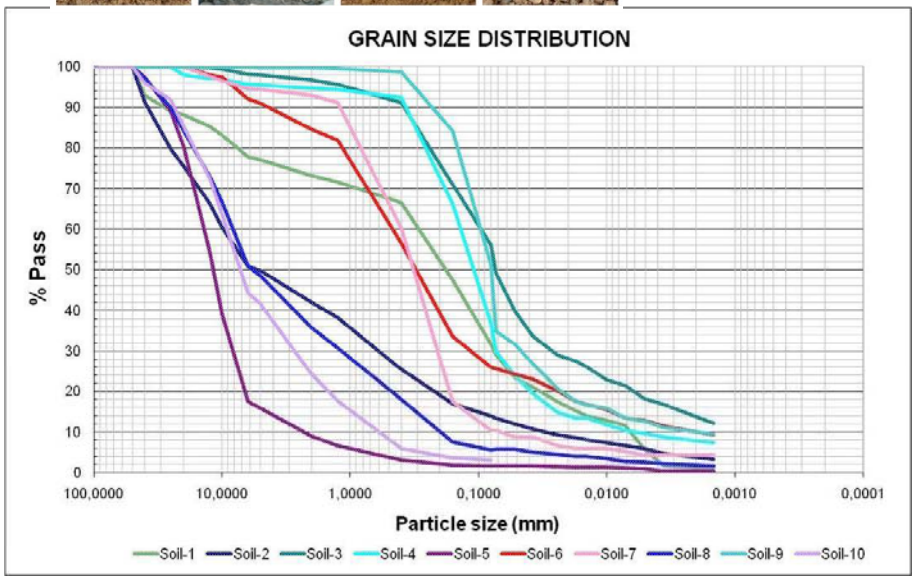




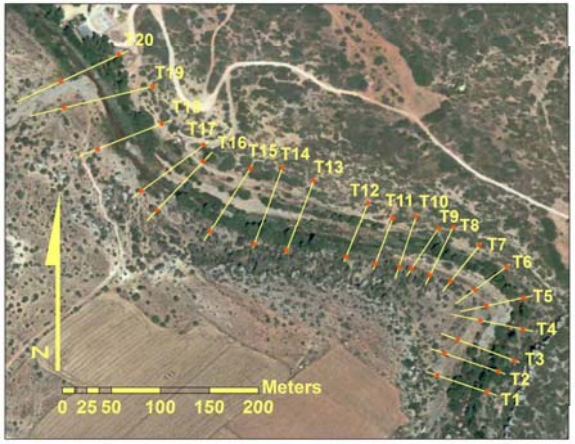
Soil survey

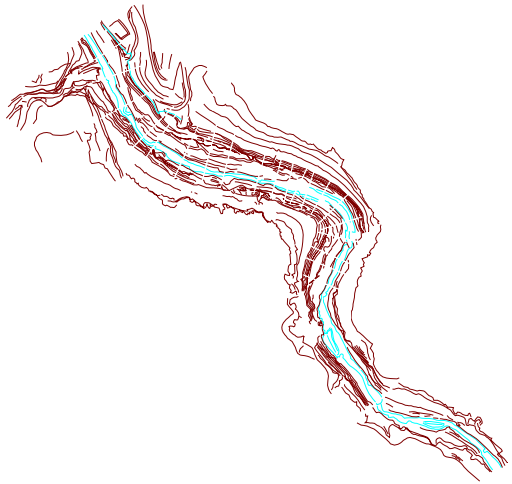

Legend
Soil sample
Soil type 1
Soil type 2
Soil type 3
Soil type 4
Soil type 5
Soil type 6
Soil type 7
Soil type 8
Soil type 9
Soil type 10
Soil type 11

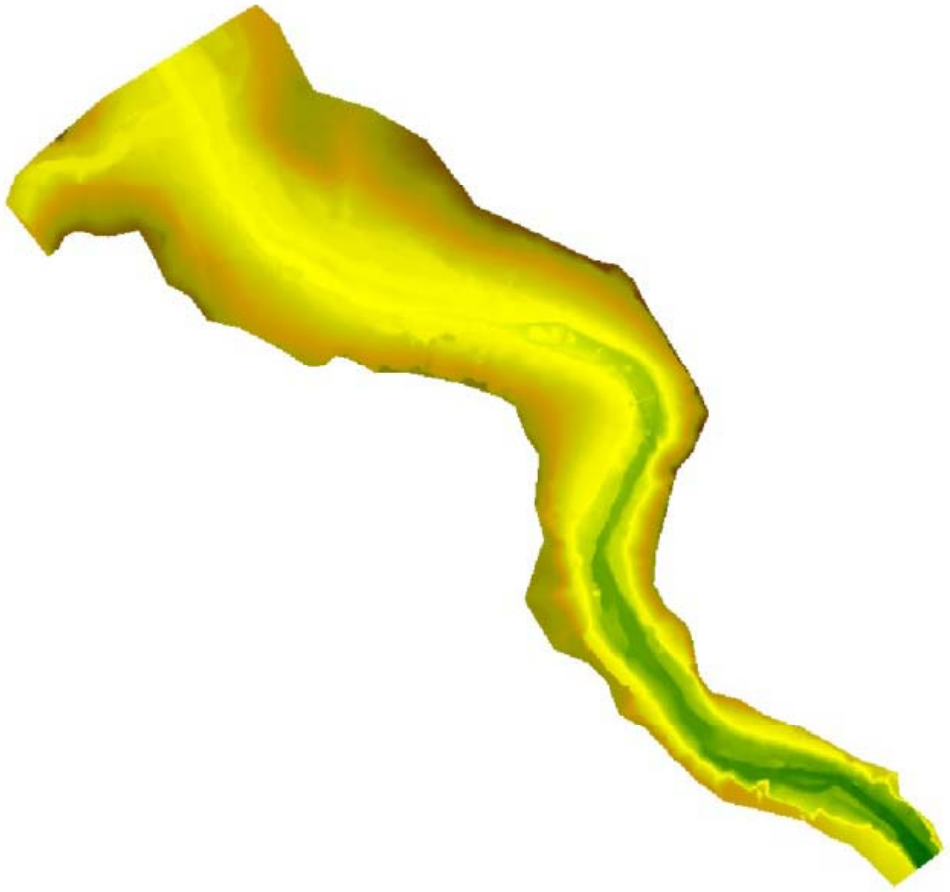

Soil samples
Mijares-Terde


GRAIN SIZE DISTRIBUTION
% Pass
Particle size (mm)
100,0000
10,0000
1,0000
0,1000
0,0100
0,0010
0,0001
Soil-1
Soil-2
Soil-3
Soil-4
Soil-5
Soil-6
Soil-7
Soil-8
Soil-9
Soil-10

1x1m DEM


T20
T19
T17
T16
T15
T14
T13
T12
T11
T10
T9
T8
T7
T6
T5
T4
T3
T2
T1
N
Meters
0 25 50 100 150 200





Vegetation survey

- DBH, DGL and height measurements (A-B-C)
- Core samples extraction and conservation (E- F)
- Vegetation characterization (D-G)

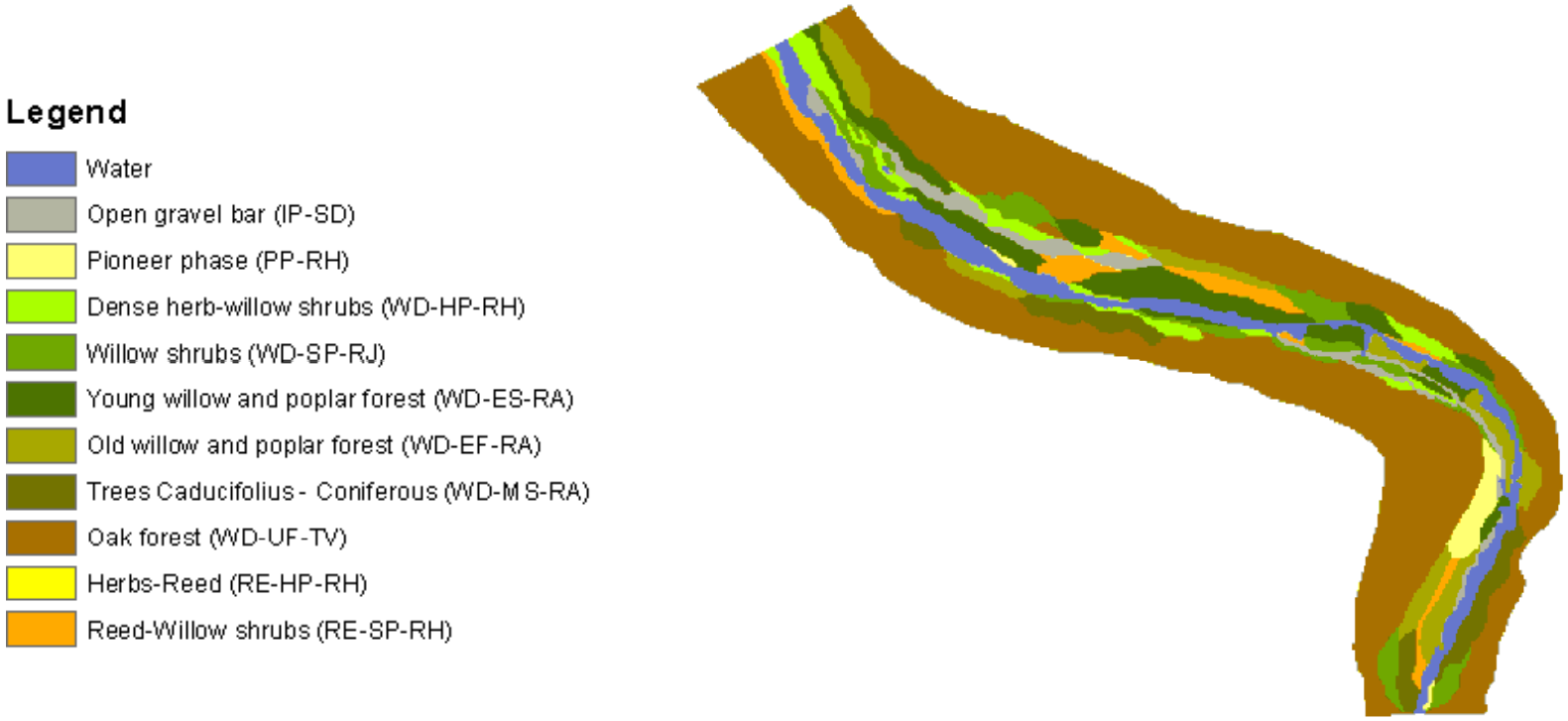
Vegetation survey results

- Growth functions

Specie	Growth function	Sampling size
Salix purpurea	AGE= 2,28367+2,14074*(DBH50)-0,036622*(DBH50)^2	28
Salix eleagnos	AGE = 5,05239+4,29125*log(DBH50)	46
Salix atrocinerea	AGE = (Log(DBH130)+0,565297)/0,173276	23
Salix alba	AGE = 4,33842+0,427715*(DGH)+0,242811*(HEIGHT)	22
Populus nigra	AGE = 4,65313+0,486221*(DBH130)-0,00233048*(DBH130)^2	53
Juniperus	AGE =0,2034*(DBH130)^2+3,7525*(DBH130)+5,998	-

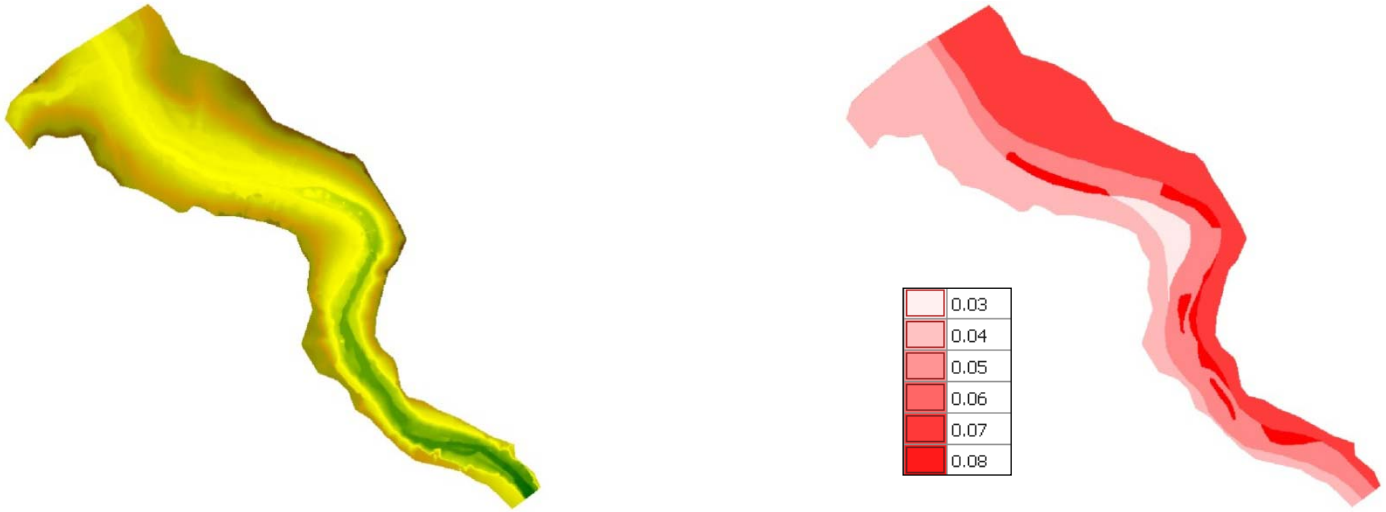
Vegetation survey inputs to ripflow

- Definition of succession series and phases
- Present vegetation succession phases map



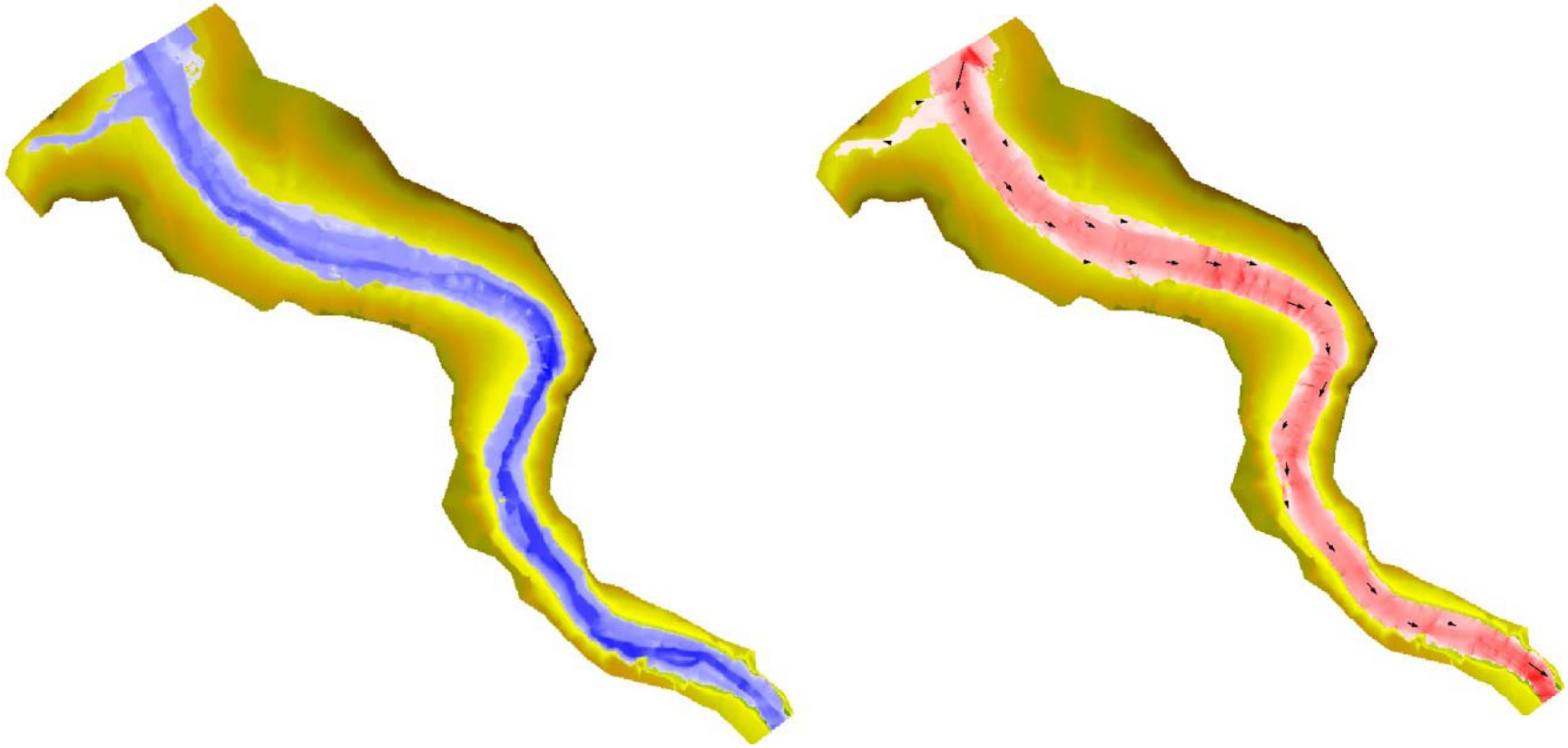
Hydraulic model: GUAD 2D

- Saint-Venant 2D equations. Integration by finite volumes
- Spatial discretization: RTIN
- Help of HEC-RAS for:
  - Calibration of Manning roughness with a survey
  - Controls location



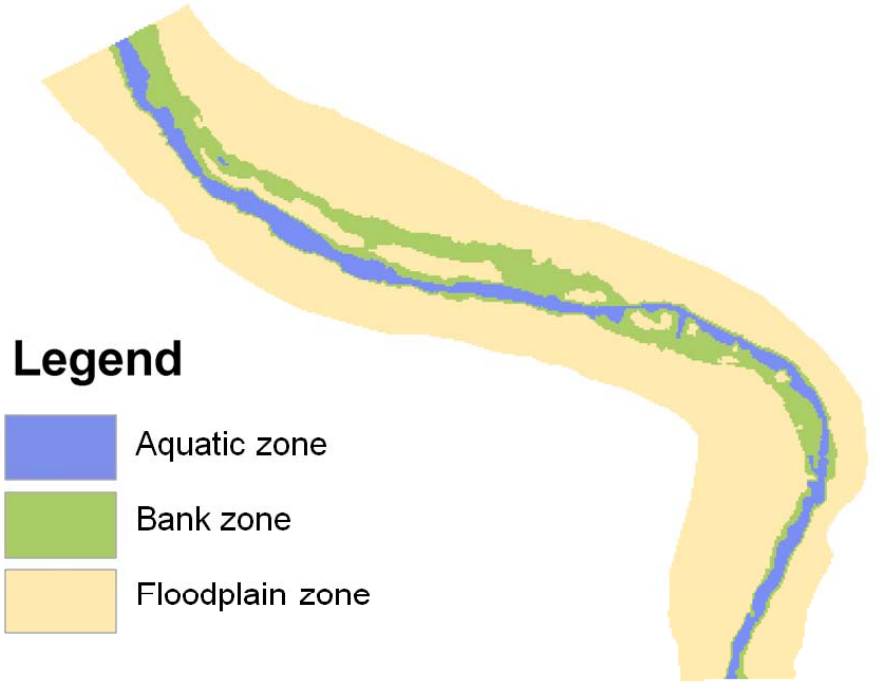
Hydraulic modelling results

- Water depths and velocities maps for Q from 0 to 150 m3/s



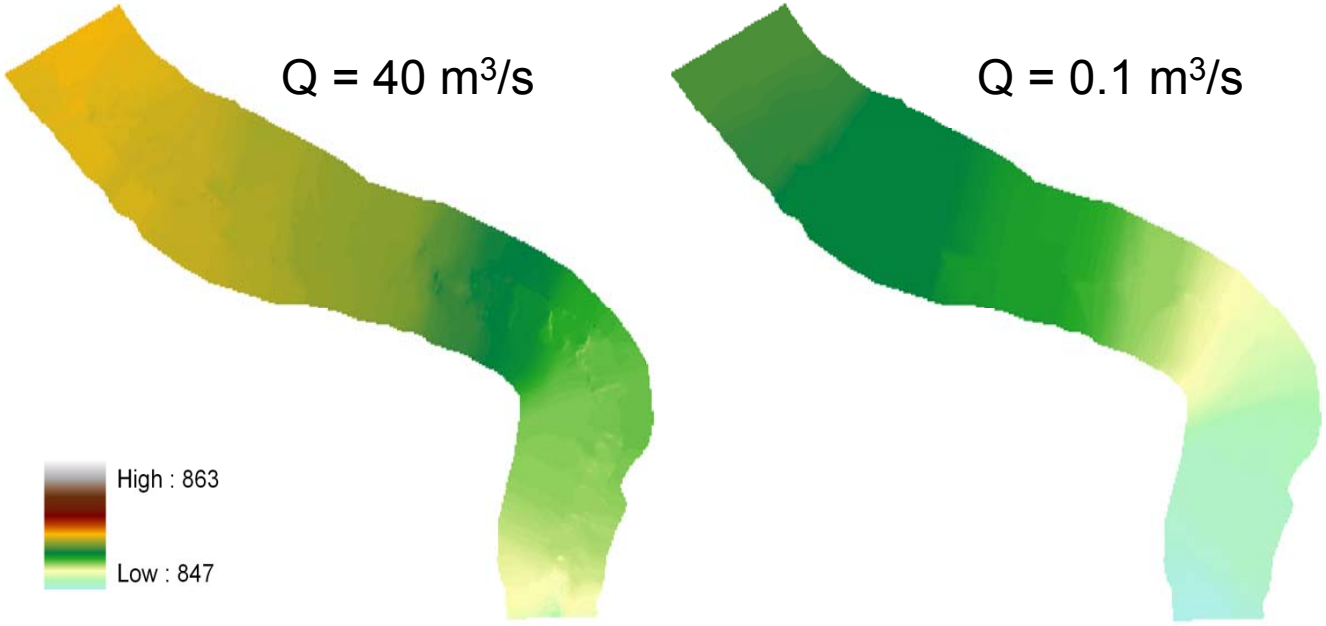
Hydraulic inputs to RIPFLOW

- Definition of aquatic, bank and floodplain zones



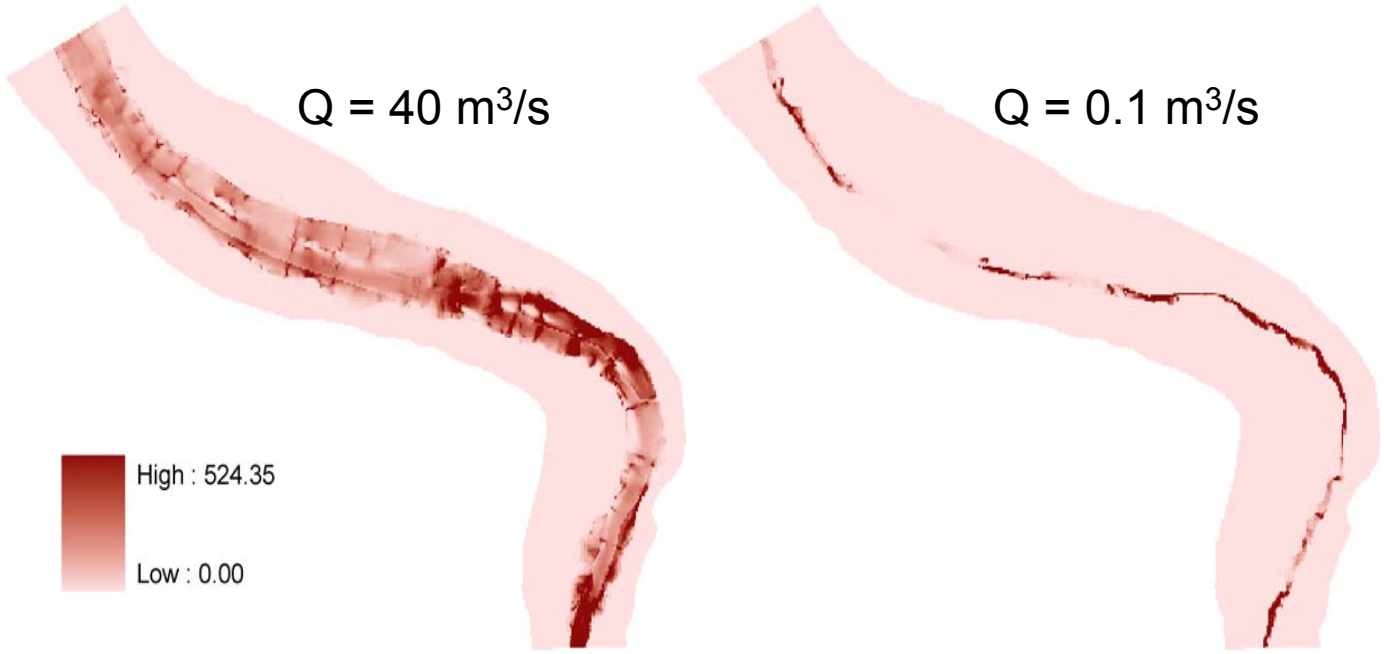
Hydraulic inputs to RIPFLOW

- Water table elevations: “horizontal” water table



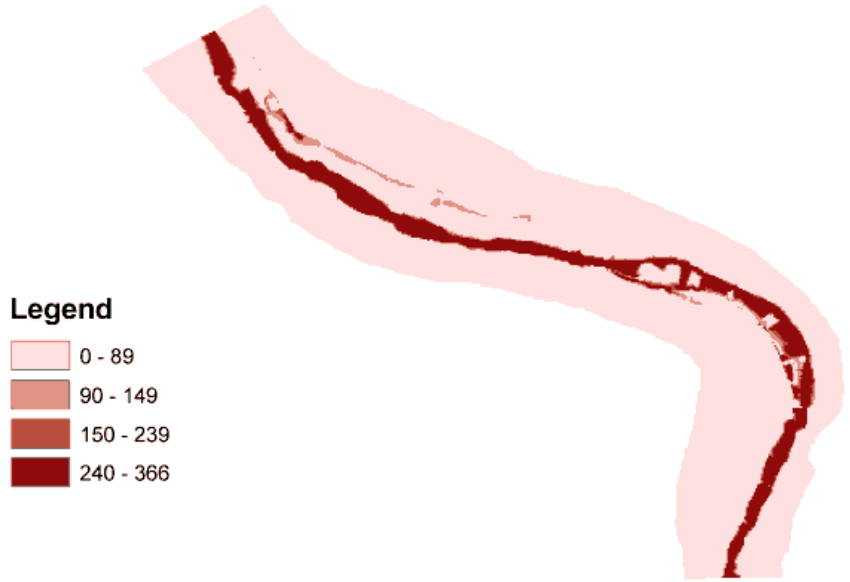
Hydraulic inputs to RIPFLOW

- Shear stress $\tau = \rho \cdot u^{*2}$ where: $u^* = 2.102 \frac{v \cdot n}{y^{1/6}}$



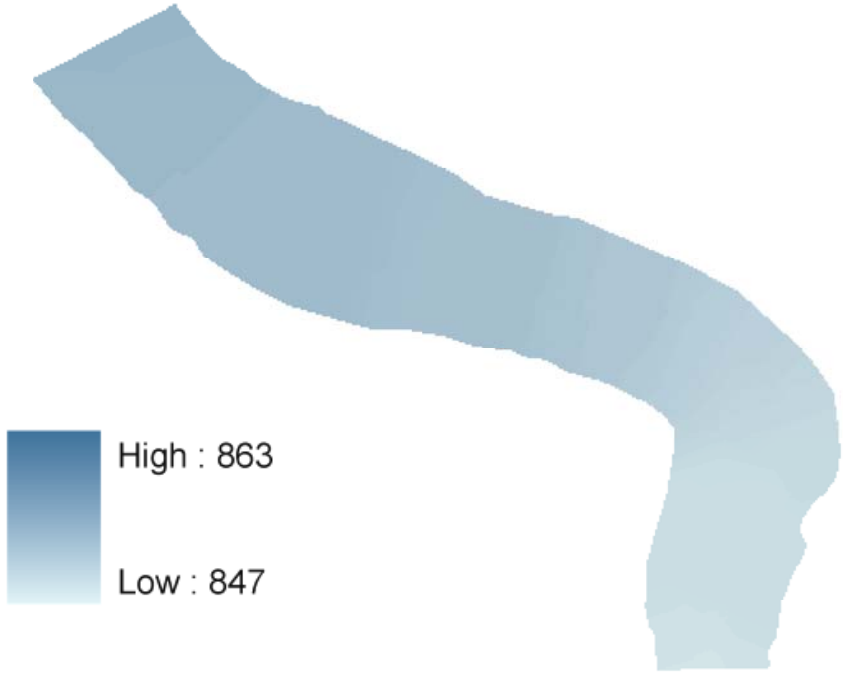
Hydraulic inputs to RIPFLOW

- Flood duration for year types
  - For “very humid year”



Hydraulic inputs to RIPFLOW

- HBF for year types:
  - For “dry” and “very dry” years (0.2 m^3/s base flow)



Calibrated plant functional types parameters

Plant functional types	Vegetation parameters								
	Zr (m)	**Ze** (m)	**Zsat** (m)	**Ri** ( )	**Rj** ( )	**CRT** ($mm.Mpa^{-1}.h^{-1}$)	**Pwp** (KPa)	**Pcrit** (KPa)	**Cov** ( )
RH	1.25	0.7	-0.9	0.7	0.9	0.97	1500	500	0.7
RJ	1.3	0.8	-0.3	0.7	0.3	0.97	1500	350	0.7
RA	3.2	0.8	-0.3	0.7	0.3	0.97	1500	125	0.8
TV	1.9	1.6	1.6	1	0	0.97	1500	95	0.8

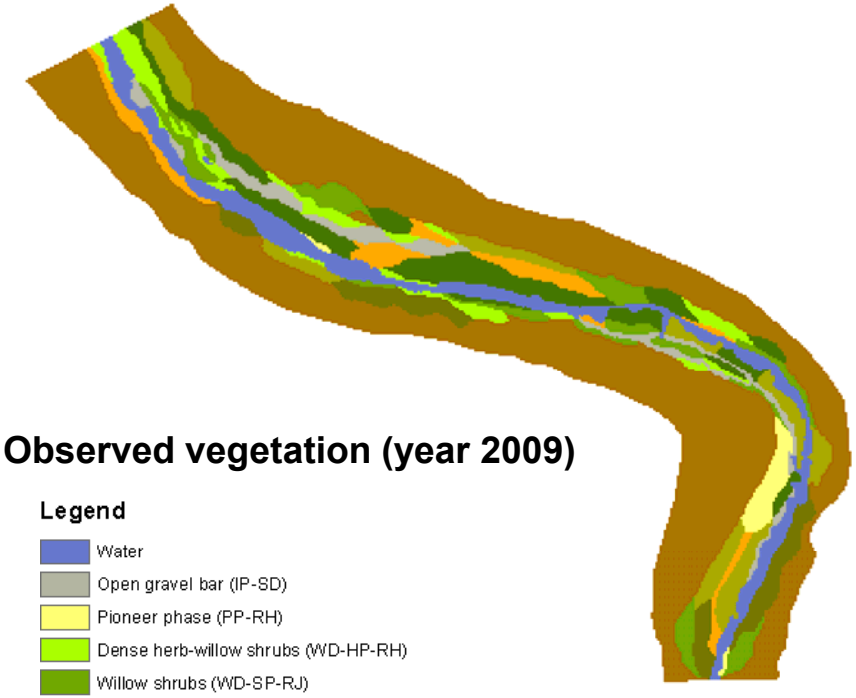
Calibrated Ripflow parameters

	Parameter	Value	Units
1	HBFL for Floodplain Recruitment Dry	> 7	meters
	HBFL for Woodland Recruitment Zone	0.6 – 3	meters
	HBFL for Scour Disturbance Zone	< -5 and > 7	meters
	Pioneer zone	≤ 3	years
2	Critical Shear Stress of Woodland	12 (IP-SD) 22 (PP-RH) 24 (WD-HP-RH) 26 (WD-SP-RJ) 26 (WD-ES-RA) 27 (WD-EF-RA) 30 (WD-MS-RA) 30 (WD-UF-TV)	$N.m^{-2}$
	Critical Shear Stress of Reed	12 (IP-SD) 22 (PP-RH) 23 (RE-HP-RH) 24 (RE-SP-RH)	$N.m^{-2}$

Calibrated Ripflow parameters

	Parameter	Value	Units
3	Flood Strong Impacts Flood Moderate Impacts Flood Low Impacts No flood impacts	240 – 366 150 – 239 90 – 149 0 – 89	days days days days
4	Succession Reed to Woodland	< 10	years
5	Woodland upper ETidx limit	0.85 (IP-SD, PP-RH, WD-HP-RH) 0.90 (WD-SP-RJ, WD-ES-RA) 0.95 (WD-EF-RA, WD-MS-RA, WD-UF-TV)	-
	Woodland lower ETidx limit	0.40 (IP-SD, PP-RH, WD-HP-RH, WD-SP-RJ, WD-ES-RA) 0.30 (WD-EF-RA, WD-MS-RA) 0.20 (WD-UF-TV)	-
	Reed upper ETidx limit	0.80 (IP-SD, PP-RH, RE-HP-RH) 0.95 (RE-SP-RH)	-
	Reed lower ETidx limit	0.50 (IP-SD, PP-RH, RE-HP-RH) 0.70 (RE-SP-RH)	-

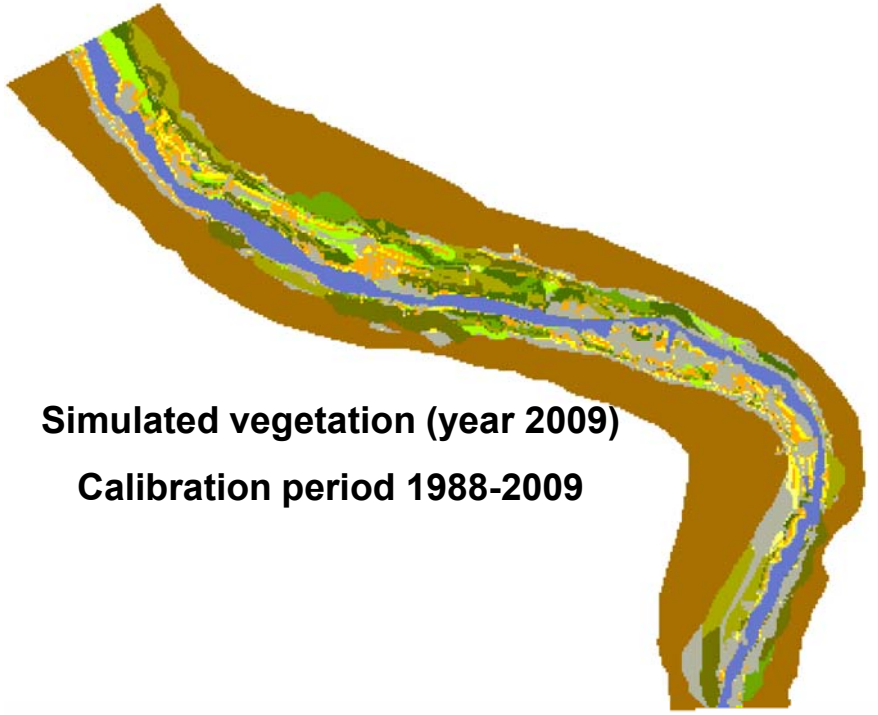
Calibration results



Observed vegetation (year 2009)

Legend

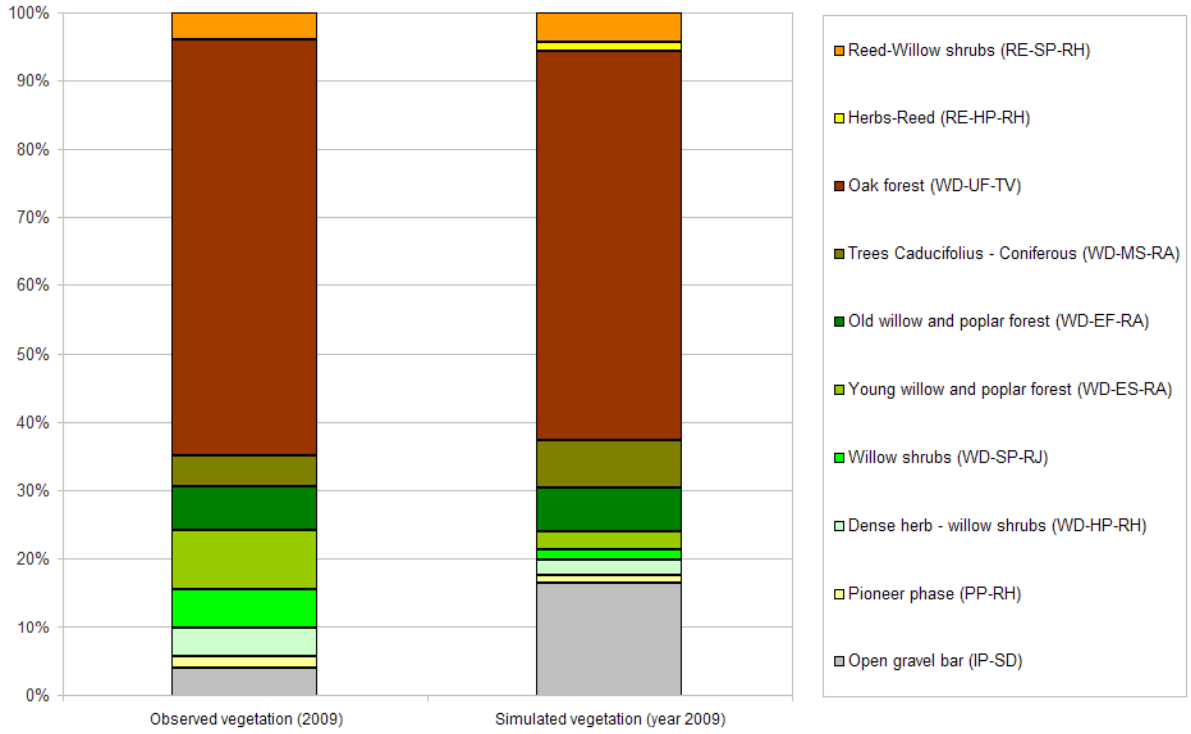
- Water
- Open gravel bar (IP-SD)
- Pioneer phase (PP-RH)
- Dense herb-willow shrubs (WD-HP-RH)
- Willow shrubs (WD-SP-RJ)
- Young willow and poplar forest (WD-ES-RA)
- Old willow and poplar forest (WD-EF-RA)
- Trees Caducifolius - Coniferous (WD-MS-RA)
- Oak forest (WD-UF-TV)
- Herbs-Reed (RE-HP-RH)
- Reed-Willow shrubs (RE-SP-RH)



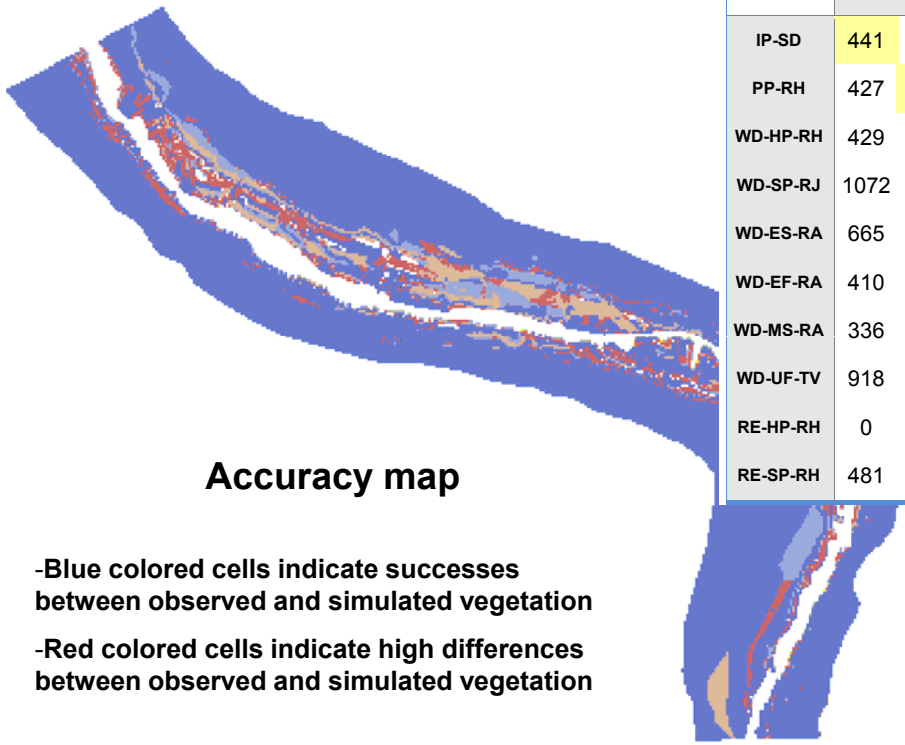
Simulated vegetation (year 2009)

Calibration period 1988-2009

Calibration results



Calibration results



Accuracy map

-**Blue colored cells indicate successes between observed and simulated vegetation**

-**Red colored cells indicate high differences between observed and simulated vegetation**

	Confusion matrix									
	IP-SD	PP-RH	WD-HP-RH	WD-SP-RJ	WD-ES-RA	WD-EF-RA	WD-MS-RA	WD-UF-TV	RE-HP-RH	RE-SP-RH
IP-SD	441	175	143	50	41	68	18	0	50	239
PP-RH	427	23	1	0	2	1	0	17	37	19
WD-HP-RH	429	10	413	35	54	68	44	27	34	163
WD-SP-RJ	1072	23	23	278	64	42	71	45	41	233
WD-ES-RA	665	30	23	16	615	468	608	59	49	189
WD-EF-RA	410	15	5	1	1	1083	247	62	87	83
WD-MS-RA	336	3	10	6	2	12	1010	4	15	16
WD-UF-TV	918	61	23	44	5	46	136	17721	71	82
RE-HP-RH	0	0	0	0	0	0	0	0	0	0
RE-SP-RH	481	34	74	28	46	235	36	7	30	303

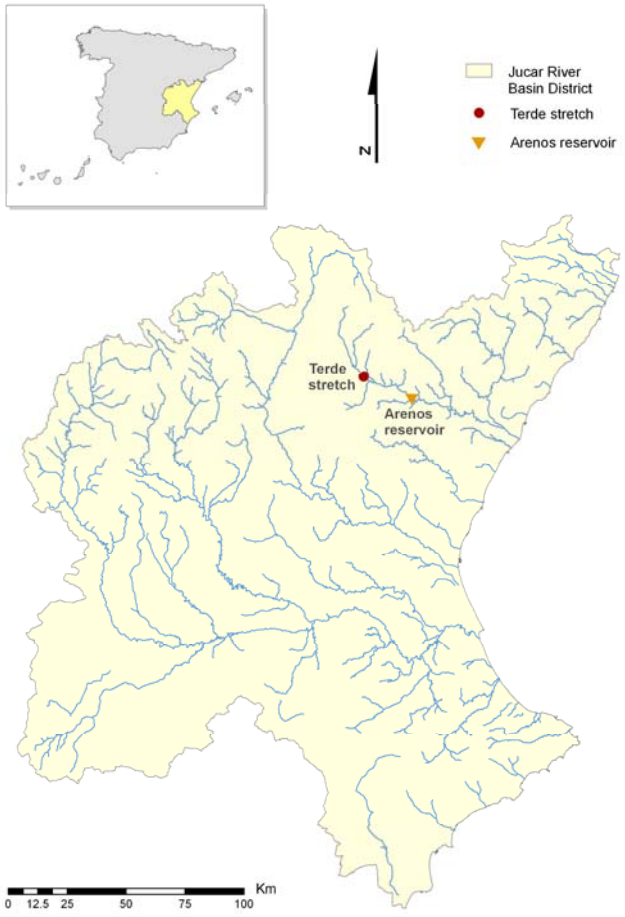
Calibration results:

Kappa coefficient = 0.7127 ± 0.00675 (95% confidence limit)

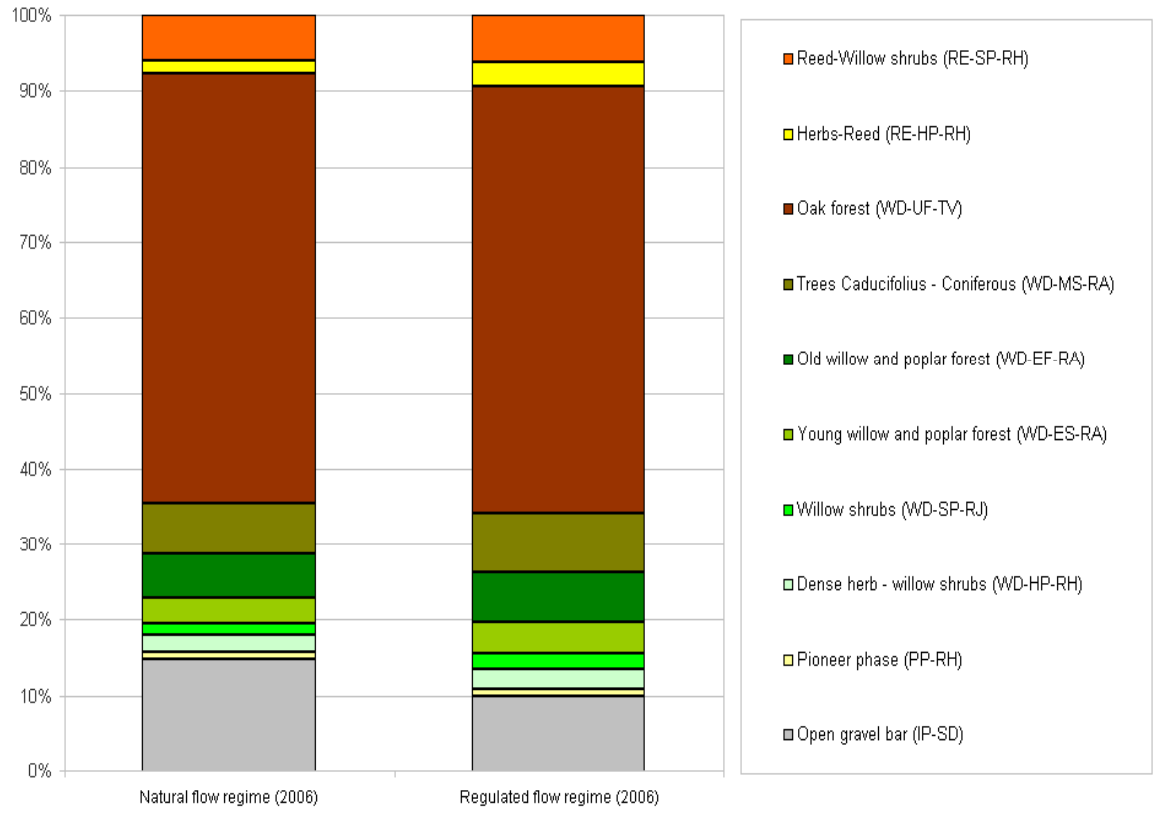
- Introduction: RIPFLOW project description
- RIPFLOW model
- Implementation in Terde reach at upper Mijares River
- **Scenarios simulation**
  - **Regulated**
  - **Minimum environmental flows**
- Conclusions

Regulated scenario

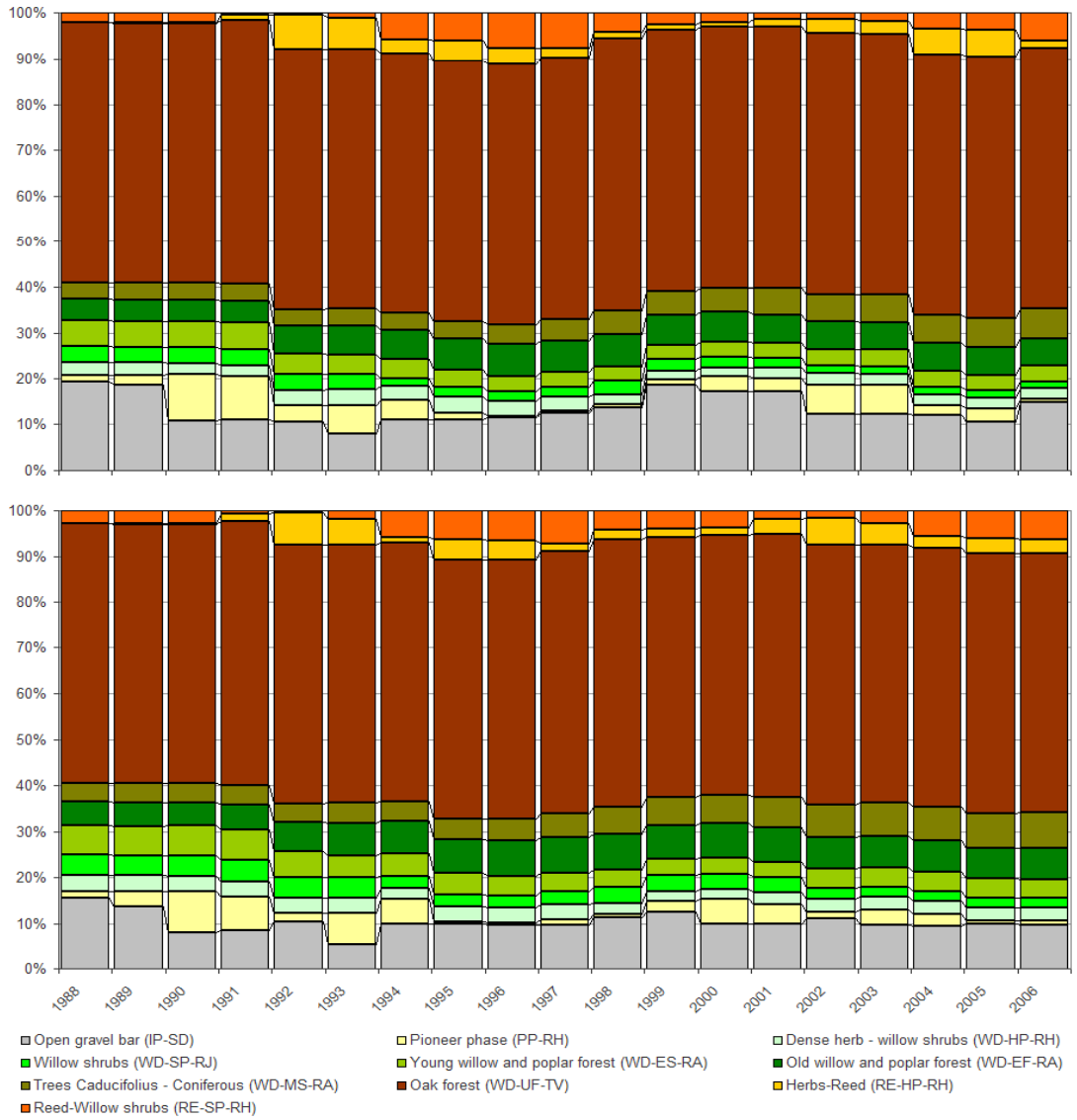
- Dam outflows proportional to Arenos reservoir (1988-2006)



Natural vs regulated, 2006



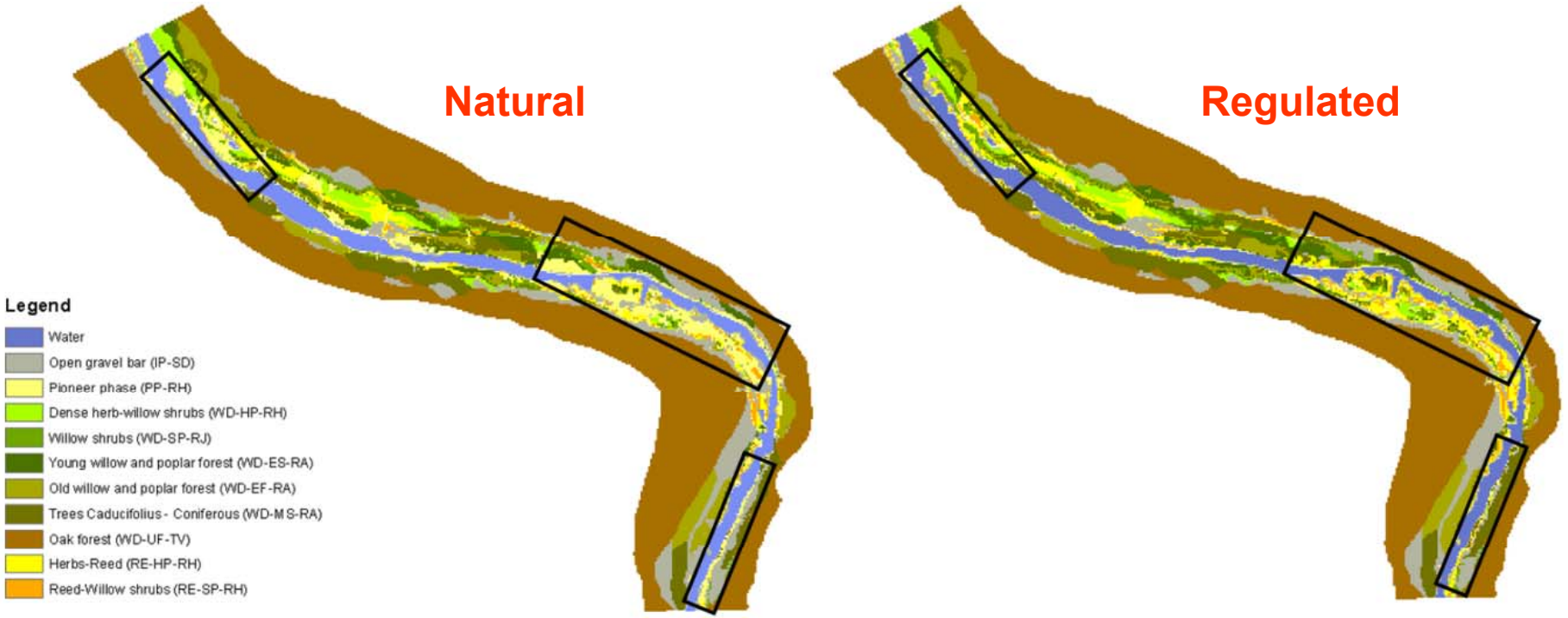
Natural vs regulated, 1988-2006



Natural

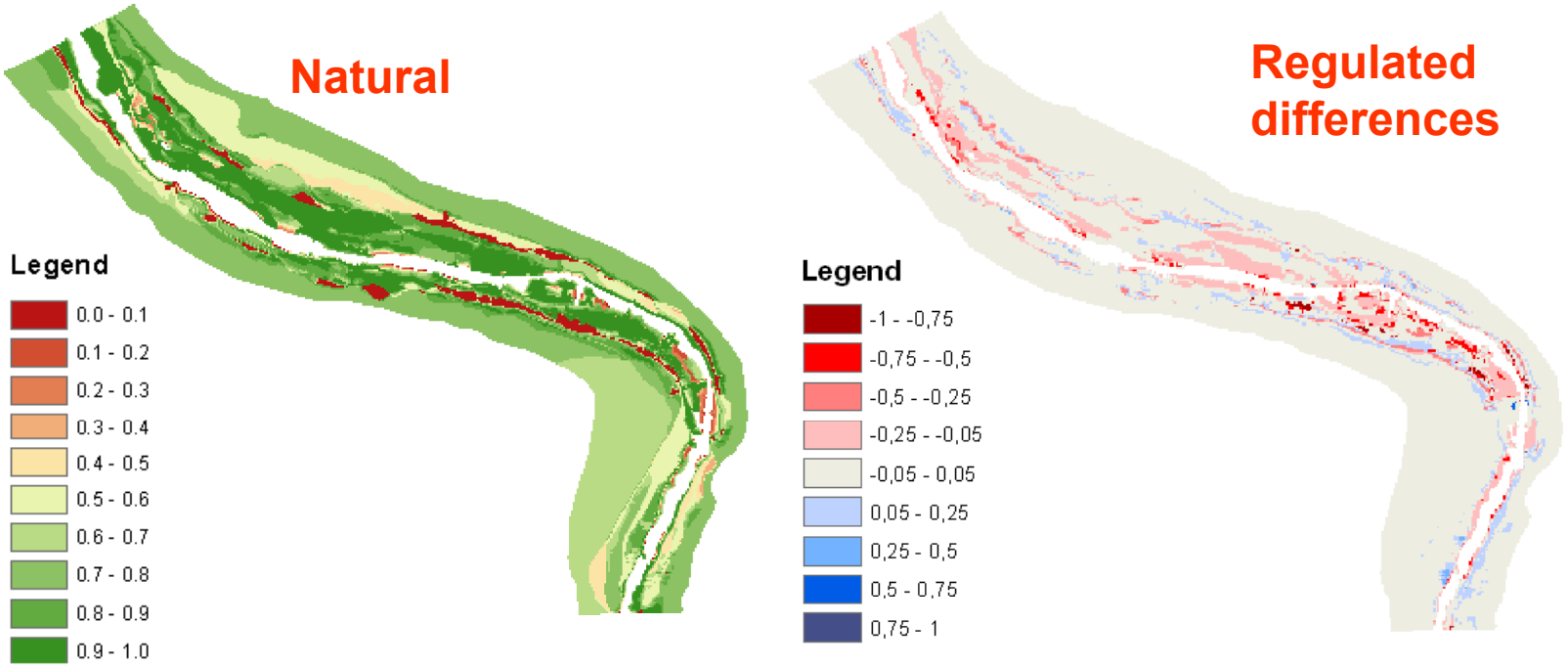
Regulated

Natural vs regulated, 2002



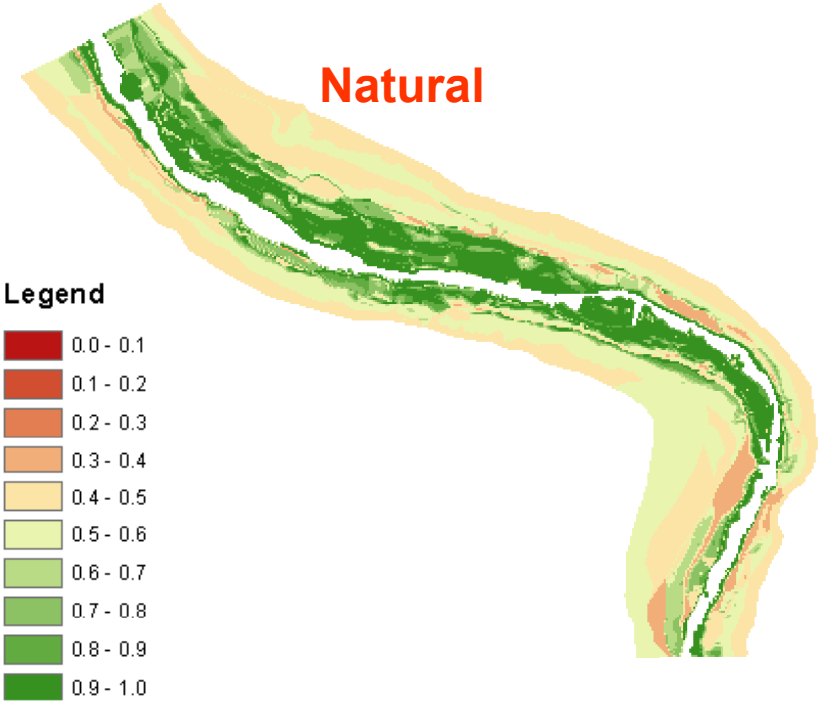
Natural vs regulated, 1988

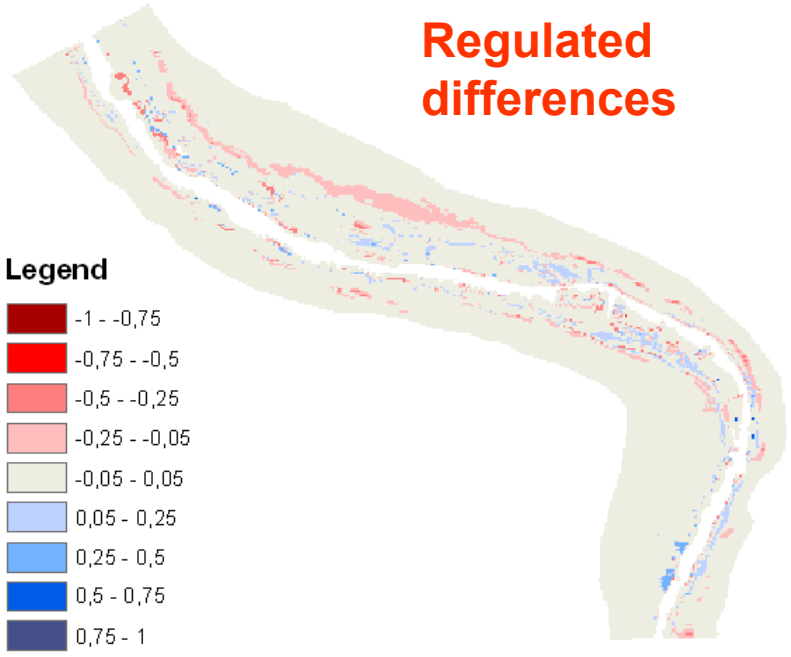
- ETidx in a “very humid” year



Natural vs regulated, 2000

- ETidx in a “dry” year



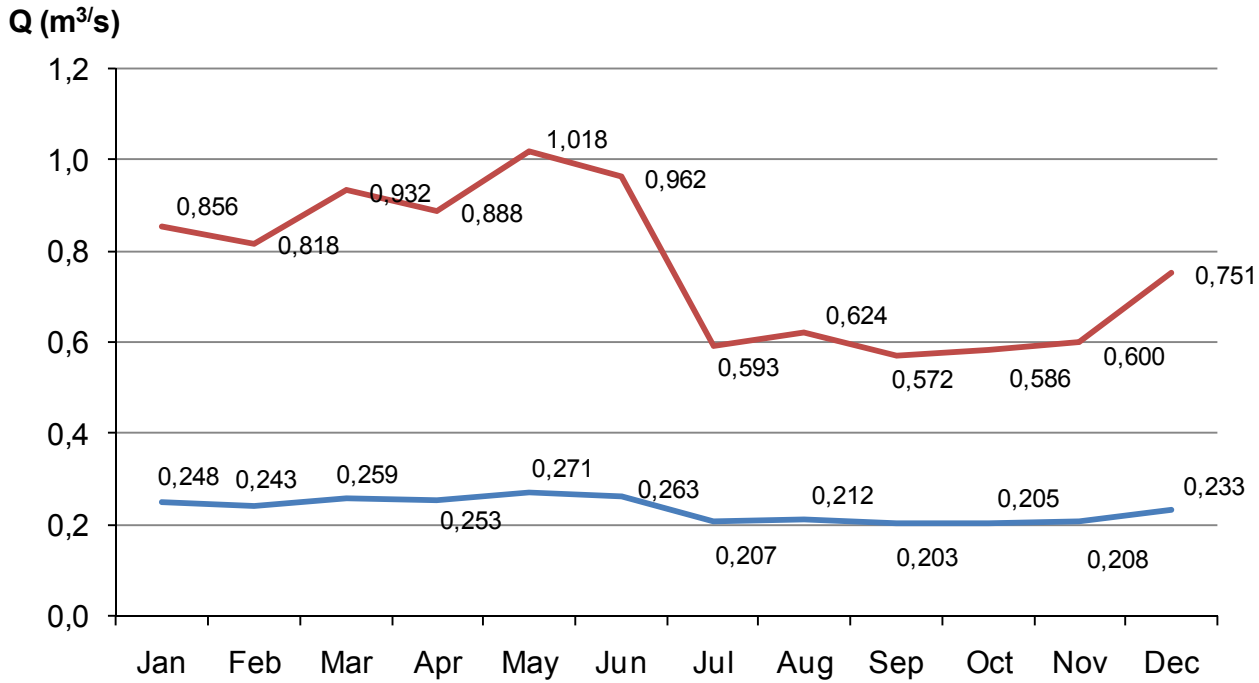


Minimum env. flow scenario

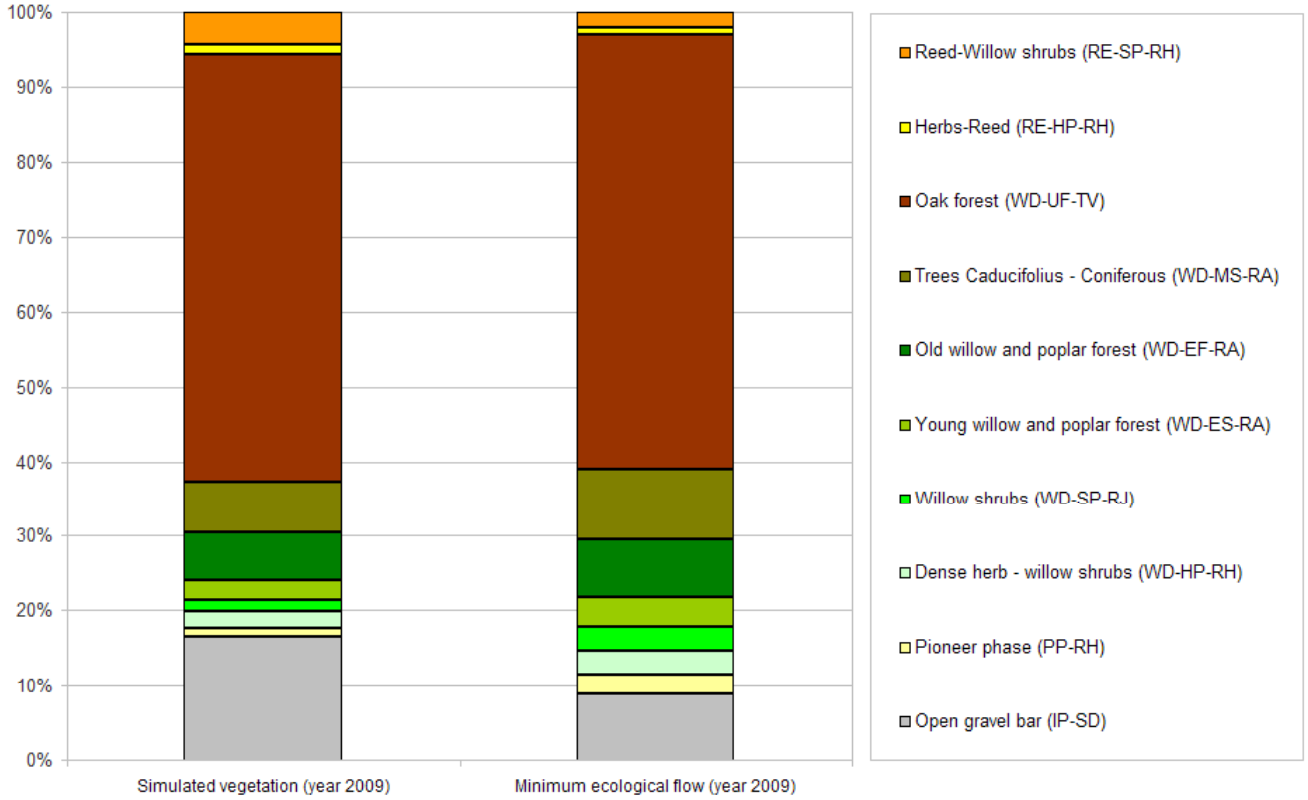
- Based on studies of physical habitat simulation:
  - minimum value must be within the range of flows corresponding to the 50 and 80% of the maximum Weighted Usable Area (WUA)
  - The target species were: the Iberian chub (*Squalius pyrenaicus*), brown trout (*Salmo trutta fario*) and Mediterranean barbel (*Barbus guiranois*)
- *Qmin* is 0.203 m^3/s. Intra-annual variability:

$$Q_{eco} = Q_{\min} \cdot VF_i \qquad VF_i = \sqrt{\frac{Q_i}{Q_{\min}}}$$

Minimum env. flow scenario



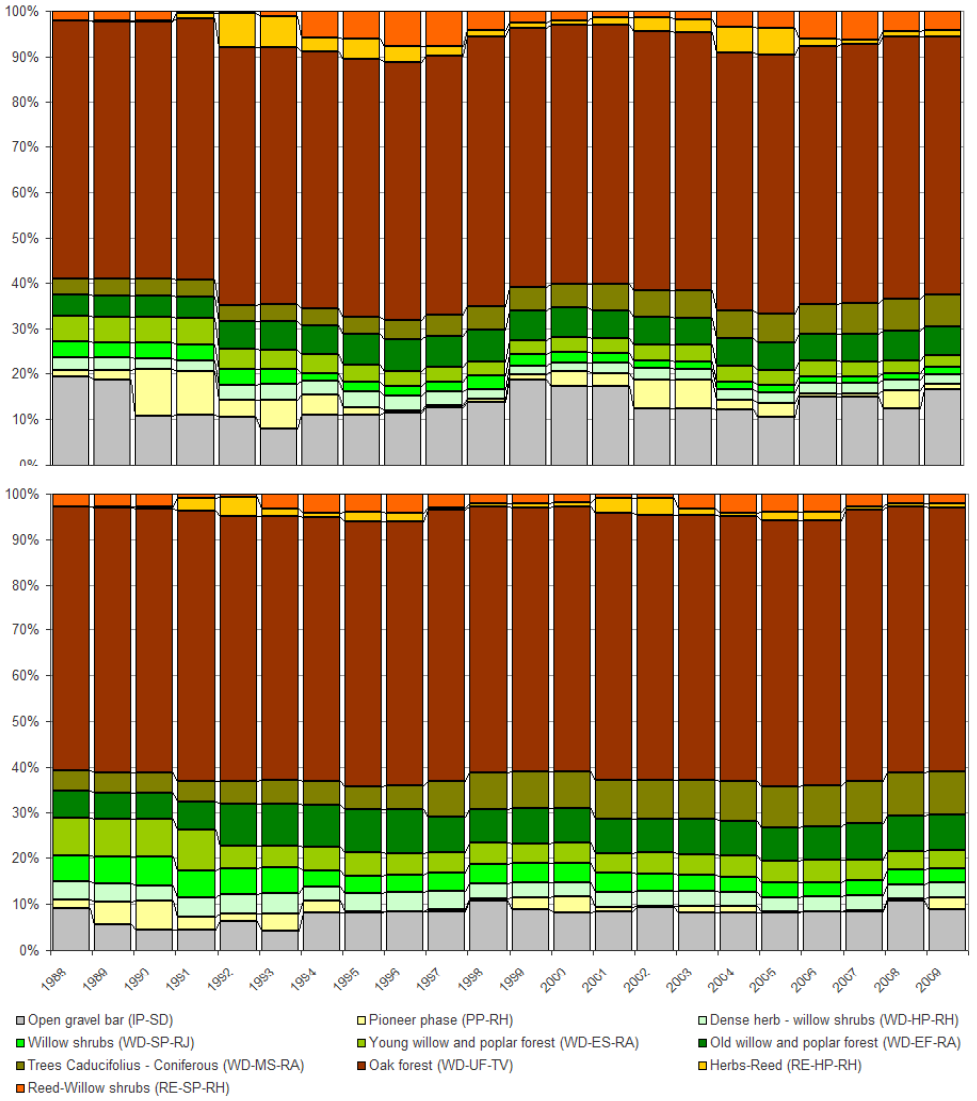
Natural vs minimum env., 2009



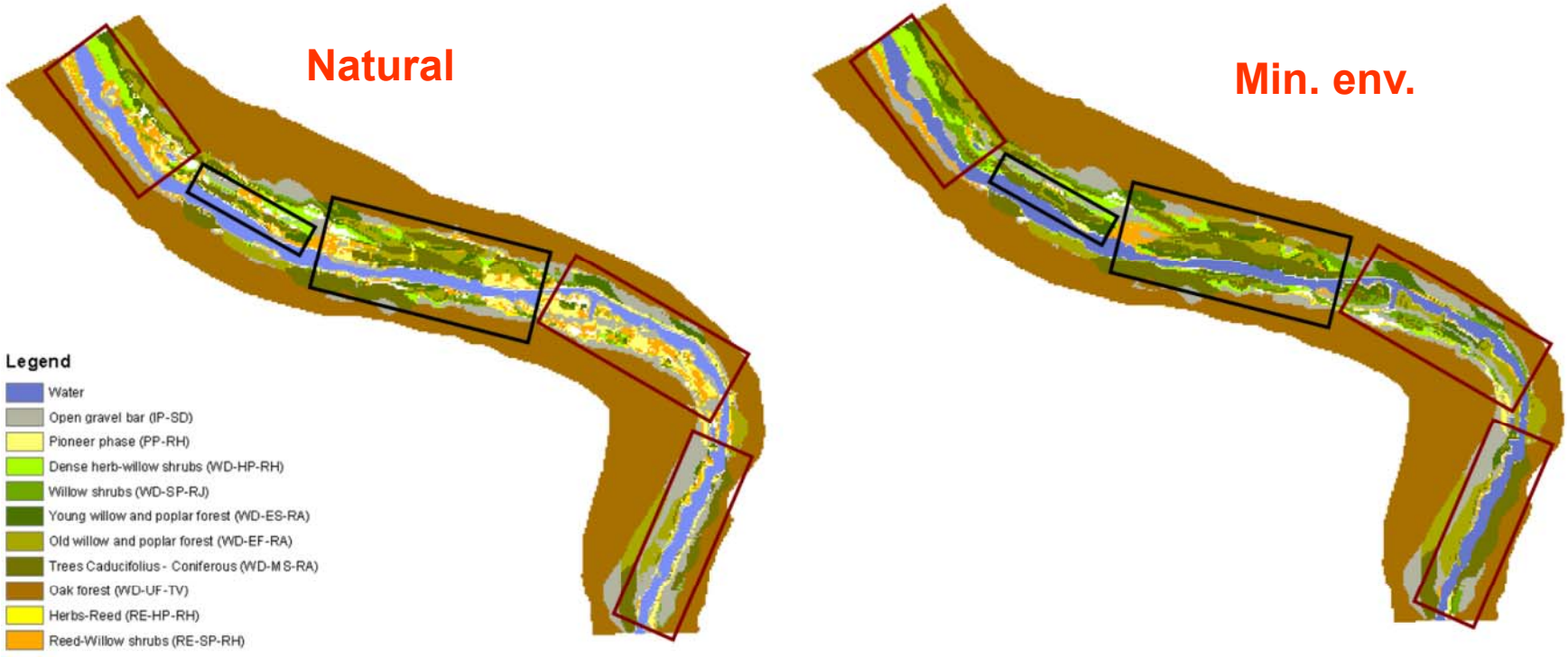
Natural vs minimum env., 1988-2009

Natural

Min. env.

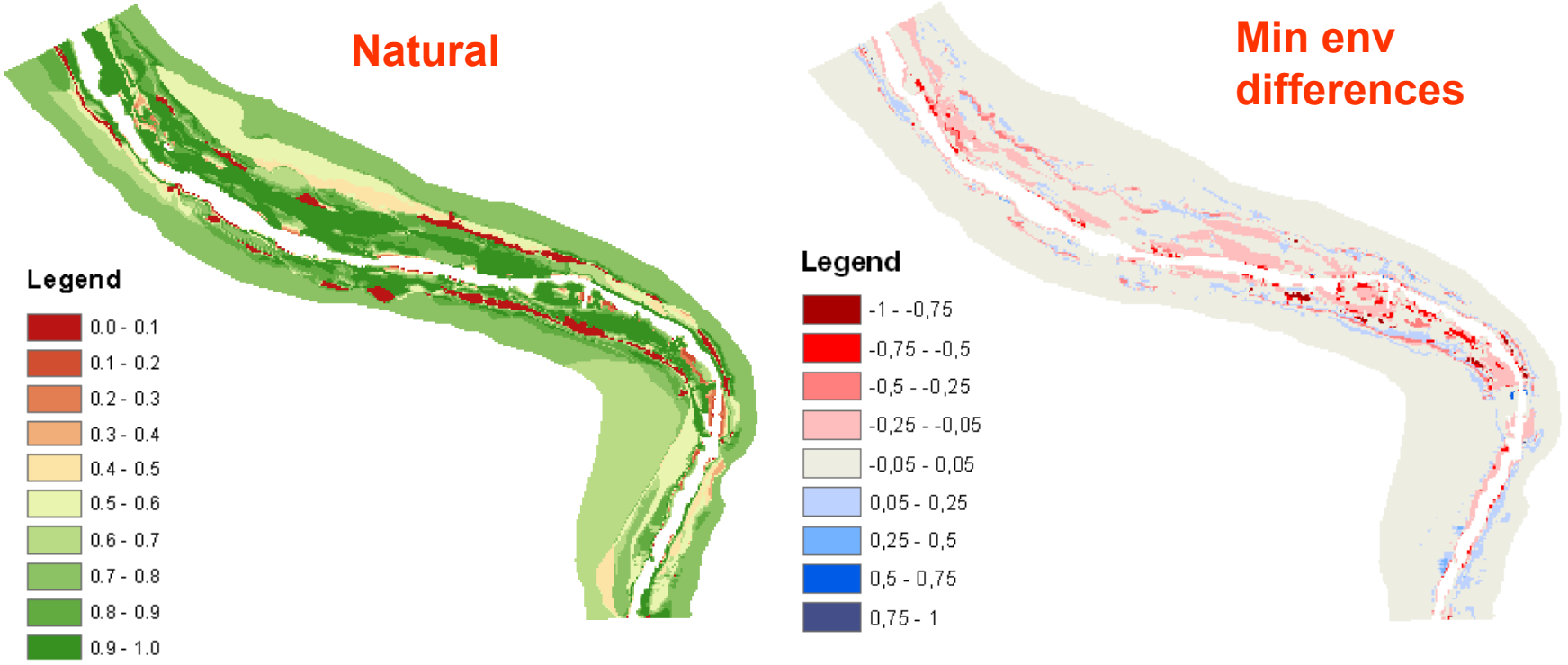


Natural vs minimum env., 2008



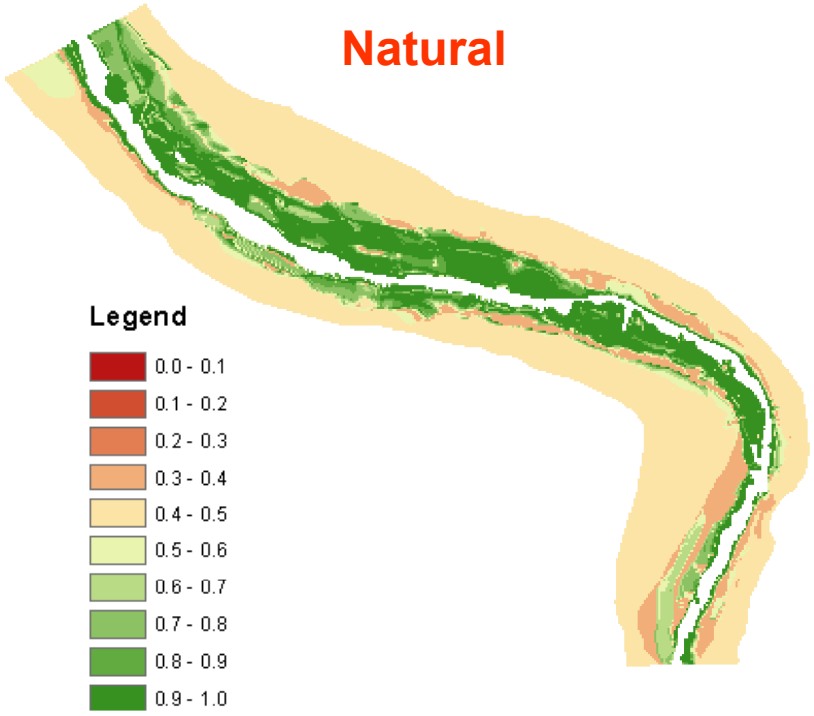
Natural vs min. env., 1988

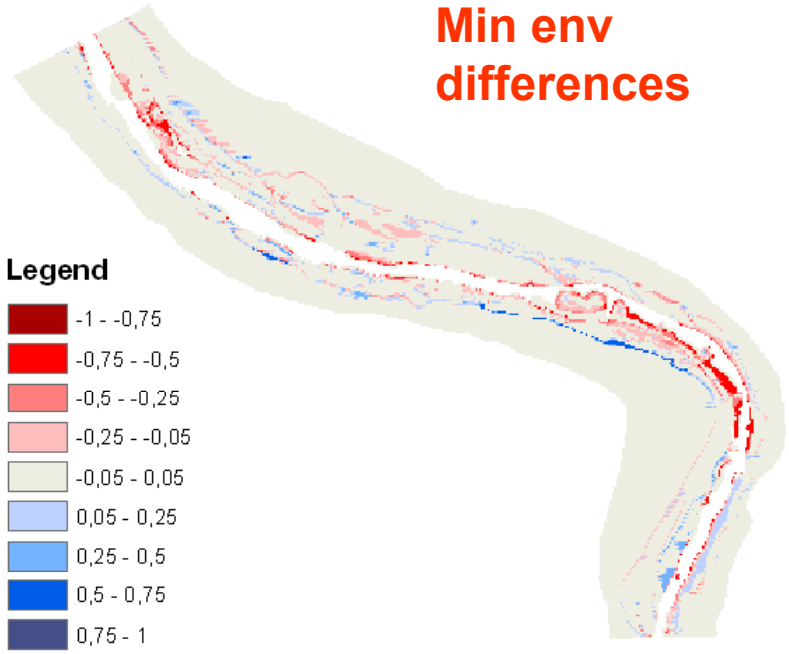
- ETidx in a “very humid” year



Natural vs min. env., 1994

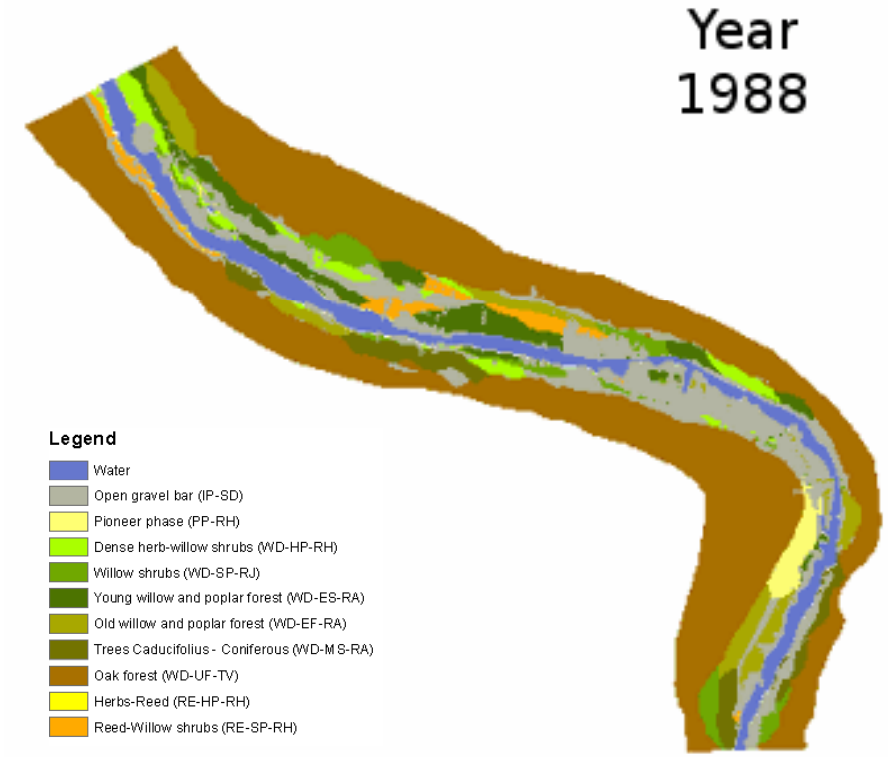
- ETidx in a “very dry” year

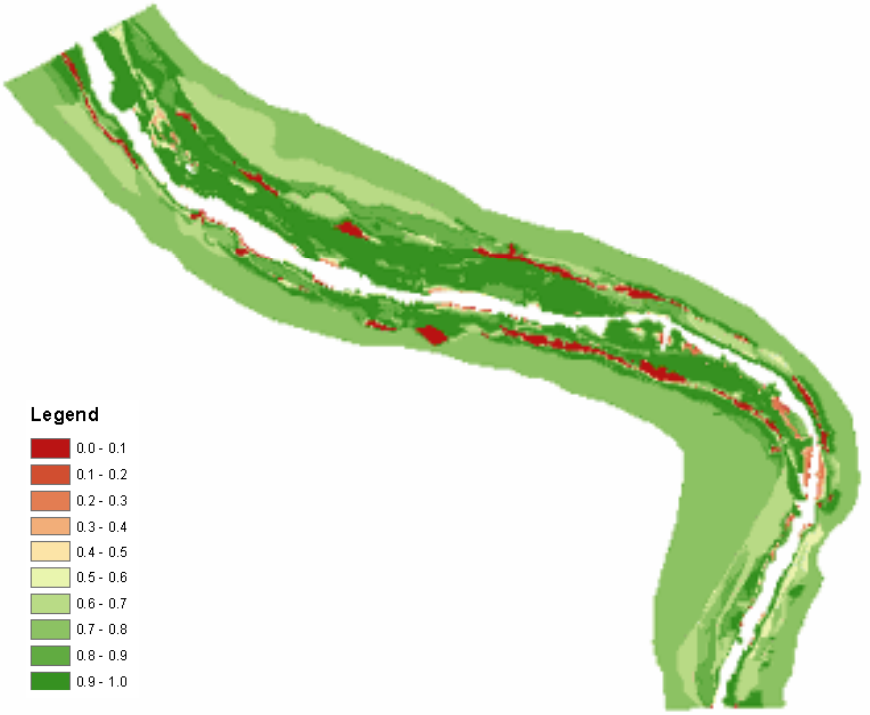




Conclusions

1988 – 2009 inTerde (Mijares River, Spain)





Succession Phases

ETidx