Simulating water management using SWAT+: Application of the water allocation module and reservoirs release decision tables in a highly managed catchment.

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SWAT Soil & Water Assessment Tool

Universidad de Alcalá

Introduction: The gap between hydrological and water management models

Hydrological models (SWAT, MIKE SHE, TOP Mo

- ✓ Focused on the simulation of **hydro-environmental processes.**
- ✓ Evaluation of water resources availability under different scenarios (e.g., climate change).

gement actions.

affect their reliability.

- Coupling models (Hydrological models outputs used as inputs in Water management models).
- Including the simulation of water management actions in hydrological models.

Water manageme BASIN, WEAP, AQUATOOL, etc.).

ement actions.**

scenarios (e.g., demand increase).

- × Most lack hydrological processes simulation (**require hydrological inputs**).

Introduction: Simulation of management actions in SWAT+

Decision tables

Configuration of management actions in SWAT+

Water allocation module

- Allow to configure **management actions** (irrigation, water movements, etc.) depending [illegible] combined in **alternatives.**

ALTERNATIVES

ACTIONS EXECUTION

.DTL FILES IN SWAT+

lum.dtl file → Land use management (irrigation, harvest, etc.).

res_rel.dtl file → Reservoir release.

flo_con.dtl file → Water movements (water transfers, irrigation, etc.).

Example res_rel.dtl file
1

name	conds	alts
ex_rel_table	4	5

var	obj	obj_num	[illegible]	alt3	alt4	alt5
month	null	0	[illegible]	-	-	-
month	null	0	[illegible]	>	-	-
vol	res	0	[illegible]	<	>	-
vol	res	0	[illegible]	-	-	>

act_typ	obj	obj_num	name	option	const	const2	fp	outcome
release	res	0	summer_rate	rate	0.10000	0.00000	null	y n n n n
release	res	0	winter_rlse	inflo_frac	0.15000	0.00000	null	n y y n n
release	res	0	full_rlse	days	5.00000	0.00000	pvol	n n n y n
release	res	0	emerg_rlse	ab_emer	0.00000	0.00000	null	n n n n y

Introduction: Simulation of management actions in SWAT+

Decision tables

Configuration of management actions in SWAT+

Water allocation module

- Allow to allocate water between SWAT+ objects.
- Utilities: water transfers among reservois, allocation of water for human consumption, interbasin water transfers, irrigation, etc.
- Specific input file → **water_allocation.wro** → Composed by water allocation tables.

SIMULATED MANAGEMENT ACTIONS

Reservoirs release (DT)
Irrigation (DT + WRO)
Water transfers (DT + WRO)

HA_DB

UN_MIN	JUL_MIN	AUG_MIN	SEP_MIN	OCT_MIN	NOV_MIN	DEC_MIN
.01	0.01	0.01	0.01	0.01	0.01	0.01
.01	0.01	0.01	0.01	0.01	0.01	0.01

OB	RCV_NUM	RCV_DTL	SRCS	SCRC1	FRAC1	COMP1
	0	null	1	1	1	n
	0	null	1	1	1	n
	0	null	1	2	1	n
	0	null	1	2	1	n
	0	null	1	2	1	n
	0	null	1	2	1	n

SOURCES **MINIMUM WATER AVAILABILITY IN SOURCES**

DEMAND OBJECTS **WATER TRANSFER DETAILS (conditions*, amount)**

*** Created using decision tables → lum.dtl / flo_con.dtl file**

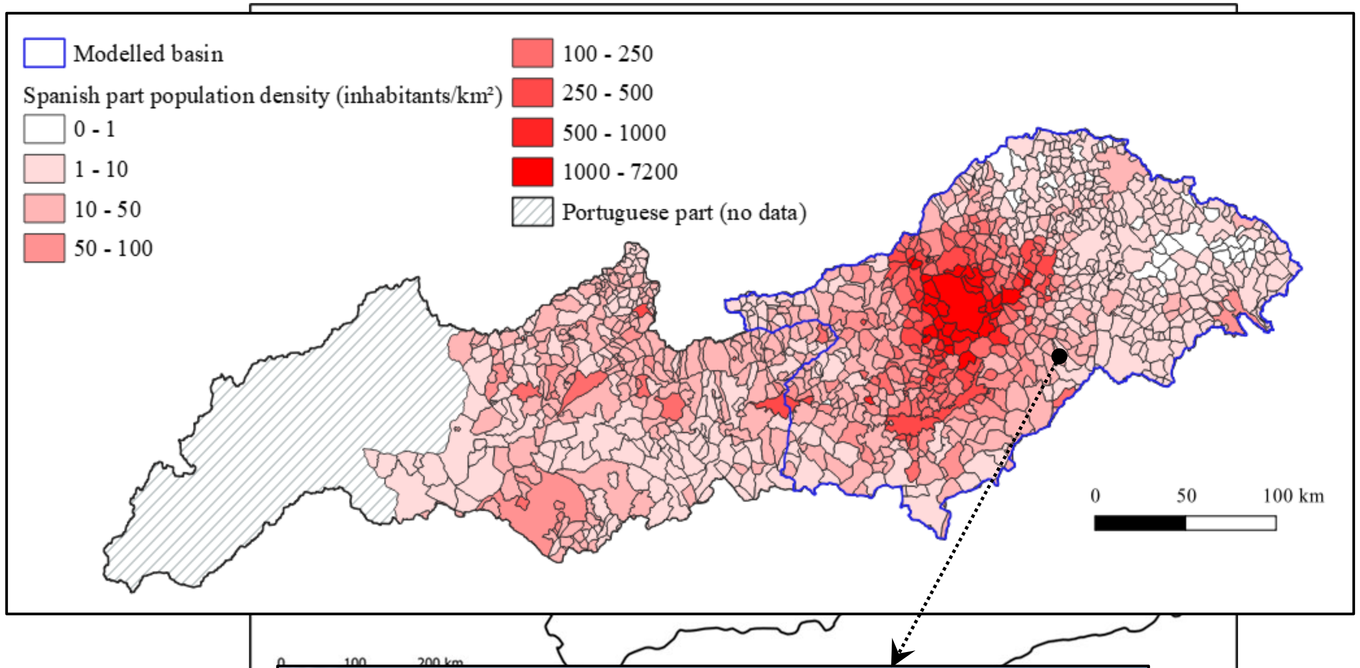
Study area: The Tagus River Basin

The Tagus River Basin:

- Longest river in the Iberian Peninsula, third largest basin.
- **Most populated** basin in the Iberian Peninsula (around **14 million people** depend on its water resources).

The Upper Tagus River Basin (UTRB)

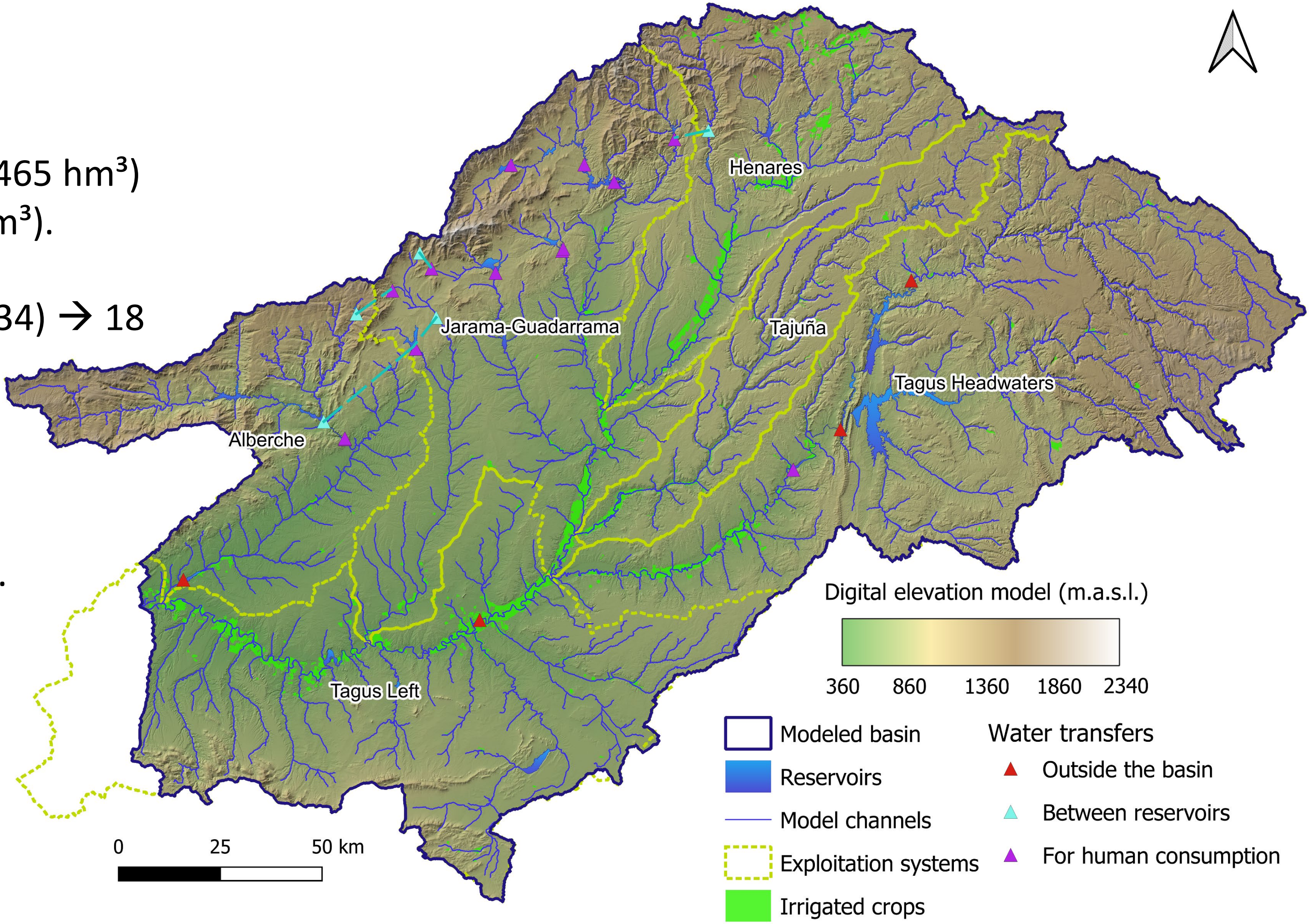
- Most relevant sector considering water resources management:
  - Largest renewable water resources.
  - Most populated area (< 7.5 million inhabitants).
  - Major part of **demans/pressures** located here (e.g., Madrid city or Tagus-Segura Water Transfer, **TSWT**).



Study area: The Upper Tagus River Basin

Water management in the UTRB:

- More than 65 reservoirs in the UTRB (4,465 hm³) → 31 introduced to the model (4,373 hm³).
- Numerous water transfers in the URTB (34) → 18 introduced to the model (1,100 hm³):
  - Outside the basin (437 + 18 hm³).
  - Between reservoirs (120 hm³).
  - For human consumption (544 hm³).
- Wastewater treatment plants (*WWTPs*) and other discharge points → More than 1,200.



Objectives:

- **Simulate with SWAT+ the management of water resources of the UTRB: Reservoirs, Irrigation and Water transfers.**

  ✓ Analyse water resources management in the UTRB.

  ✓ Explore the capabilities of the decision tables applied to reservoirs and of the water allocation module.

  ✓ Evaluate the implementation of management simulation.

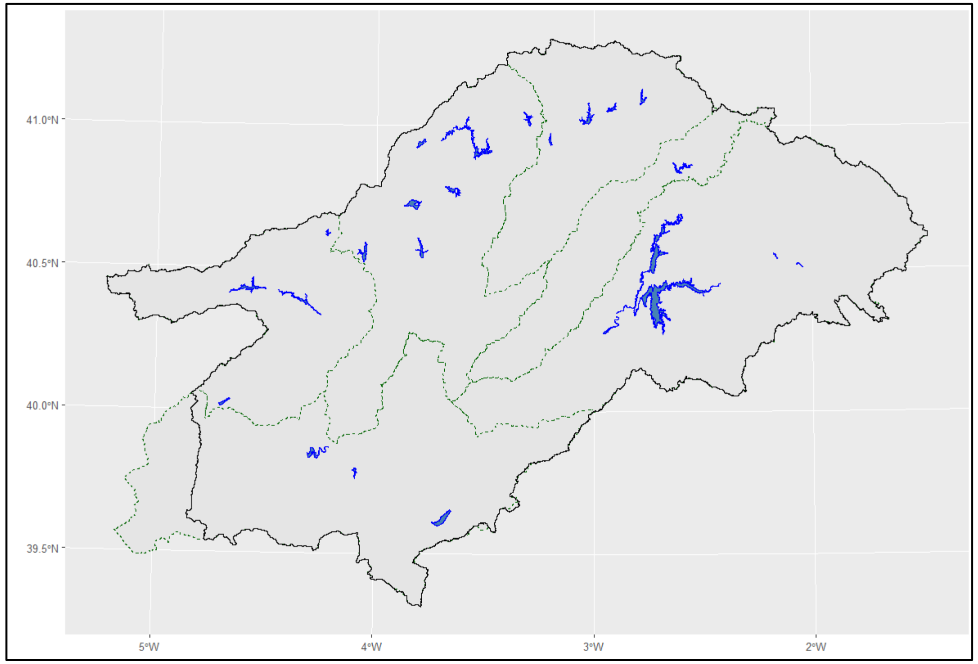
Methodology: Simulation of Reservoirs (DT)

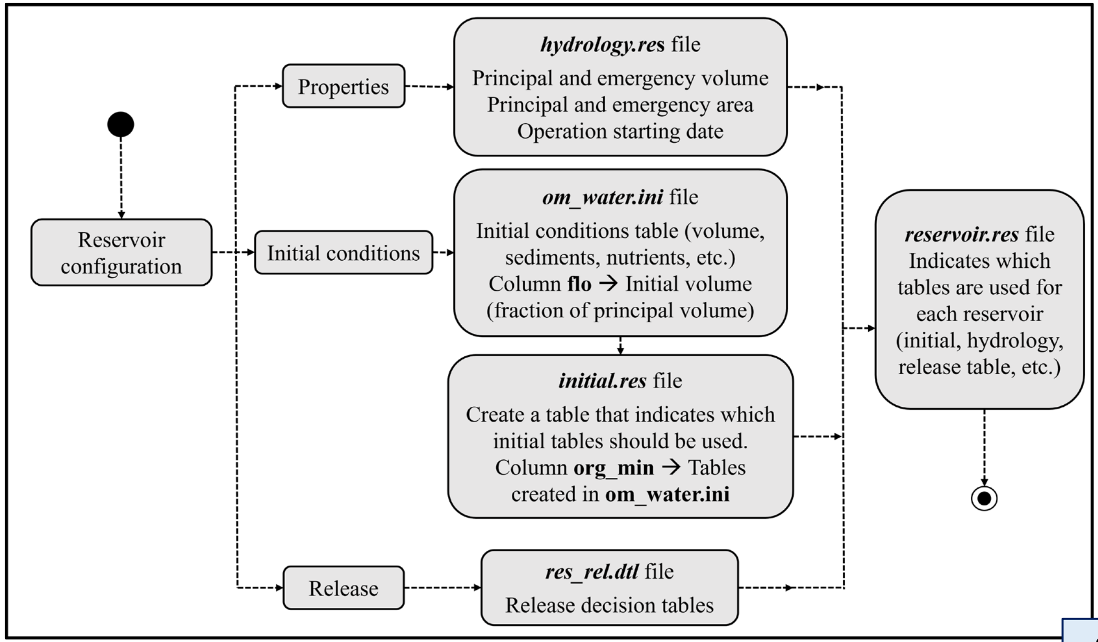
- <u>Step 1:</u> Introduction to the model → 31 reservoirs introduced.

- <u>Step 2: </u>Adapting Properties and Initial conditions →

  - Principal and emergency volume adapted to real values in *hydrology.res* file.

  - Initial volume adapted to the observed value at the beggining of the simulation:
    - Definition of tables in *om_water.ini* file (from 20% to 90% of volume fraction).
    - Definition of tables in *initial.res* (one for each *om_water* table).
    - Using created tables in *reservoir.res* file.



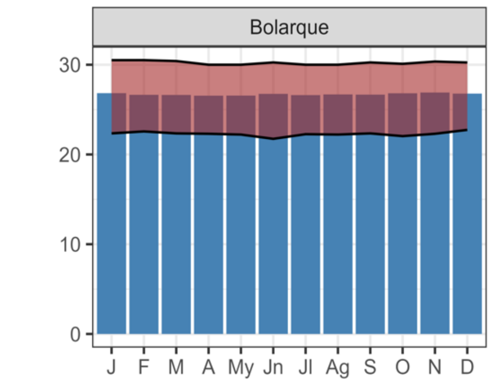


Methodology: Simulation of Reservoirs (DT)

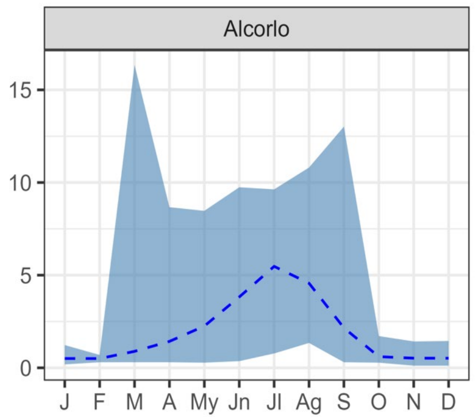
Reservoirs simulation:

- <u>Step 3:</u> Analysis of reservoirs storage/outflow records. Clustering reservoirs based on their management →
  - I → Reservoirs that keeps a constant volume.
  - II → Reservoirs with higher outflow in wet season, and minimum release in summer.
  - III → Reservoirs with maximum release in summer.
  - IV → Reservoirs with other trends.
  - V → Reservoirs with lack of data.

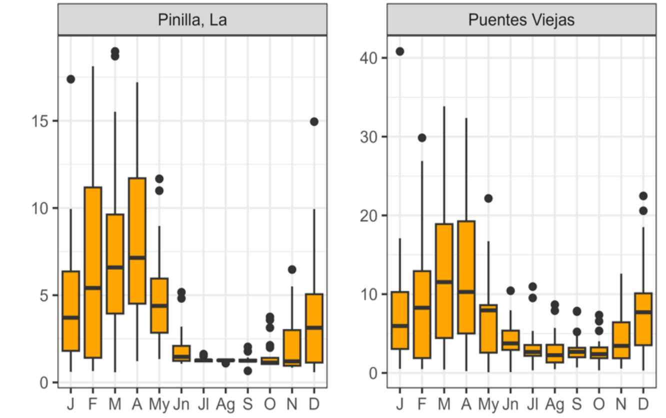
Storage (hm³): Monthly average and extreme values



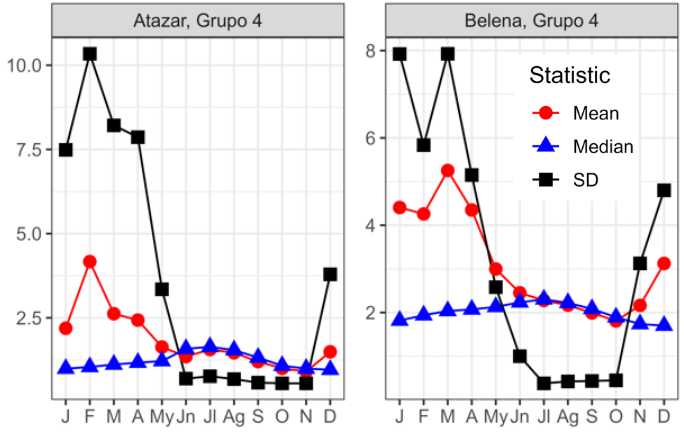
Outflow range (m³/s): Monthly average and extreme values



Average release (m³/s): Distribution at monthly scale



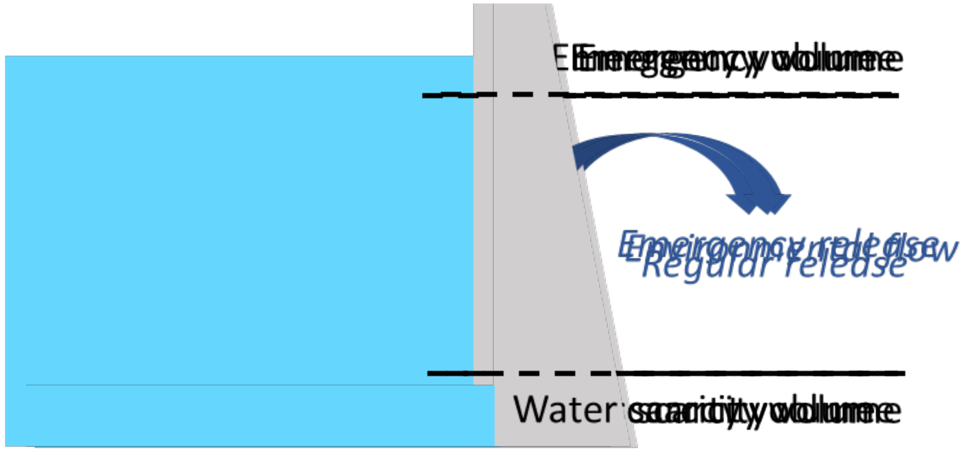
Outflow: Average monthly (m³/s)



Methodology: Simulation of Reservoirs (DT)

- <u>Step 4:</u> Creation of a general decision table structure → **3 different scenarios:**
  - i) Emergency: **Volume** > Emergency volume → **Emergency release.**
  - ii) Water scarcity: **Volume** < Water scarcity volume → Release the **environmental flow.**
  - iii) Regular conditions: Water scarcity volume < **Volume** < Emergency volume → Regular release.

- <u>Step 5:</u> Adapting the decision table structure for the different groups → The regular release was configured differently for the groups:
  - Cluster I: Release the **inflow**.
  - Cluster V (no data): Release the **environmental flow** (defined for every 3 months in the RBMP).
  - Clusters 2-4: Release the **median observed release** for every 2 months.



Release options → *res_hydro.f90 file*

Name	Purpose	const1	const2	fp
ab_emer	Release all volume above evol in a day	-	-	-
days	Release all the volume above file pointer (above 0 in case of null) divided by const_1 and divided by the number of days since the first excess was produced	Number of days to release excess	-	null, pvol, evol
dyrt	Release all the volume above file pointer (above 0 in case of null) divided by const_1 and divided by the number of days since the first excess was produced, plus a percentage of the principal volume	Number of days to release excess	Percentage of pvol to release (%)	null, pvol, evol
inflo_frac	Release a fraction of the inflow	Fraction of the inflow to release	-	-
inflo_rate	Release inflow plus a rate or release a stablished rate (the greater)	Release rate in addition to inflow (m^3/s)	Release rate (m^3/s)	-
inflo_targ	Relase inflow plus volume above evol fraction (defined in lim_const of the condition)	-	-	-
irrig_dmd	Release to supply a fraction of a demand of irrigation or water rigths objects	Fraction of the demand (m^3/d) to supply	Demand number identifier	wro, hru
meas	Release outflow according to records (requires recall data)	-	-	1, 2, 3, (daily, monthly, annual)
rate	Release a constant rate	Release rate (m^3/s)	-	-
rate_pct	Release a percentage of pvol	Percentage of pvol to release (%)	-	-
weir	Release based on weir equation using water level	-	-	-

Methodology: Simulation of Reservoirs (DT)

- Step 6: Adapting decision tables for the different reservoirs: Example of decision table for Reservoir 26 (Cluster 3)

name	conds	alts	acts
lake_26_g3_buendia	12	11	11

var	obj	obj_num	lim_var	lim_op	lim_const	alt1	alt2	alt3	alt4	alt5	alt6	alt7	alt8	alt9	alt10	alt11
vol	res	0	evol	*	0.90000	>	-	-	-	-	<	<	<	<	<	<
vol	res	0	evol	*	0.10000	-	<	<	<	<	>	>	>	>	>	>
month	null	0	null	-	4.00000	-	<	-	-	-	-	-	>	-	-	-
month	null	0	null	-	7.00000	-	-	<	-	-	-	-	<	-	-	-
month	null	0	null	-	10.00000	-	-	-	<	-	-	-	-	-	-	>
month	null	0	null	-	9.00000	-	-	-	-	>	-	-	-	<	-	-
month	null	0	null	-	2.00000	-	-	-	-	-	-	>	-	-	-	-
month	null	0	null	-	3.00000	-	-	>	-	-	<	-	-	-	-	-
month	null	0	null	-	5.00000	-	-	-	-	-	-	<	-	-	-	-
month	null	0	null	-	6.00000	-	-	-	>	-	-	-	-	>	-	-
month	null	0	null	-	8.00000	-	-	-	-	-	-	-	-	-	>	-
month	null	0	null	-	11.00000	-	-	-	-	-	-	-	-	-	<	-

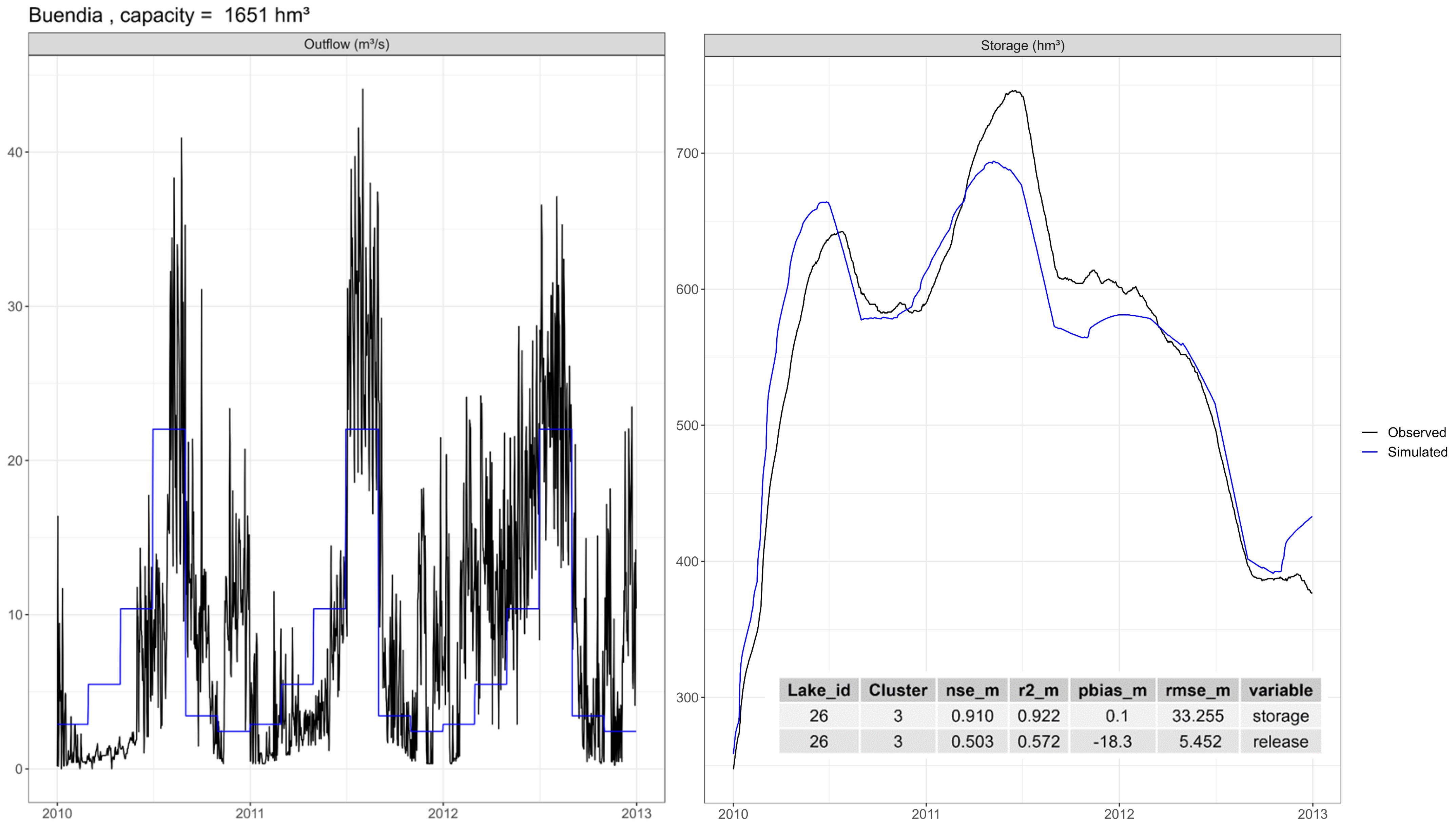
act_typ	obj	obj_num	name	option	const	const2	fp	outcome										
release	res	0	emergency	days	3.00000	0.85000	evol	y	n	n	n	n	n	n	n	n	n	n
release	res	0	minim_1	rate	2.53000	0.00000	null	n	y	n	n	n	n	n	n	n	n	n
release	res	0	minim_2	rate	2.24000	0.00000	null	n	n	y	n	n	n	n	n	n	n	n
release	res	0	minim_3	rate	1.77000	0.00000	null	n	n	n	y	n	n	n	n	n	n	n
release	res	0	minim_4	rate	1.95000	0.00000	null	n	n	n	n	y	n	n	n	n	n	n
release	res	0	norm_1	rate	2.61600	0.00000	null	n	n	n	n	n	y	n	n	n	n	n
release	res	0	norm_2	rate	5.49800	0.00000	null	n	n	n	n	n	n	y	n	n	n	n
release	res	0	norm_3	rate	10.45100	0.00000	null	n	n	n	n	n	n	n	y	n	n	n
release	res	0	norm_4	rate	21.93800	0.00000	null	n	n	n	n	n	n	n	n	y	n	n
release	res	0	norm_5	rate	3.46000	0.00000	null	n	n	n	n	n	n	n	n	n	y	n
release	res	0	norm_6	rate	2.41900	0.00000	null	n	n	n	n	n	n	n	n	n	n	y

EMERGENCY

WATER SCARCITY

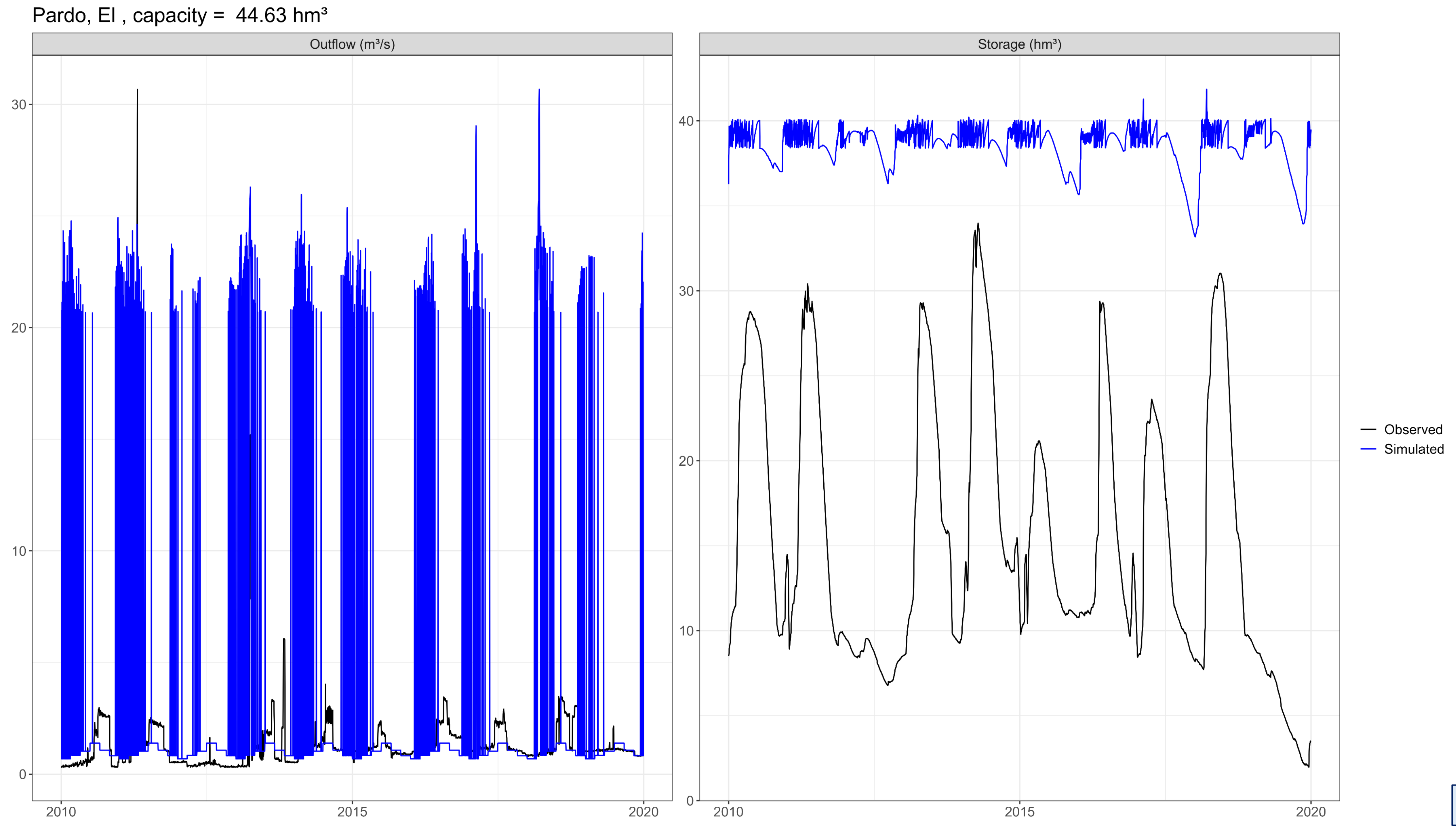
REGULAR

Results: Simulation of Reservoirs



Lake_id	Cluster	nse_m	r2_m	pbias_m	rmse_m	variable
26	3	0.910	0.922	0.1	33.255	storage
26	3	0.503	0.572	-18.3	5.452	release

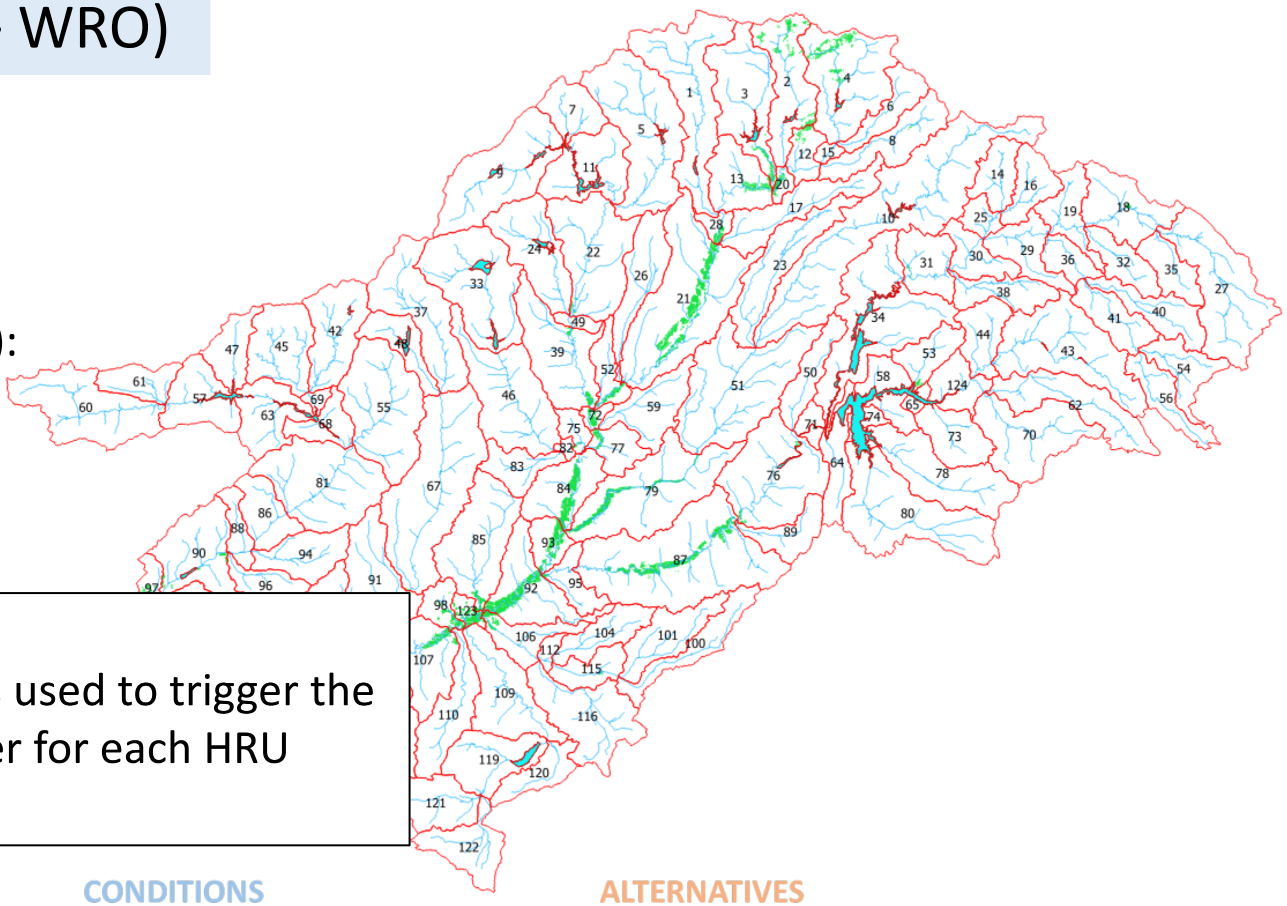
Results: Simulation of Reservoirs



Methodology: Simulation of Irrigation (DT + WRO)

- Step 1: Introduction of irrigated crops to the model → Specific land use (AGRR), simulated as corn.
- Step 2: Configuring an irrigation decision table (*lum.dtl*):
  - Conditions → Months, water stress and number of days since last application.
  - Irrigate during irrigation seas… below 0.9.
  - Irrigate anytime if water stres…

This decision table is used to trigger the demand of water for each HRU



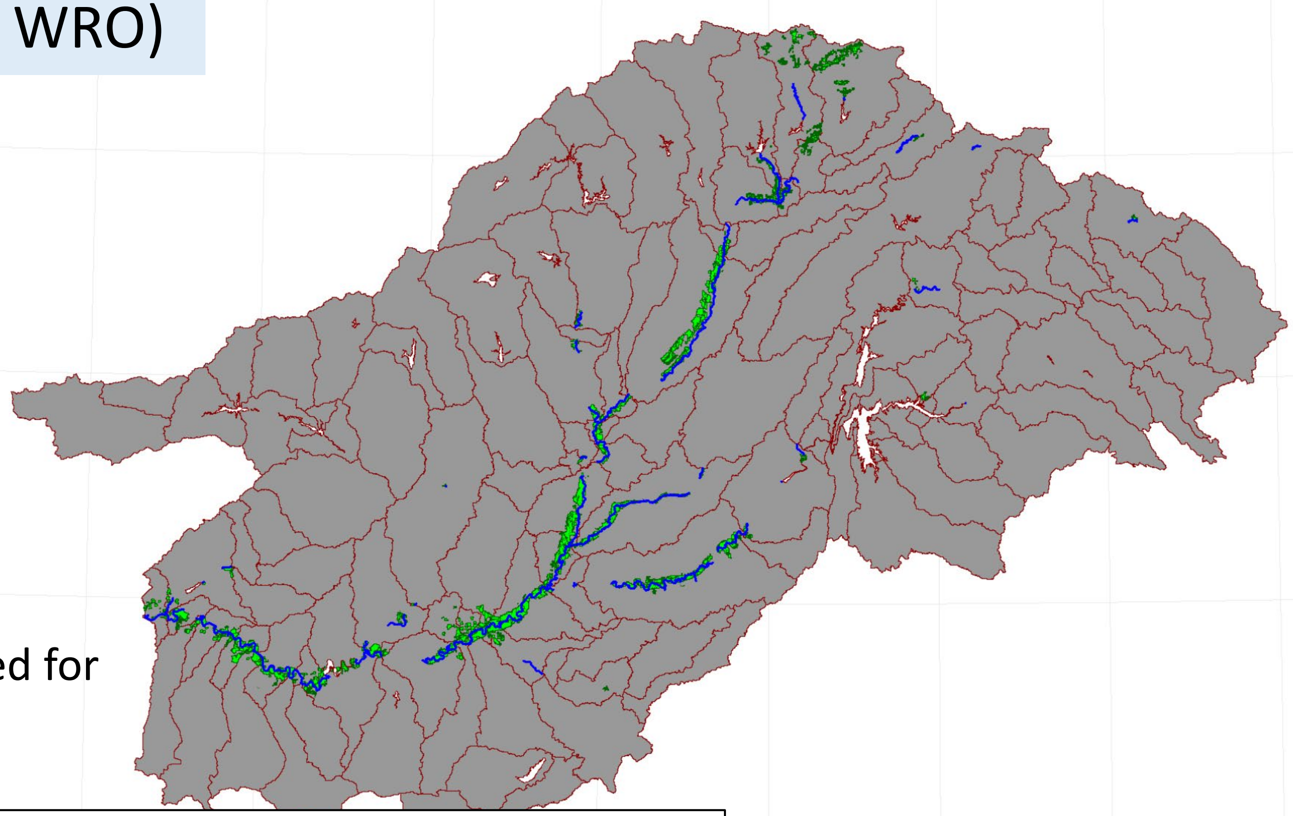
CONDITIONS ALTERNATIVES
ACTIONS CONFIGURATION ACTIONS EXECUTION

name	conds	alts	acts
irr_crt	5	2	1

var	obj	obj_num	lim_var	lim_op	lim_const	alt1	alt2
month	null	0	null	-	4.00000	>=	-
month	null	0	null	-	10.00000	<=	-
days_irr	hru	0	null	-	3.00000	>	>
w_stress	hru	0	null	-	0.90000	<	-
w_stress	hru	0	null	-	0.60000	-	<

act_typ	obj	obj_num	name	option	const	const2	fp	outcome	
irr_demand	hru	0	irr_apr_oct	sprinkler_med	20.00000	20.00000	null	y	y

Methodology: Simulation of Irrigation (DT + WRO)



- Step 3: Configuring the water allocation file:

A) Define source and demand objects.

- Demand objects → Every AGRR HRU (282)
- Source objects → Closest channel for each HRU.

B) Create water allocation tables → One table was created for each source.

```
NAME                 RULE_TYP     SRC_OBS    DMD_OBS  CHA_DB
channel_19_irrig     high_right_first_serve     1      12      y
    SRC_NUM  OB_TYP      OB_NUM  JAN_MIN  FEB_MIN  MAR_MIN  APR_MIN  MAY_MIN  JUN_MIN  JUL_MIN  AUG_MIN  SEP_MIN  OCT_MIN  NOV_MIN  DEC_MIN
1       cha      19    0.01      0.01      0.01      0.01      0.01      0.01      0.01      0.01      0.01      0.01      0.01      0.01
  NUMB  OB_TYP     OB_NUM   WITHDR        AMOUNT   W_RT  TR_TYP  TREAT  RCV_OB    RCV_NUM  RCV_DTL  SRCS     SCRC1       FRAC1  COMP1
1        hru       452    irr_crt           15      sr       null    null    null    0        null      1        1          1       n
2        hru       453    irr_crt           15      sr       null    null    null    0        null      1        1          1       n
3        hru       434    irr_crt           15      sr       null    null    null    0        null      1        1          1       n
4        hru       435    irr_crt           15      sr       null    null    null    0        null      1        1          1       n
5        hru       436    irr_crt           15      sr       null    null    null    0        null      1        1          1       n
6        hru       437    irr_crt           15      sr       null    null    null    0        null      1        1          1       n
7        hru       388    irr_crt           15      sr       null    null    null    0        null      1        1          1       n
8        hru       389    irr_crt           15      sr       null    null    null    0        null      1        1          1       n
9        hru       340    irr_crt           15      sr       null    null    null    0        null      1        1          1       n
10       hru       341    irr_crt           15      sr       null    null    null    0        null      1        1          1       n
11       hru       342    irr_crt           15      sr       null    null    null    0        null      1        1          1       n
12       hru       343    irr_crt           15      sr       null    null    null    0        null      1        1          1       n
```

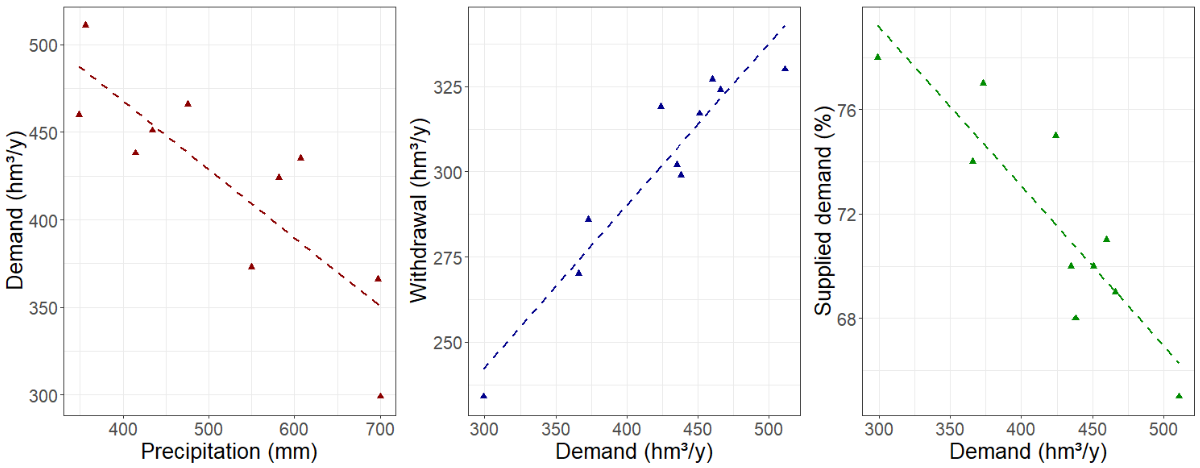
SOURCES

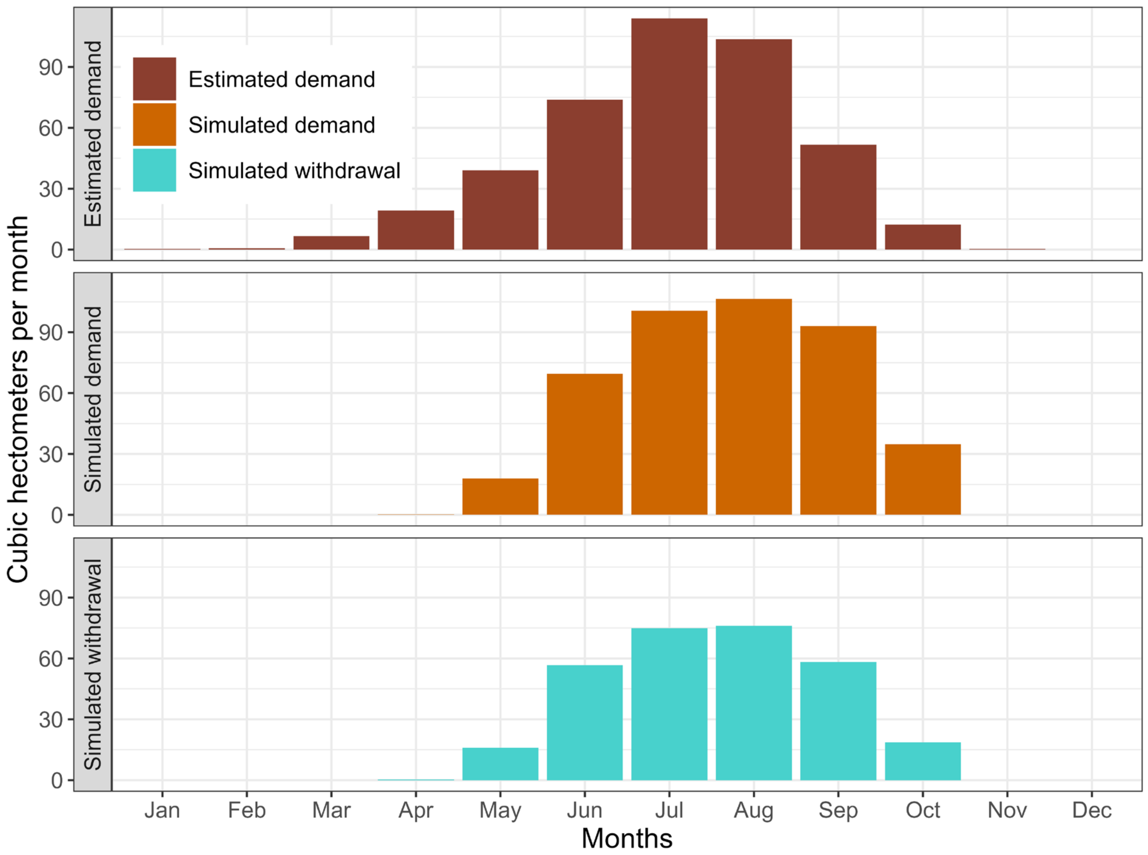
DEMAND OBJECTS

IRRIGATION DT AND AMOUNT

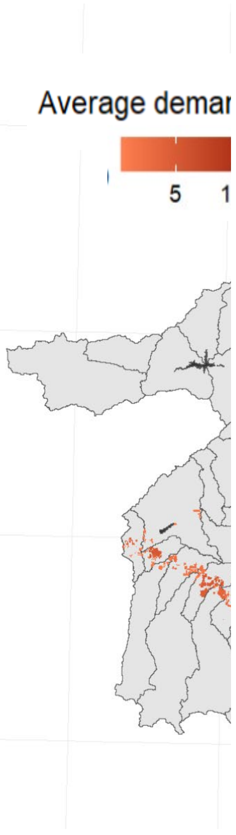
Results: Irrigation implementation

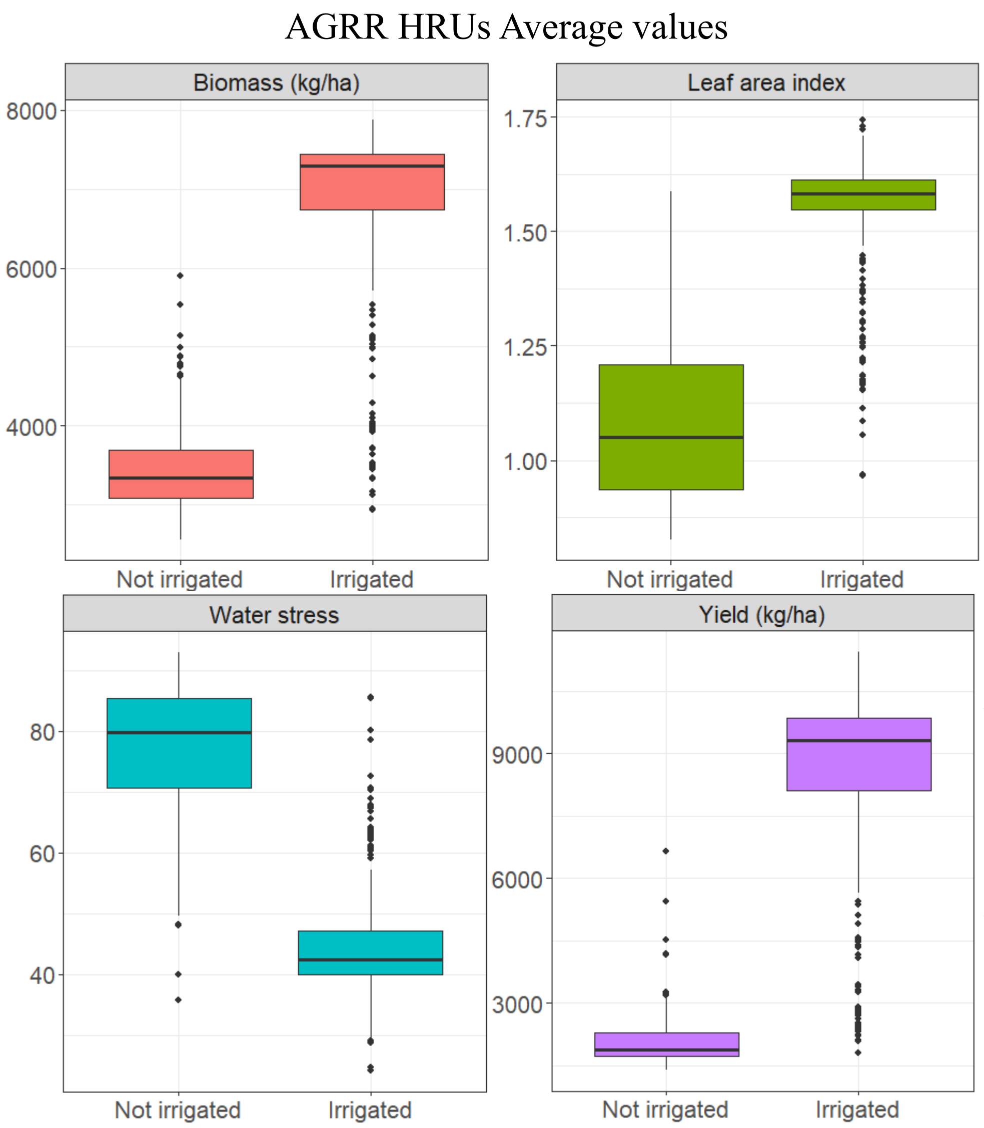
Period	Precipitation (mm/y)	Demand (hm³/y)	Withdrawal (hm³/y)	Supplied demand (%)
2010	700	299	234	78
2011	475	466	324	69
2012	414	438	299	68
2013	549	373	286	77
2014	581	424	319	75
2015	348	460	327	71
2016	607	435	302	70
2017	355	511	330	65
2018	697	366	270	74
2019	433	451	317	70
2010-2019	**516**	**422**	**301**	**71**

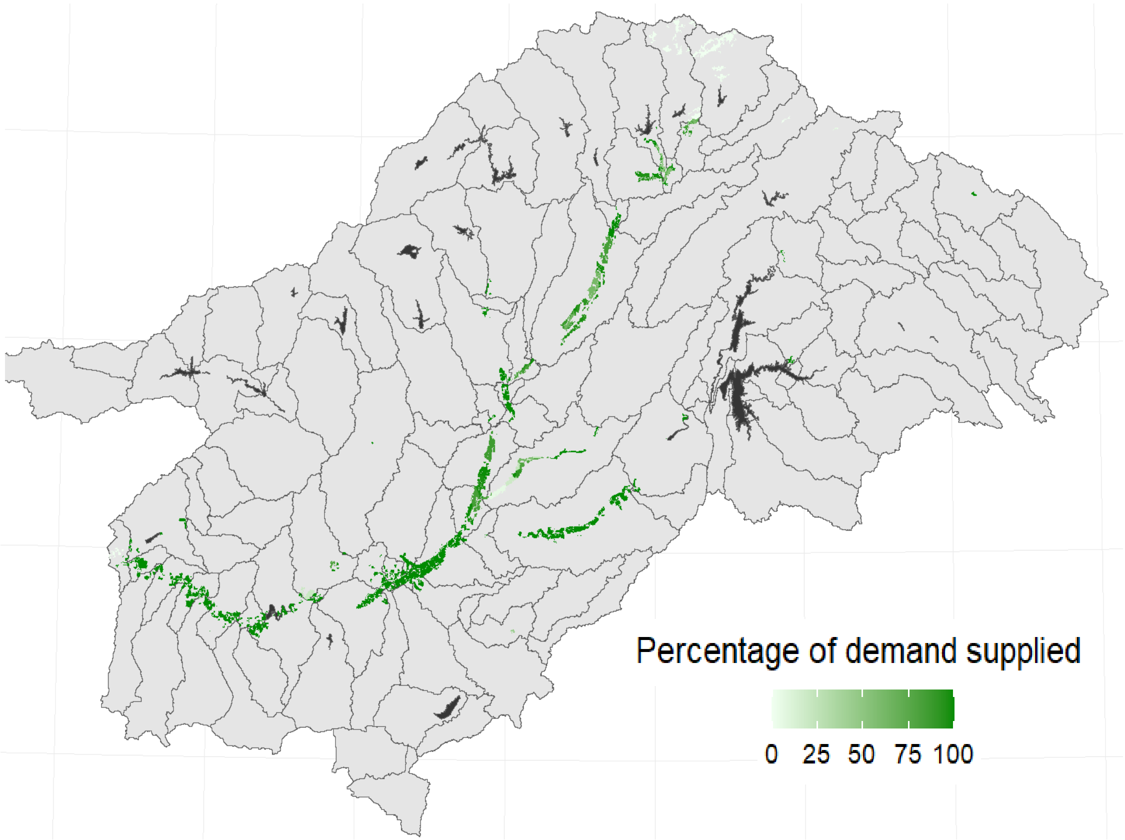




Results: Irrigation implementation



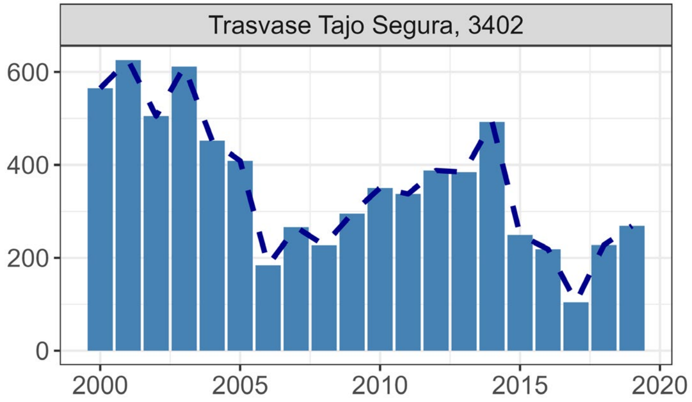




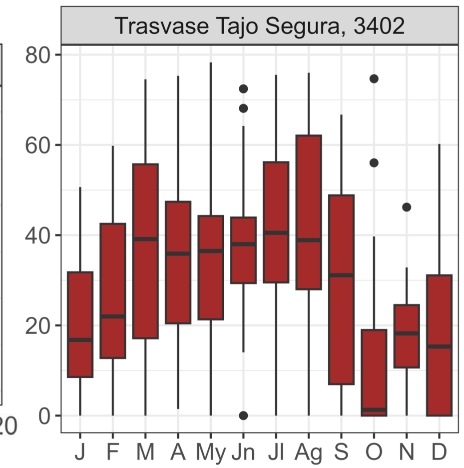
Methodology: Simulation of Water transfers (DT+WRO)

- Step 1: Configuring water transfers decision tables (*flo_con.dtl*).
  - Water transfer records were analysed.
  - A decision table was created for each water transfer to allocate the mean volumen recorded for every two months.

Transferred volume (hm³/y)



Transferred volume (hm³/month)




```
flo_con.dtl
 36

NAME               CONDS    ALTS    ACTS
out_tag_seg_wt       10       6       6
VAR             OBJ  OB_NUM LIM_VAR  LIM_OP  LIM_CONST  ALT1  ALT2  ALT3  ALT4  ALT5  ALT6
month           null     0   null      -     2.00000    -     >     -     -     -     -
month           null     0   null      -     3.00000    <     -     -     -     -     -
month           null     0   null      -     4.00000    -     -     >     -     -     -
month           null     0   null      -     5.00000    -     <     -     -     -     -
month           null     0   null      -     6.00000    -     -     -     >     -     -
month           null     0   null      -     7.00000    -     -     <     -     -     -
month           null     0   null      -     8.00000    -     -     -     -     >     -
month           null     0   null      -     9.00000    -     -     -     <     -     -
month           null     0   null      -    10.00000    -     -     -     -     -     >
month           null     0   null      -    11.00000    -     -     -     -     <     -
ACT_TYP         OBJ    OBJ_NUM  NAME        OPTION   CONST   CONST2    FP       OUTCOMES
divert          null     0    tswt_dvt_1  flo_cms   9.07       0     null   y  n  n  n  n  n
divert          null     0    tswt_dvt_2  flo_cms  14.00       0     null   n  y  n  n  n  n
divert          null     0    tswt_dvt_3  flo_cms  14.00       0     null   n  n  y  n  n  n
divert          null     0    tswt_dvt_4  flo_cms  15.60       0     null   n  n  n  y  n  n
divert          null     0    tswt_dvt_5  flo_cms   8.04       0     null   n  n  n  n  y  n
divert          null     0    tswt_dvt_6  flo_cms   7.20       0     null   n  n  n  n  n  y
```

Transfer options → *actions.f90 file*

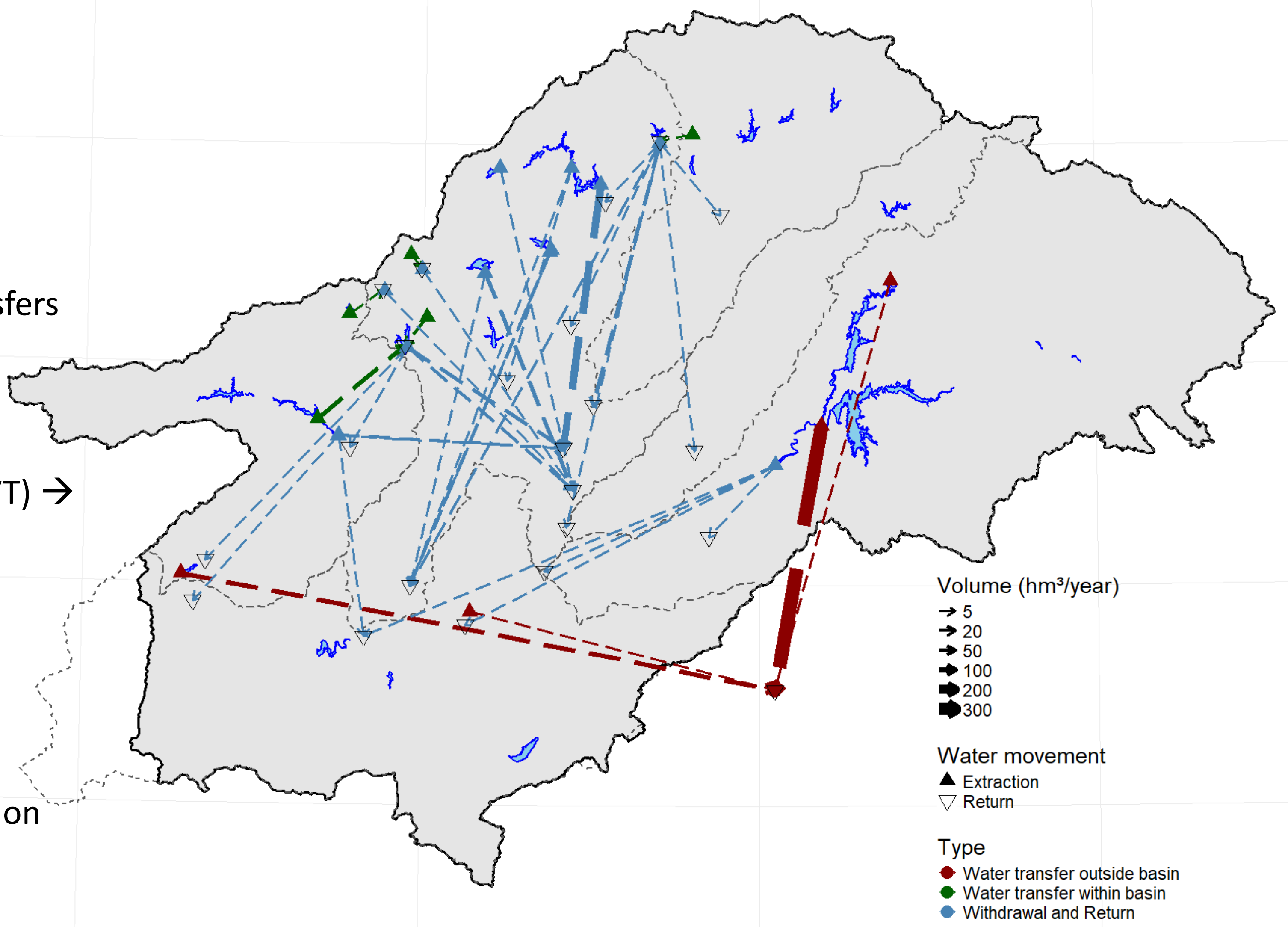
Option	Description
flo_cms	Configure the transferred volume in cubic meters per second.
min_cms	Define a minimum flow in the source; only transfer the excess.
all_flow	Transfer all the flow from the source.
min_frac	Transfer a fraction of the source's flow.
recall	Use records of transferred volumes at daily, monthly, and yearly time steps.

Methodology: Simulation of Water transfers (DT + WRO)

- Step 2: Configuring the water allocation file.

  A) Define source and demand objects.

  - **Source objects** → Reservoirs where water transfers are located.
  - **Demand objects** identification:
    - Water diverts outside the basin (e.g., TSWT) → Non SWAT objects (arbitrary).
    - Water transfers between reservoirs → Receiver reservoirs.
    - Transfers for human consumption → 17 receiver points (channels) were defined according to the WWTPs/discharges location and volume.



Methodology: Simulation of Water transfers (DT + WRO)

- Configuring the water allocation file.

B) Create water allocation tables → One table for each type of water transfer (3 in total).

```
NAME                  RULE_TYP                    SRC_OBS    DMD_OBS  CHA_OB
wtransfs_outside_wro high_right_first_serve          4          4       y
NUM  OB_TYP OB_NUM  MIN MONTHLY (M3/S FOR CHANNELS; FRAC PRIN SPILL FOR RES; DEP BELOW SURF FOR AQU)
  1     res     27  0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15
  2     res      5  0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15
  3     res     21  0.05 0.05 0.05 0.05 0.05 0.05 0.05 0.05 0.05 0.05 0.05 0.05
  4     cha    849  0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
NUMB OB_TYP   OB_NUM          WITHDR   AMOUNT  W_RT TR_TYP TREAT  RCV_OB  RCV_NUM RCV_DTL  SRCS   SCRC1  FRAC1 COMP1
1    divert        1   out_tag_seg_wt     0.0   sr    null  null   tswt        1    null     1       1   1.0     n
2    divert        1  out_czalegas_wt     0.0   sr    null  null   czlg        1    null     1       2   1.0     n
3    divert        1          ave_day 51322.0   sr    null  null   trnp        1    null     1       3   1.0     n
4    divert        1          ave_day  2160.0   sr    null  null   acca        1    null     1       4   1.0     n
```

SOURCES

DEMAND OBJECTS

WATER TRANSFER DT AND AMOUNT

```
NAME                 RULE_TYP                  SRC_OBS   DMD_OBS   CHA_OB
wtransfs_within_wro high_right_first_serve        5         5        y
NUM OB_TYP  OB_NUM  MIN MONTHLY (M3/S FOR CHANNELS; FRAC PRIN SPILL FOR RES; DEP BELOW SURF FOR AQU)
  1    res      18  0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15
  2    cha     231  0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  3    cha     542  0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01 0.01
  4    res       1  0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15
  5    res      25  0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15 0.15
NUMB OB_TYP   OB_NUM             WITHDR  AMOUNT  W_RT  TR_TYP  TREAT RCV_OB RCV_NUM RCV_DTL  SRCS  SCRC1  FRAC1 COMP1
1    divert        1    wti_sorbe_canal     0.0    sr    null   null   res      28    null     1      1    1.0     n
2    divert        1  wti_navlmdio_canal    0.0    sr    null   null   cha     321    null     1      2    1.0     n
3    divert        1   wti_nieves_canal     0.0    sr    null   null   res      11    null     1      3    1.0     n
4    divert        1    wti_acena_canal     0.0    sr    null   null   cha     296    null     1      4    1.0     n
5    divert        1    wti_sjuan_canal     0.0    sr    null   null   res      11    null     1      5    1.0     n
```

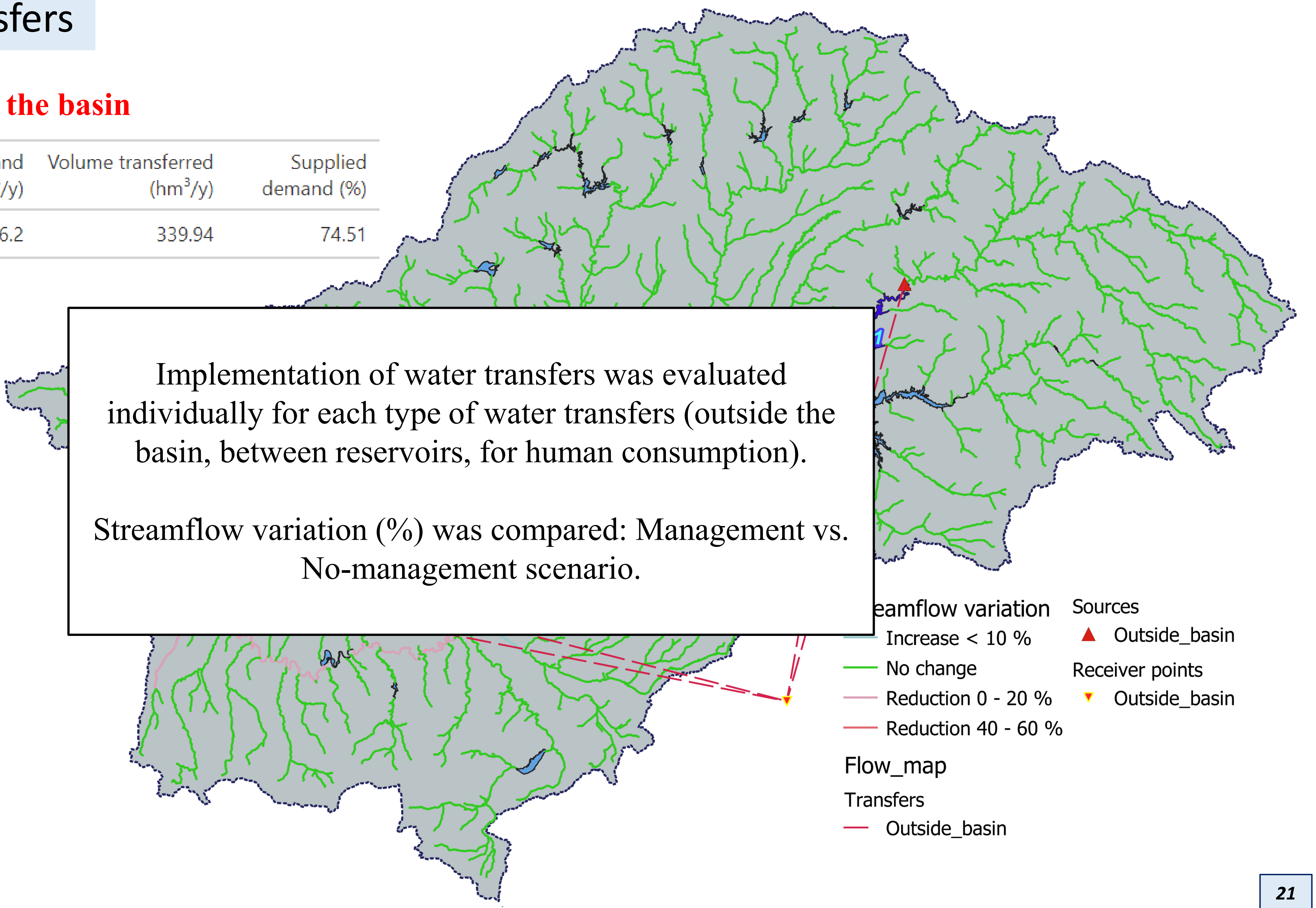
Results: Water transfers

Water transfers outside the basin

Observed demand (hm^3/y)	Simulated demand (hm^3/y)	Volume transferred (hm^3/y)	Supplied demand (%)
456	456.2	339.94	74.51

Implementation of water transfers was evaluated individually for each type of water transfers (outside the basin, between reservoirs, for human consumption).

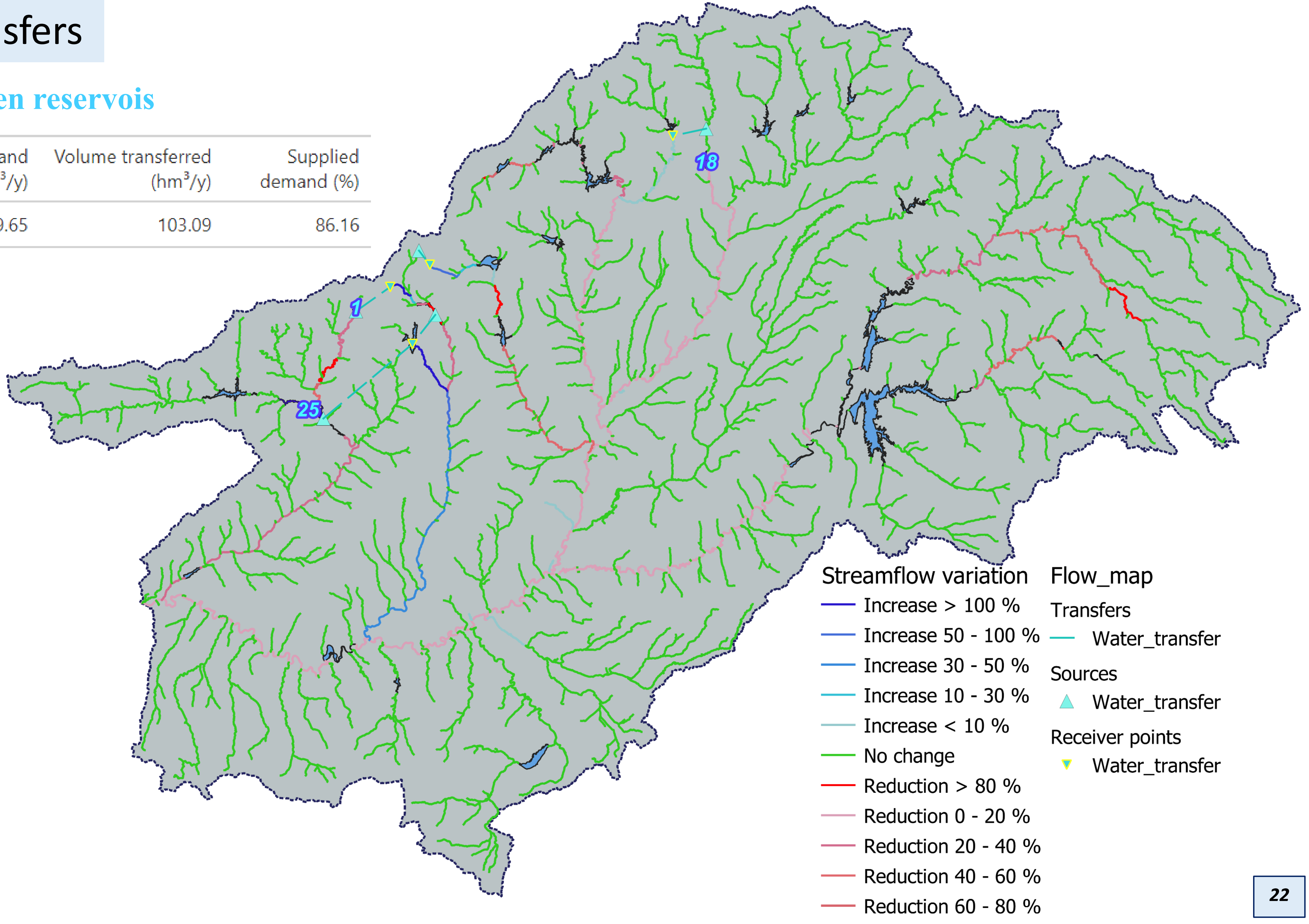
Streamflow variation (%) was compared: Management vs. No-management scenario.



Results: Water transfers

Water transfers between reservois

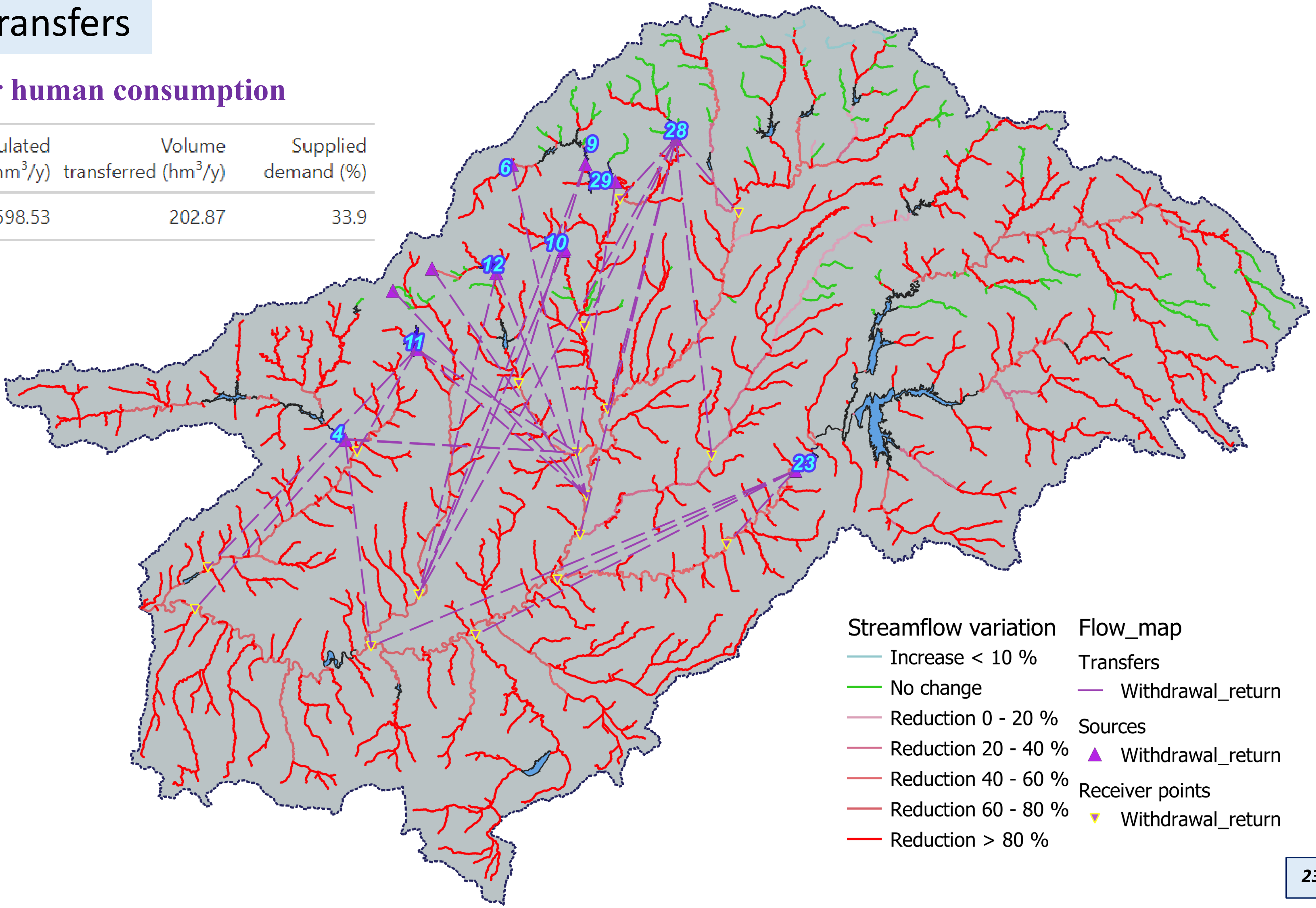
Observed demand (hm^3/y)	Simulated demand (hm^3/y)	Volume transferred (hm^3/y)	Supplied demand (%)
120	119.65	103.09	86.16



Results: Water transfers

Water transfers for human consumption

Observed demand (hm^3/y)	Simulated demand (hm^3/y)	Volume transferred (hm^3/y)	Supplied demand (%)
600	598.53	202.87	33.9



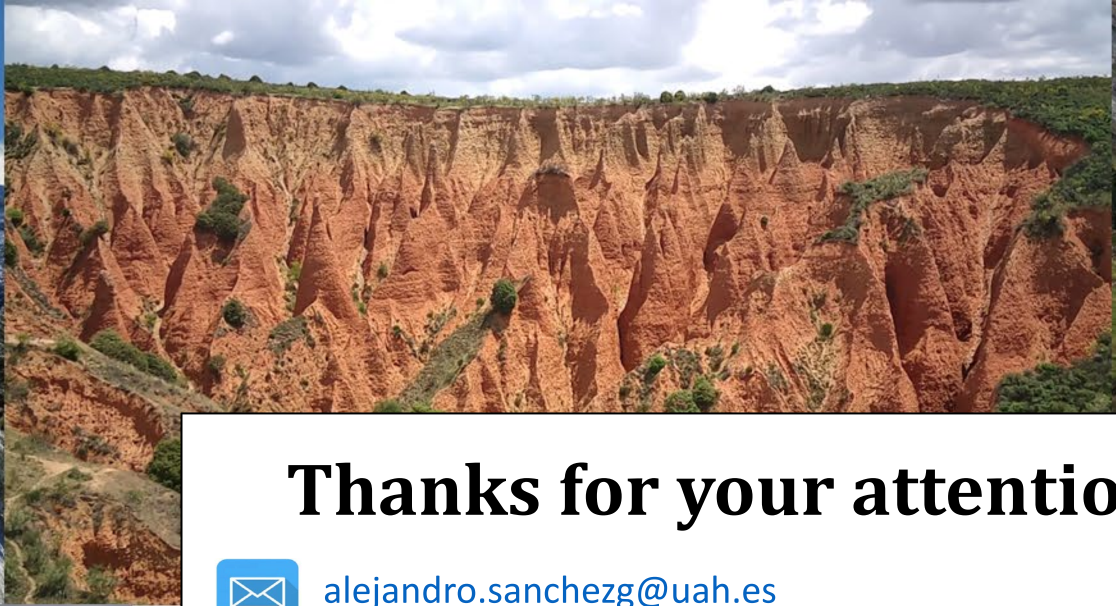
Conclusions

Water management in the UTRB was explored and simulated with SWAT+, using **decision tables** and the **water allocation module**.

The flexibility of these new features allowed to simulate **irrigation**, different kinds of **water transfers** and **reservoirs operations**.

Some **promising results** were obtained, certain aspects are not functioning properly and **will be fixed**.

Simulating water management actions **increases SWAT capabilities and will boost its use**.


Thanks for your attention!

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SWAT Soil & Water Assessment Tool

Universidad de Alcalá

ACMA Agua, Clima y Medio Ambiente

Cofinanciado por la Unión Europea

MINISTERIO DE HACIENDA Y FUNCIÓN PÚBLICA

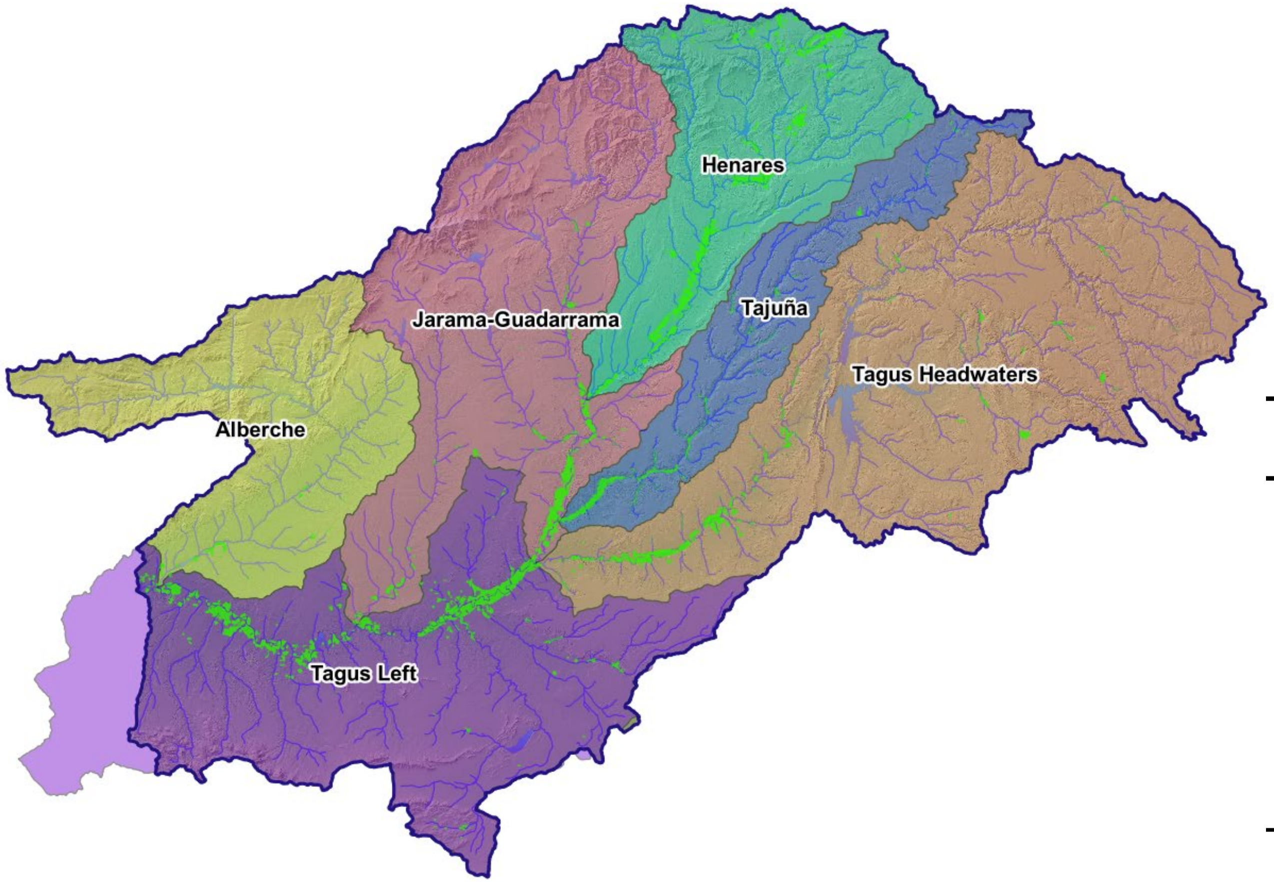
Fondos Europeos

Castilla-La Mancha

Study area: The Upper Tagus River Basin

Water management in the UTRB:

- Based on the Water Framework Directive (*WFD*) and the Tagus River Basin Management Plan (*RBMP*).
- Management scale: Exploitation system.



Water demands

- Human, industrial and agricultural demand estimated using data from the RMBP for each exploitation system.

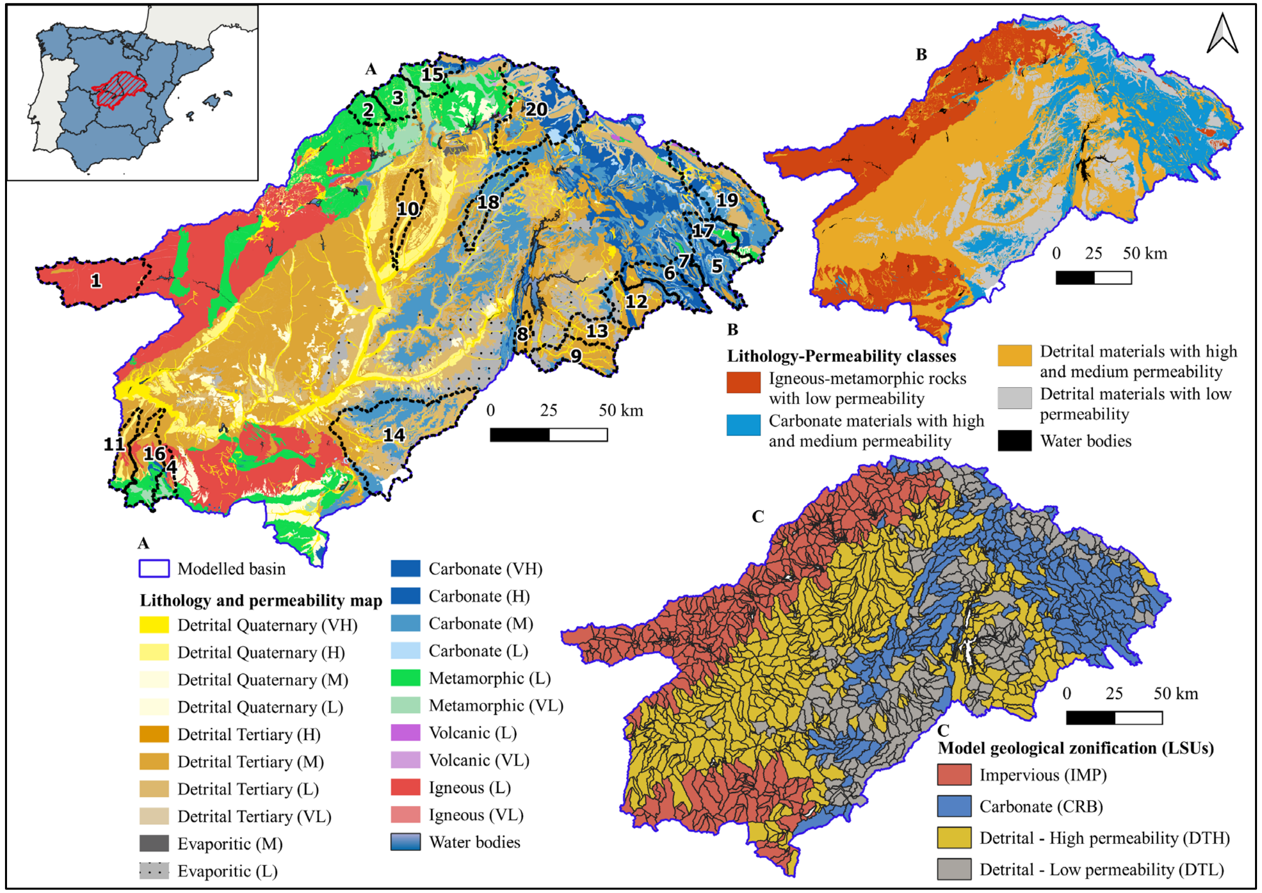
Exploitation system	Population	Human and industrial demand (hm^3)	Industrial demand (% of total demand)	Water loss (% of total demand)
1, Tagus Headwaters	213,584	23.4	14.3	19.1
2, Tajuña	65,818	35.3	8.7	11.4
3, Henares	564,830	83.1	15.5	8.9
4, Jarama-Guadarrama	5,816,537	548.9	5.2	7.2
5, Alberche	209,522	44.7	5.2	14.4
6, Tagus Left	675,769	112.5	14.7	13.7
Total	7,546,060	847.8	7.89	9.11

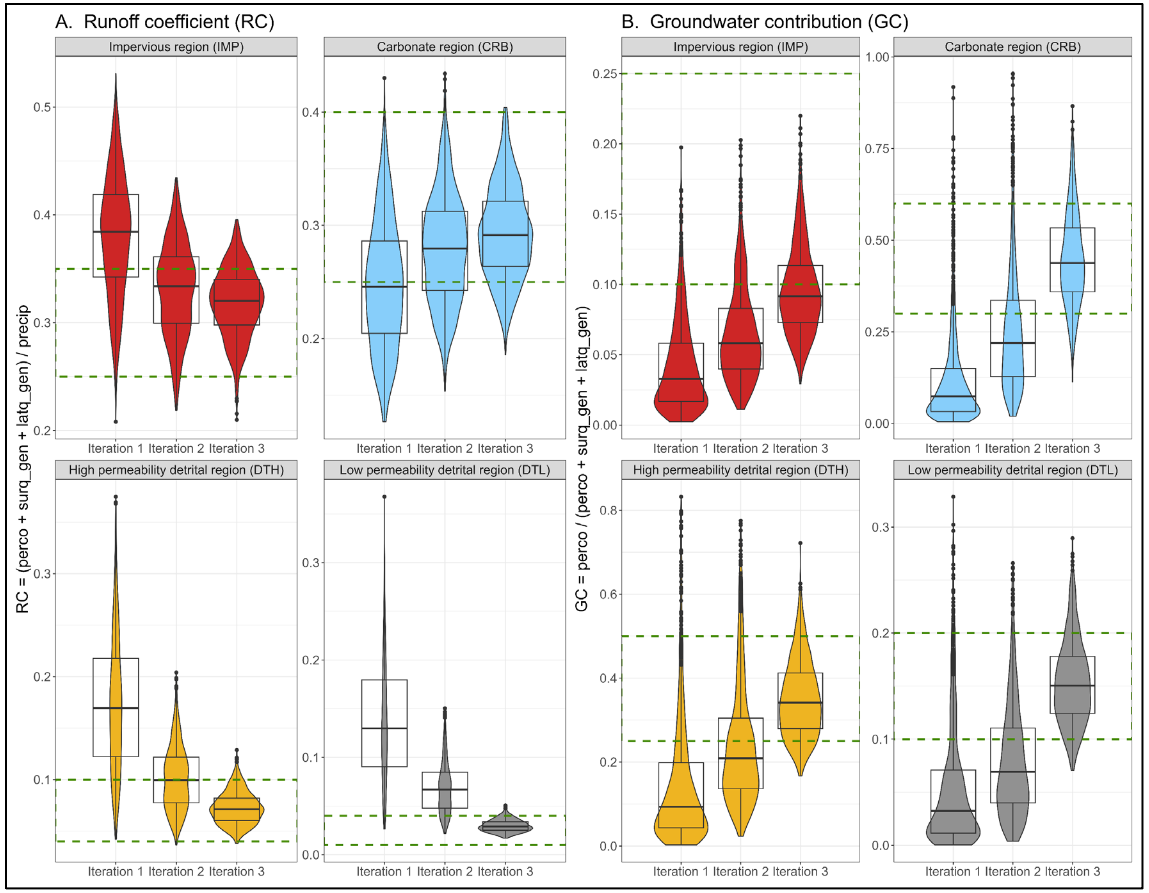
Exploitation system	Irrigated surface (ha)	Raw demand (hm^3/y)	Net demand (hm^3/y)	Irrigation amount (mm/y)
1, Tagus Headwaters	20,278 (14%)	123.8 (8%)	84.6 (11%)	417
2, Tajuña	6,269 (21%)	41 (10%)	24.4 (15%)	389
3, Henares	19,573 (15%)	134.7 (8%)	75.5 (13%)	386
4, Jarama-Guadarrama	17,178 (37%)	97.2 (24%)	71.4 (29%)	416
5, Alberche	6,641 (47%)	32.8 (28%)	23.5 (35%)	354
6, Tagus Left	31,846 (4%)	327.1 (1%)	142.6 (3%)	448
Total	101,784 (23%)	756.6 (13%)	421.9 (18%)	415

Methodology: Model calibration

A Multi-spatial and Multi-criteria Zonal calibration was performed:

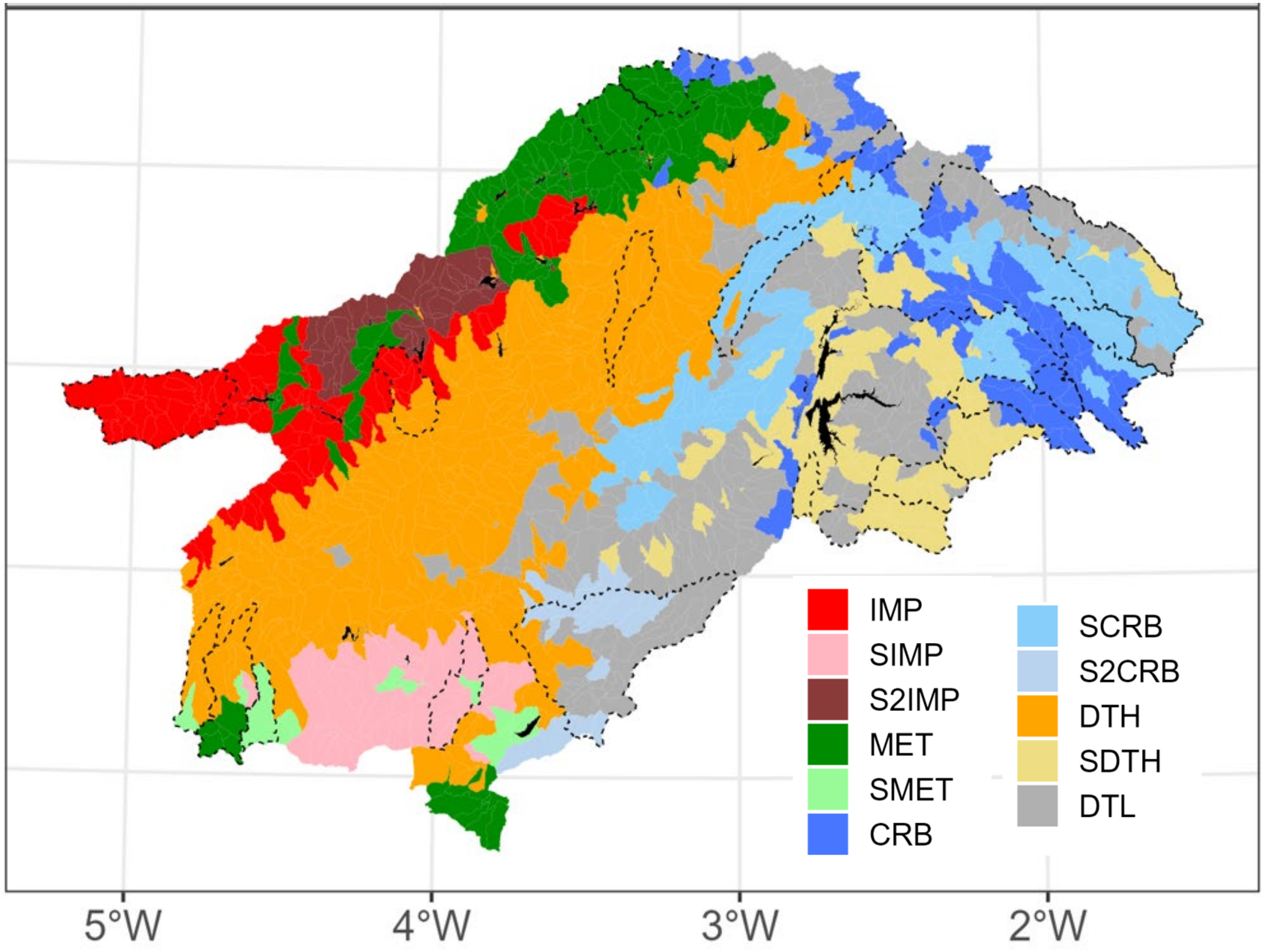
Soft calibration → Adjusting water yield and groundwater contribution in 4 geological regions.



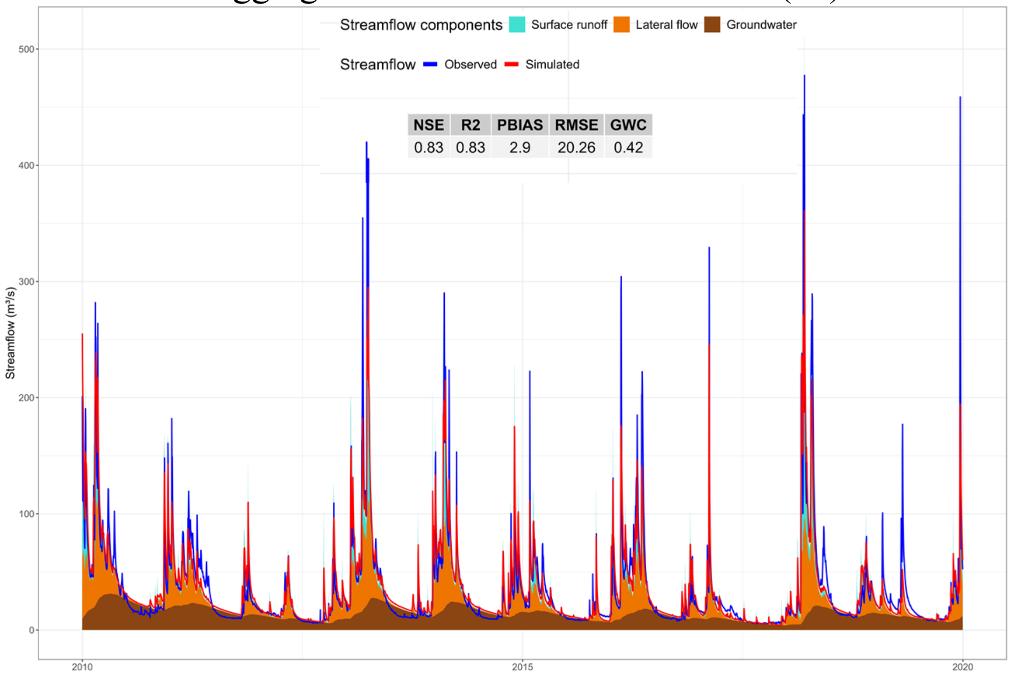


Methodology: Model calibration

Hard calibration and validation → Streamflow simulation performance and groundwater contribution in **22 sub-catchments** + Reservoir inflow performance in **13 reservoirs.**



Aggregated results of sub-catchments (22)



Aggregated results of reservoirs (13)