9th INTECOL INTERNATIONAL WETLANDS CONFERENCE
WETLANDS IN A COMPLEX WORLD
JUNE 3-8, 2012
ORLANDO FLORIDA, USA

Planning Wetland Restoration in Agricultural Watersheds to improve water quality

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Outline

Introduction
Study area: River Flumen watershed
Objective: *A Protocol to identify and select zones to create/restore wetlands in irrigated agricultural watesheds*
Methods: The tools to select and prioritize action zones
Results: Selected sites
Discussion: Restoration Actions

http://www.creamagua.com “Creation and restoration of aquatic ecosystems to improve water quality and biodiversity”

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Introduction

In intensively irrigated agricultural watersheds:

-excess of pollutants discharged into rivers causes water quality degradation





-wetlands can be efficient systems to retain and remove pollutants from agricultural wastewater, thus contributing to the improvement of the river water and ecosystem.






-Planning wetland creation/restoration at watershed scale is required for this purpose:

Objective

Establishing a **protocol** for restoring/creating wetlands at watershed scale to improve water quality and biodiversity.

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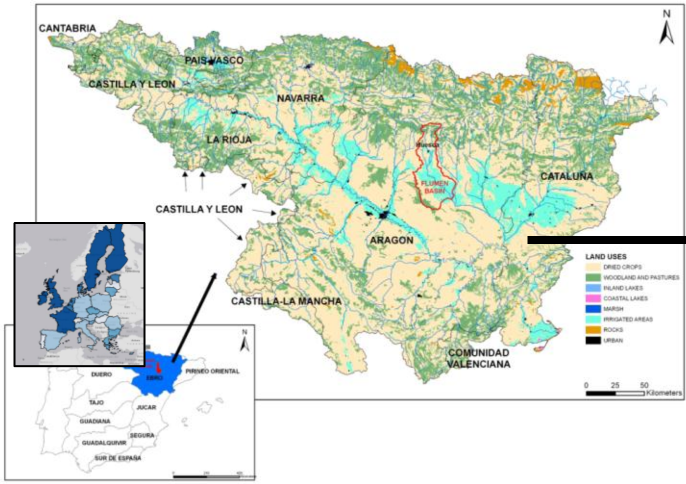
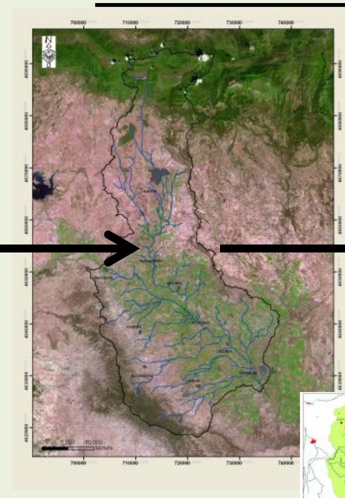
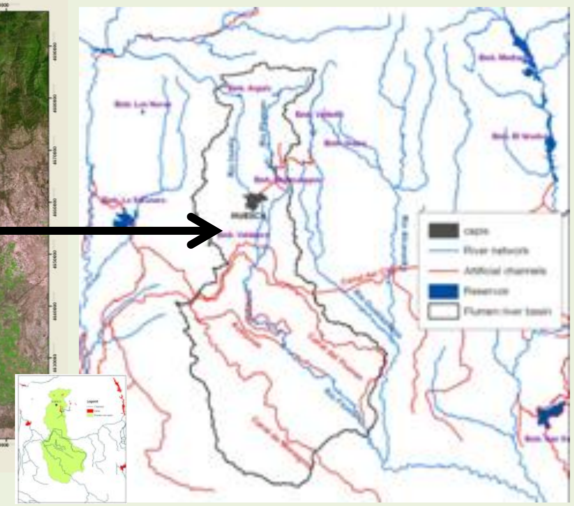
Study area

Ebro Basin (NE Spain)



River Flumen wateshed



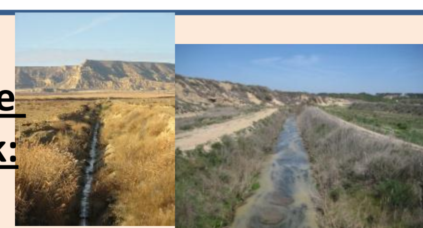


Basin area: 1431 km^2
River length: 120 km
Climate: semiarid-
Rainfall: 150-400 mm/yr
PET = 1144.1 mm/yr
Inhabitants: 65,000
Flumen av. flow: 6 m^3/s
(2001)
Intensively regulated

Irrigation network:

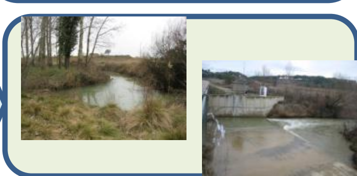
Irrigated agricultural lands:

Drainage network:



To the river:

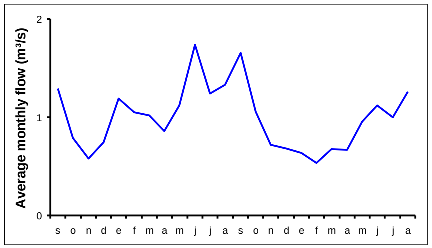
Wet-lands



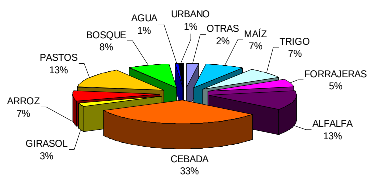
River Flumen its watershed and its key environmental variables

2010--2011

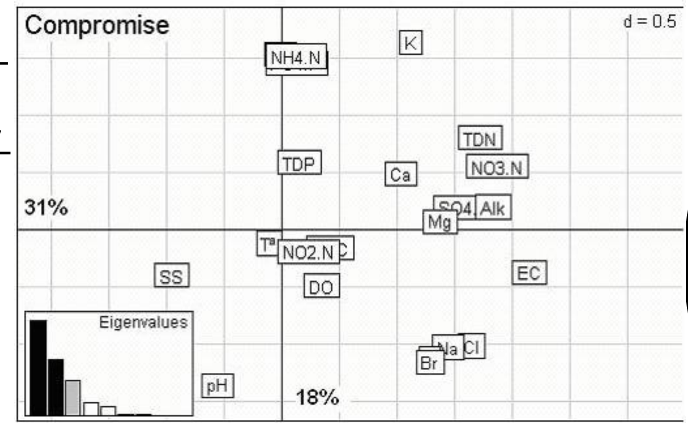
Water flow at the river mouth (*)



Relative watershed land covers

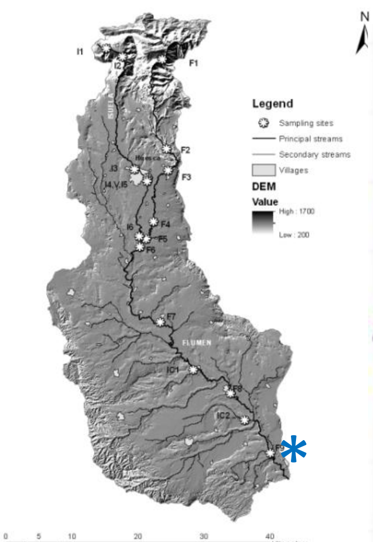


Multifactorial analysis of water quality variables

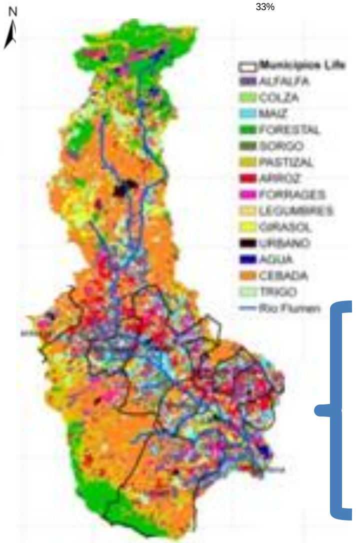


Key variables

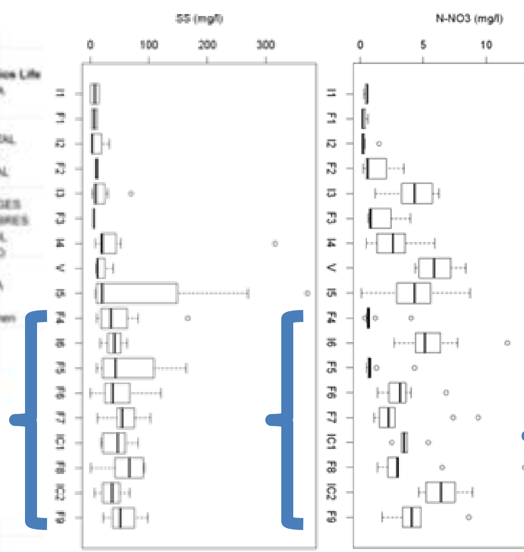
NO_3 vs. SS & NH_4



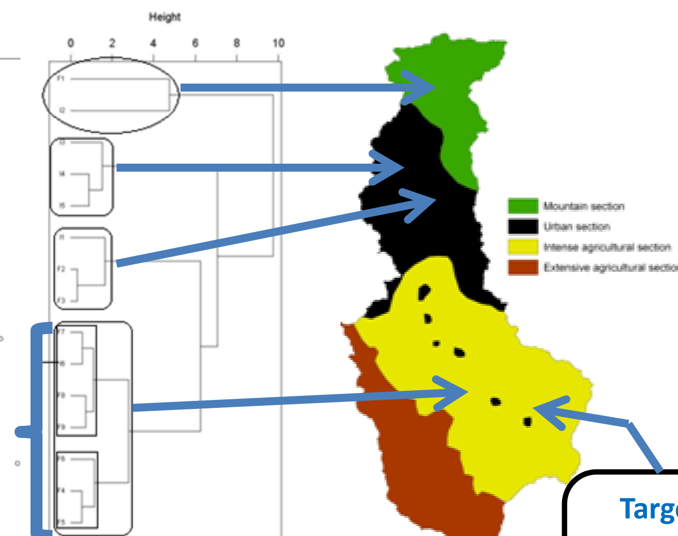
Natural river drainage network
Locationof sampling sites



Land cover



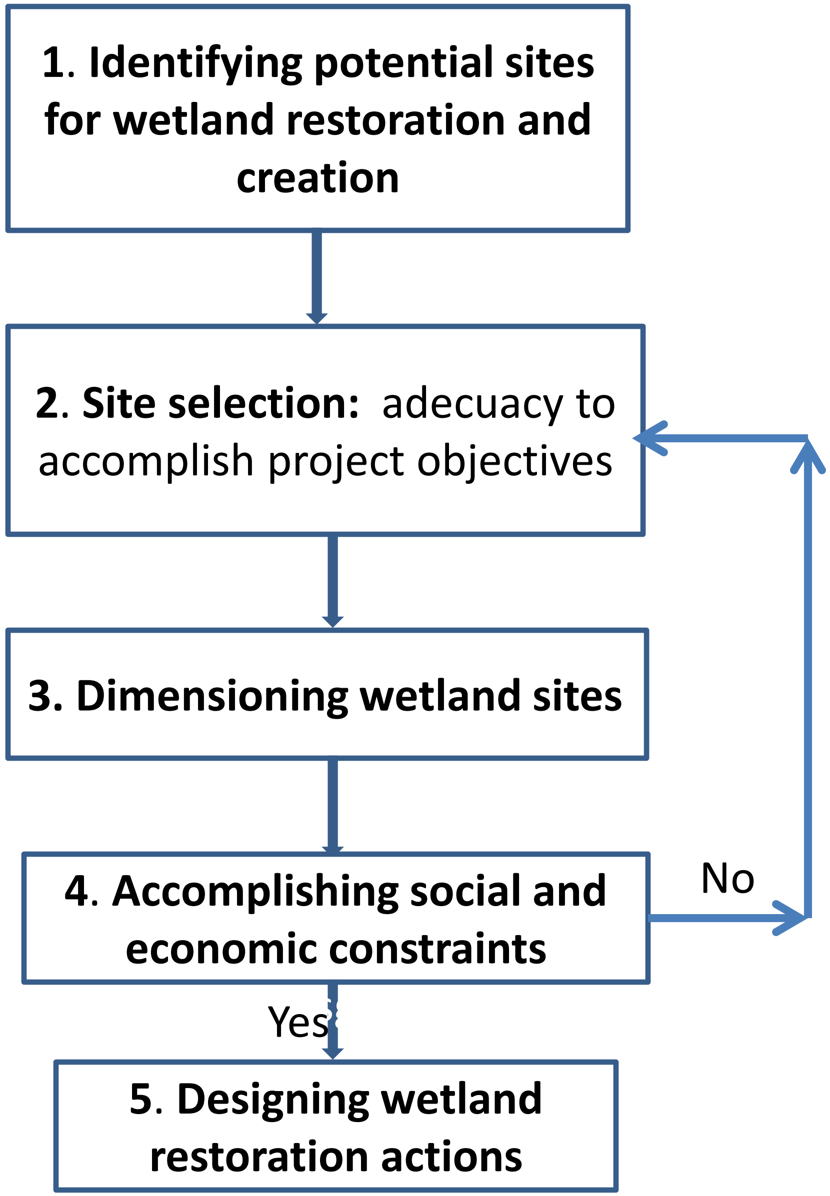
Suspended solids **NO_3** concentrations along the river axis



Clustering river zones by water quality similarity

Target zone to restore/ create wetlands

Protocol steps:



Criteria	Protocol steps	Tools
-Recovering destroyed and degraded wetlands -Agreement with hidrogeomorphic characteristics of wetland sites	**1. Identifying potential sites for wetland restoration and creation**	Land cover Maps SWAT GIS
-Absolute and relative importance for removing nitrate discharge to the river	**2. Site selection:** adecuacy to accomplish project objectives	SWAT-GIS Frequential distribution of nitrate and water discharges in sub-basins
-Dimensioning parameters to remove nitrate	**3. Dimensioning wetland sites**	Dimensioning 1st order areal removal model for surface flow wetlands (Kadlec & Knight 1996)
-Social constraints: Land availability for wetland creation/restoration -Economic constraints: Budget availability for wetland creation/restoration	**4. Accomplishing social and economic constraints**	Checking land registry and constructing costs against available funding
-Design characteristics for the improvement of wetland functions	**5. Designing wetland restoration actions**	Constructing actions to Improve functional performance

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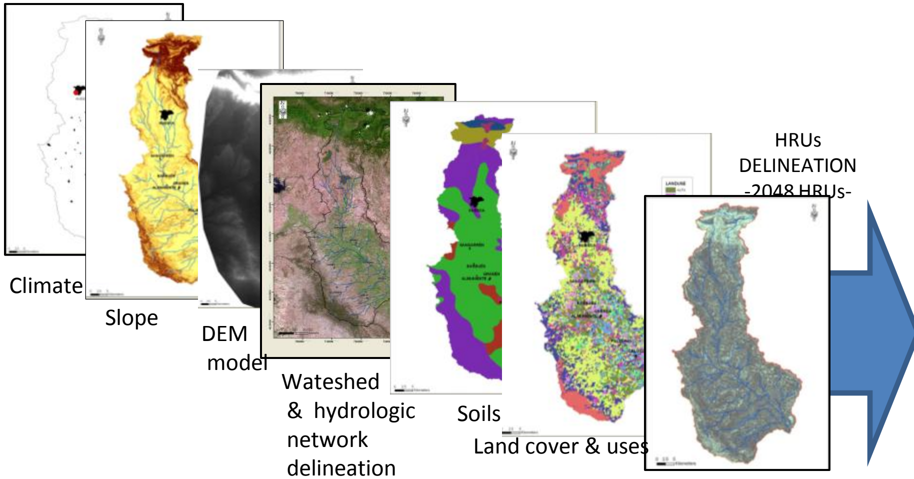
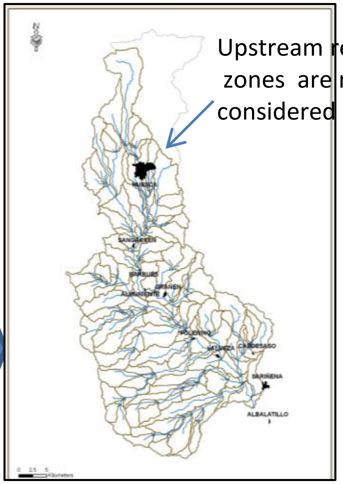
1. Identifying potential sites for wetland restoration and creation: The SWAT tool

SWAT-The Soil and Water Assessment Tool 2009 SWAT is a river basin scale model developed to quantify the impact of land management practices in large, complex watersheds.

Delineate subwatersheds of Flumen River with direct surface run-off to the river





Sub-basins delineation -163 subbasins-

	Area [ha]	Area[acres]	%Wat.Area
Watershed	127134.1200	314154.7672	
Number of Subbasins: 163			
LANDUSE:			
Spring Canola-Polish --> CANP	663.3512	1639.1740	0.52
Corn --> CORN	9207.2871	22751.6667	7.24
Winter Wheat --> WWHT	9182.4281	22690.2389	7.22
Italian (Annual) Ryegrass --> RYEG	6944.8759	17161.1356	5.46
Alfalfa --> ALFA	16797.0821	41506.4298	13.21
Winter Barley --> WBAR	41351.9900	102182.8349	32.53
Sunflower --> SUNF	3216.5924	7948.3607	2.53
Rice --> RICE	8985.3346	22203.2112	7.07
Grain Sorghum --> GRSG	483.1942	1193.9970	0.38
Pasture --> PAST	17085.2040	42218.3933	13.44
Soybean --> SOYB	1518.5815	3752.4908	1.19
Forest-Mixed --> FRST	9869.8298	24388.8430	7.76
Water --> WATR	841.4871	2079.3567	0.66
Residential --> URBN	986.8819	2438.6346	0.78
SOILS:			
FINE TEXTURE	102063.3577	252203.6600	80.28
MEDIUM TEXTURE	9228.0635	22803.0064	7.26
MEDIUM-FINE TEXTURE	15842.6988	39148.1009	12.46
SLOPE:			
0-2	36206.6629	89468.4743	28.48
10-20	11070.5396	27355.8568	8.71
20-9999	13256.2314	32756.8107	10.43
2-5	49147.1244	121445.0018	38.66
5-10	17453.5617	43128.6237	13.73

Farming land uses

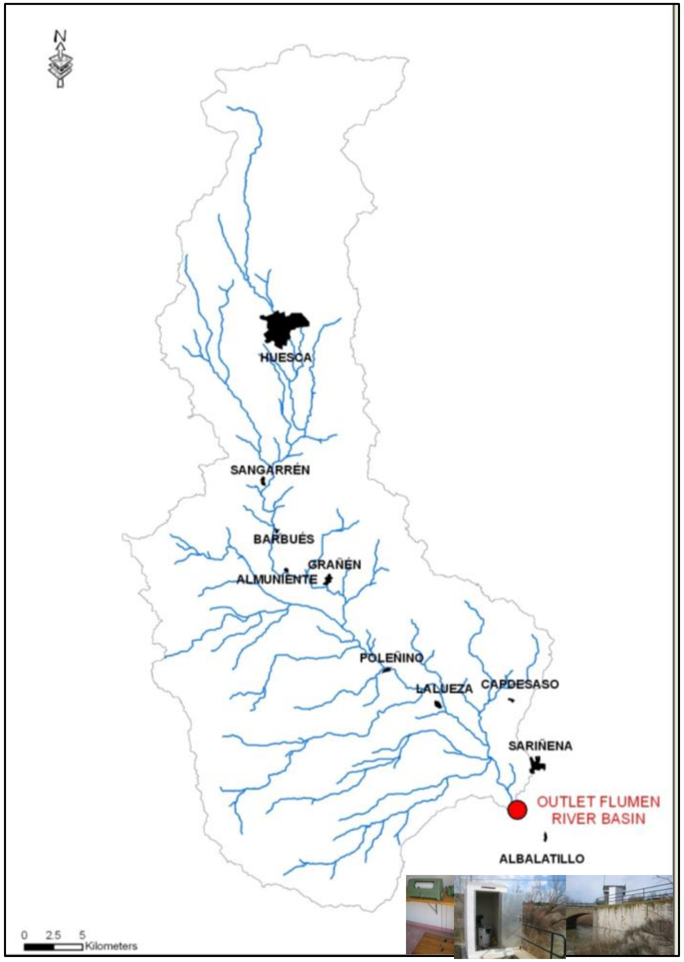
(-fertilizer use-)

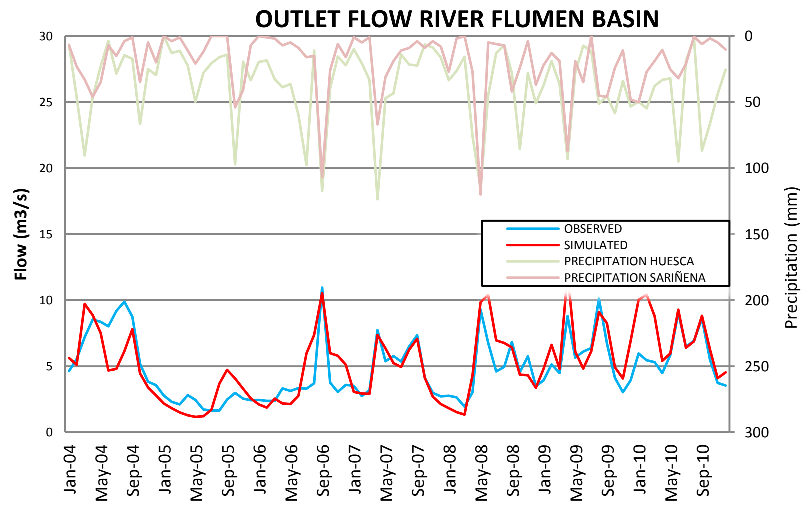
Crop	Irrigation (m3/Ha per year)	Fertilization (Kg NO^3/Ha per year)	
		Basic dressing	Top dressing
ALFALFA	9000-12000	500 (Urea)	500 (Urea)
CORN	8000-10000	1000 (NPK 8-15-15)	700 (Urea)
RICE	15000-16000	300 (Urea)	
BARLEY*	3000-4000	500 (NPK 8-15-15)	200 (Urea)
WHEAT	4000-5000	550 (NPK 8-15-15)	250 (Urea)

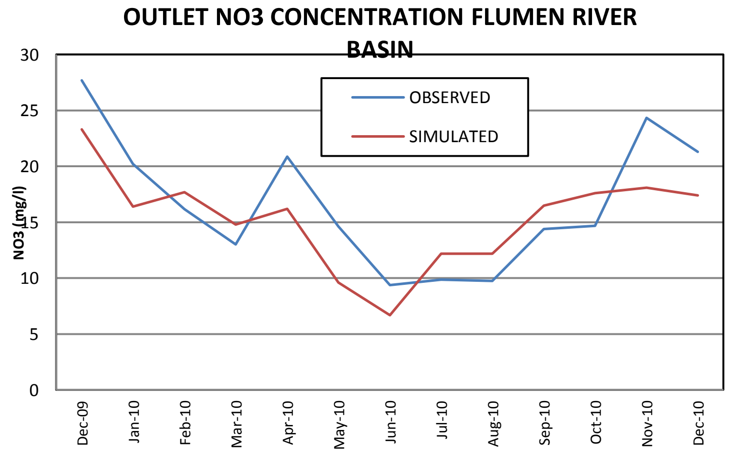
Every delineated subbasin (163) has a potential site for wetland creation/restoration at the subasin outlet

2. Site selection: Selecting subbasins with high nitrate discharge

Calibrating the SWAT model for water and NO_3 discharge at the watershed outlet







2. Site selection: Selecting subbasins with high nitrate discharge

- **The calibrated model is applied to all delineated subasins of the target area for obtaining water, suspended solids and nitrate discharges**
- SWAT provides quantity and quality flow data, sediment transport and pollution accumulation in river channel and soils for all the river sections of each subbasin.
- Depending on the time scale of the input information we can obtain daily, monthly or yearly results (monthly in this case).

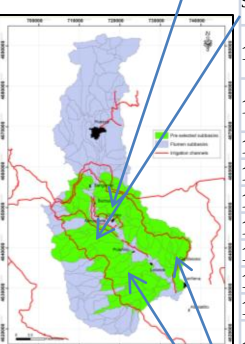
Subbasin

Area

Flow coming out of the subbasin

Sediment coming out of the subbasin

Nitrate coming out the subbasin
(annual discharge)



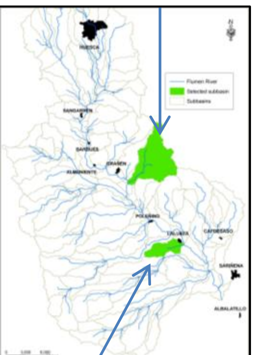
SUB	YEAR	MON	AREAkm2	FLOW_INcms	Q m^3/d	FLOW_OUTcms	SED_INtons	SED_OUTtons	ORGN_INkg	ORGN_OUTkg	ORGP_INkg	ORGP_OUTkg	NO3_INkg	NO3_OUTkg
1	2004	1	20.47	0.2111	64929,6	0.2385	2.164	2.164	8.749	8.139	1.505	1.255	8064	9106
2	2004	1	50.48	0.3702	3996	0.577	3.985	3.985	16.1	21.41	2.877	3.419	5412	8132
3	2004	1	6.129	0.06559	4329,504	0.07018	1.381	1.381	6.215	5.588	1.054	0.8495	3430	3676
4	2004	1	9.664	0.07554	4321,728	0.08524	0.8735	0.8735	3.18	3.092	0.5428	0.4725	3356	
5	2004	1	6.477	0.09237	2569,536	0.0986	0.5644	0.5644	2.783	2.512	0.4446	0.3594	2371	
6	2004	1	6.469	0.07425	10851,84	0.07739	1.082	1.082	5.037	4.383	0.851	0.6636	2417	2521
7	2004	1	73.08	0.8204	3513,888	0.8376	3.703	12.83	716.6	620.8	93.13	73.21	15630	15960
8	2004	1	19.3	0.1643	11914,56	0.1734	2.255	3.288	8.68	7.692	1.322	1.05	7761	8197
9	2004	1	12.54	0.04012	65957,76	0.0434	2.305E-07	2.305E-07	0.00002181	0	0.00006453	0	1024	1103
10	2004	1	7.946	0.02622	9504	0.03292	0.000000274	0.000000274	0.00001647	0	0.00004941	0	1104	1381
11	2004	1	20.86	0.07843	1994,976	0.07825	7.211E-07	0.173	7.852E-07	0	0.000002355	0	2654	2648
12	2004	1	16.27	0.1789	654,1344	0.2641	2.704	2.704	11.25	12.67	1.878	1.895	7139	10680
13	2004	1	102.4	1.042	2667,168	1.076	16.23	36.73	629.2	545.3	74.44	58.14	24430	25240
14	2004	1	11.39	0.03842	12329,28	0.05377	0.09556	0.983	0.7262	0.8954	0.1546	0.1723	312.6	437.3
15	2004	1	10	0.01954	2019,168	0.0228	0.05565	0.05565	0.2861	0.3149	0.08022	0.07981	2681	3127
16	2004	1	117.4	1.14	5961,6	1.145	37.79	39.43	546.6	459.9	58.42	44.28	26070	26190
17	2004	1	45.05	0.3664	2779,488	0.371	2.877	5.587	12.67	10.72	1.895	1.437	14720	14900
18	2004	1	31.02	0.2349	23544	0.2954	1.646	9.479	6.895	5.921	1.023	0.7876	6978	8765
19	2004	1	28.35	1.323	15232,32	1.334	2.235E-07	0	0.00005491	0	0.0001647	0	5592	5714
20	2004	1	9.035	0.02769	35519,	0.02779	1.379E-07	1.379E-07	0.00001656	0	0.00004967	0	807.8	810.7
21	2004	1	9.661	0.03575	23639,04	0.03554	1.532E-07	1.532E-07	0.00001636	0	0.00004909	0	1637	1627

2. Site selection: Selecting subbasins with high nitrate discharge

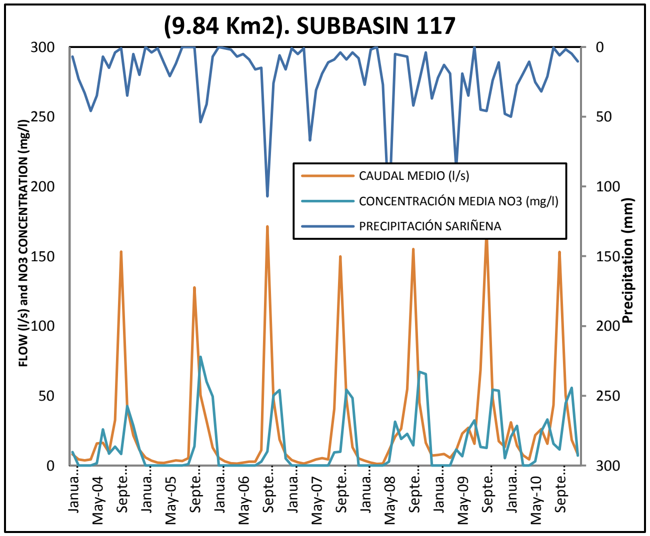
SWAT simulation of water and and nitrate discharges for every subbasin

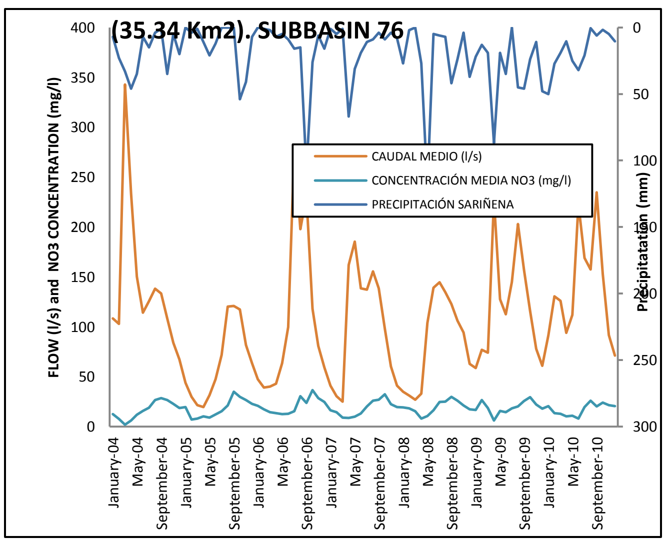
Two selected subbasins

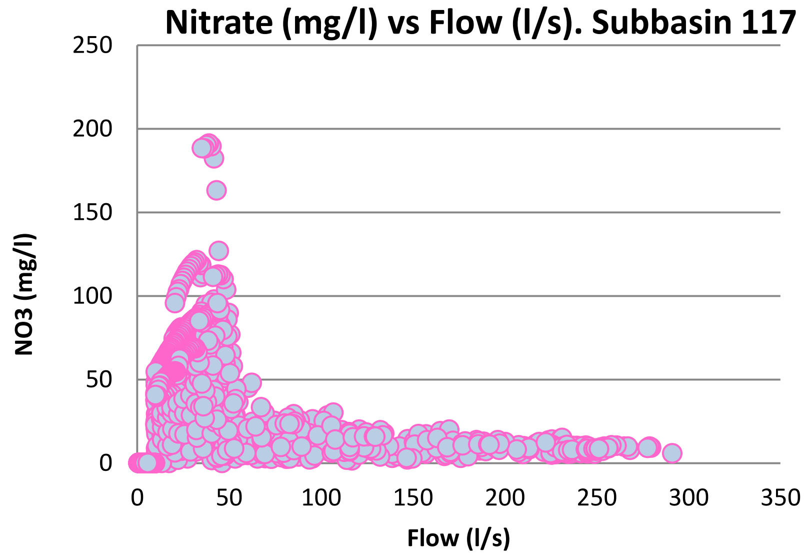
Subasin 76

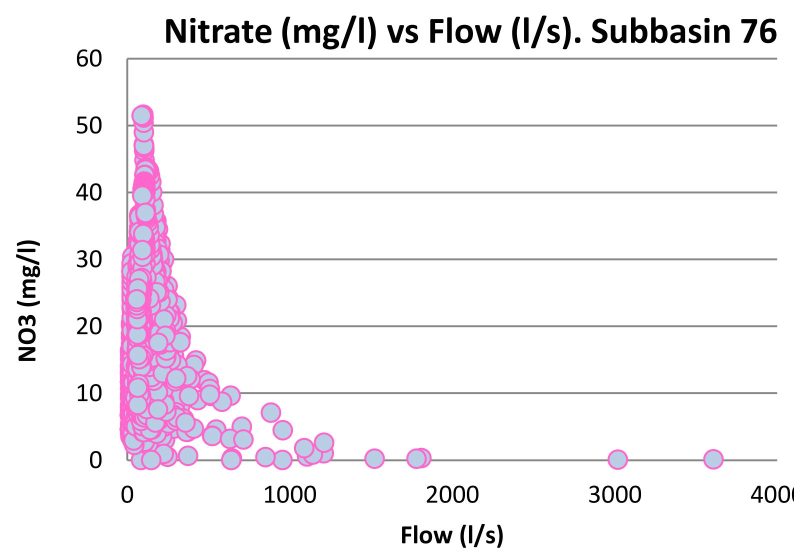


Subasin 117







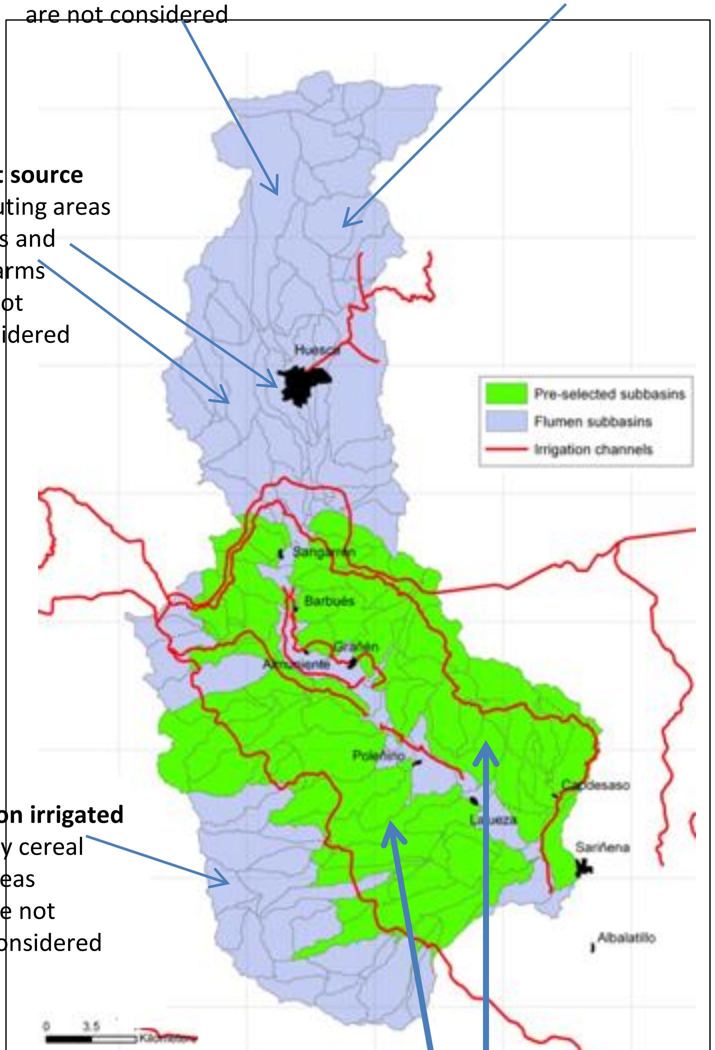


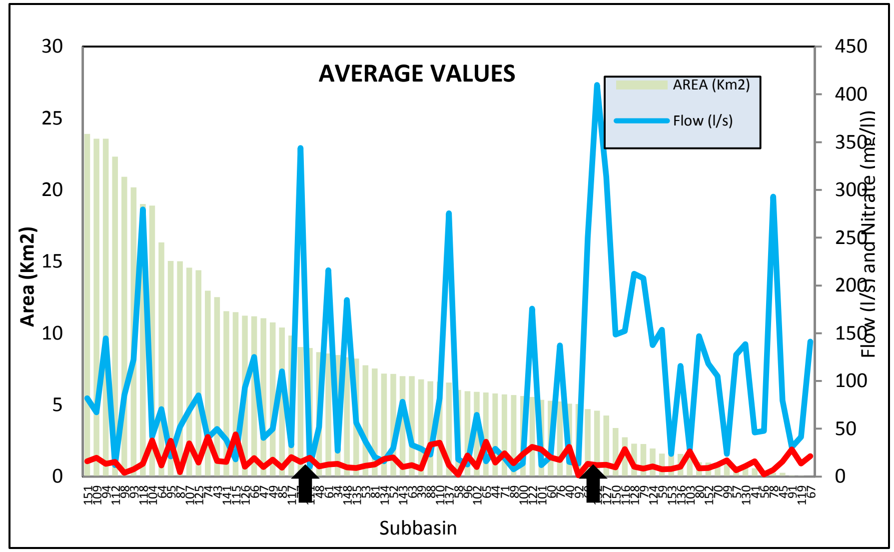
2. Site selection: Selecting subbasins with high nitrate discharge

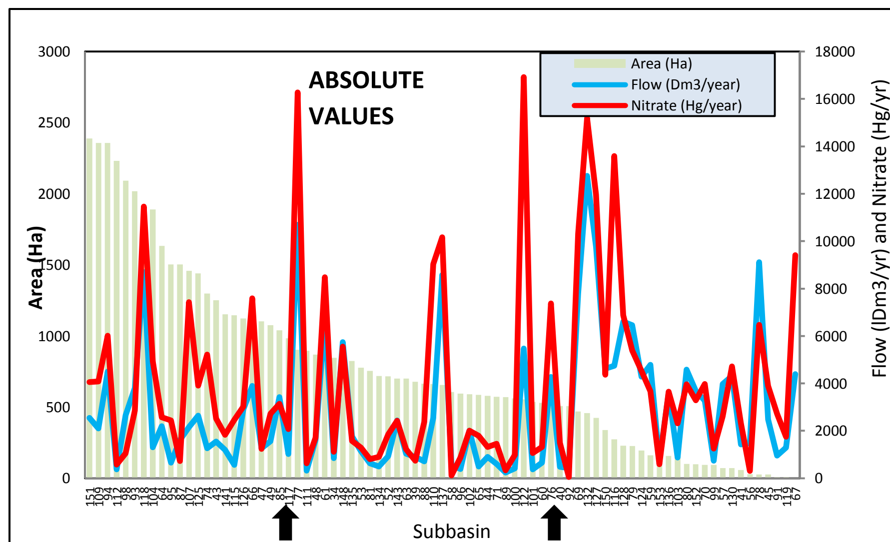
Natural wood & grassland areas and upstream reservoirs zones are not considered

Point source polluting areas -cities and pig farms are not considered here

Non irrigated dry cereal areas are not considered

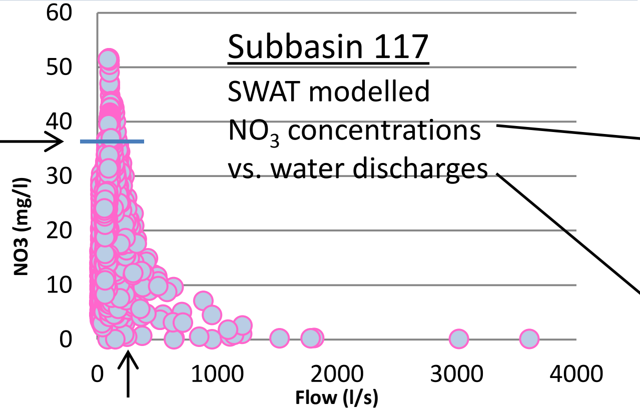






70 subbasins with high non-point agricultural NO_3 discharge are selected

3. Dimensioning wetland sites



The first order areal model to estimate the wetland area to achieve a target outlet **nitrate** concentration (Kadlec & Knight 1996)

$$A = (0{,}0365\ Q/k) \bullet \ln(C_i - C^* / C_o - C^*)$$

where

A-wetland area (ha)

C_i-inlet concentration (mg/L)

(minº concentration of the third quartile=maxº 75th percentile)

C_o-outlet concentration (mg/L) (target outlet concentration 2 mg/L)

Q- water flow rate (m^3/d) (third quartile of the range of N=3 concentrations selected)

K-first order areal rate constant (35 m/yr)

A-wetland area (ha)

SUB	SUB	YEAR	MO	Q m3/d	AREAkm2	FLOW_INcms	FLOW_OUTcms	SED_INtons	SED_OUTtons	ORGN_INkg	ORGN_OUTkg	ORGP_INkg	ORGP_OUTkg	NO3_INkg	NO3_OUTkg	N03_ in mg/L	Wetland Area (ha)
1	37	2004	1	64929,6	20.47	0.2111	0.2385	2.164	2.164	8.749	8.139	1.505	1.255	8064	9106	3,33621	92,5947
2	41	2004	1	3996	50.48	0.3702	0.577	3.985	3.985	16.1	21.41	2.877	3.419	5412	8132	15,9169	17,9168
3	43	2004	1	4329	6.129	0.06559	0.07018	1.381	1.381	6.215	5.588	1.054	0.8495	3430	3676	16,0175	19,4604
4	49	2004	1	4321,728	9.664	0.07554	0.08524	0.8735	0.8735	3.18	3.092	0.5428	0.4725	3356		17,2997	20,0129
5	52	2004	1	2569,536	6.477	0.09237	0.0986	0.5644	0.5644	2.783	2.512	0.4446	0.3594	2371		19,7048	12,4856
6	66	2004	1	10851,84	6.469	0.07425	0.07739	1.082	1.082	5.037	4.383	0.851	0.6636	2417	2521	19,2004	52,2382
7	74	2004	1	3513,888	73.08	0.8204	0.8376	3.703	12.83	716.6	620.8	93.13	73.21	15630	15960	40,9209	21,4941
8	76	2004	1	11914,56	19.3	0.1643	0.1734	2.255	3.288	8.68	7.692	1.322	1.05	7761	8197	17,0165	54,8271
9	82	2004	1	65957,7	12.54	0.04012	0.0434	2,31E-04	2,31E-04	0.00002181	0	0.00006453	0	1024	1103	10,9250	251,148
10	85	2004	1	9504	7.946	0.02622	0.03292	0.000000	0.0000002	0.000016	0	0.000049	0	1104	1381	9,05458	32,8958
11	88	2004	1	1994,976	20.86	0.07843	0.07825	7.2E-07	0.173	7,85E-04	0	0.000002	0	2654	2648	32,8688	11,4574
12	89	2004	1	654,1344	16.27	0.1789	0.2641	2.704	2.704	11.25	12.67	1.878	1.895	7139	10680	13,8931	2,77470
13	91	2004	1	2667,168	102.4	1.042	1.076	16.23	36.73	629.2	545.3	74.44	58.14	24430	25240	27,9725	14,5798
14	94	2004	1	12329,28	11.39	0.03842	0.05377	0.09556	0.983	0.7262	0.8954	0.1546	0.1723	312.6	437.3	13,1952	51,1598
15	99	2004	1	2019,168	10	0.01954	0.0228	0.05565	0.05565	0.2861	0.3149	0.08022	0.07981	2681	3127	16,8508	9,25675
16	107	2004	1	5961,6	117.4	1.14	1.145	37.79	39.43	546.6	459.9	58.42	44.28	26070	26190	34,0967	34,6123
17	117	2004	1	2779,488	45.05	0.3664	0.371	2.877	5.587	12.67	10.72	1.895	1.437	14720	14900	20,0731	13,5957
18	118	2004	1	23544	31.02	0.2349	0.2954	1.646	9.479	6.895	5.921	1.023	0.7876	6978	8765	13,0015	97,0696
19	122	2004	1	15232,32	28.35	1.323	1.334	2.2E-07	0	0.000054	0	0.000164	0	5592	5714	30,5547	85,5764
20	132	2004	1	35519,	9.035	0.02769	0.02779	1,38E-04	1,38E-04	0.000016	0	0.000049	0	807.8	810.7	11,7586	139,999
21	137	2004	1	23639,04	9.661	0.03575	0.03554	1.5E-07	1,53E-04	0.000016	0	0.000049	0	1637	1627	11,7055	92,9797

4. Accomplishing social and economic constraints

Select the next subbasin/ wetland

-Set the subbasins in order of decreasing estimated wetland area and proceed one after the other following this order

Select the next subbasin/wetland

-Social constraints: There is a (public-free) land area available at the subbasin

No

Yes

-Economic constraints: There is funding available for a simple extensive surface flow wetland creation/restoration

No

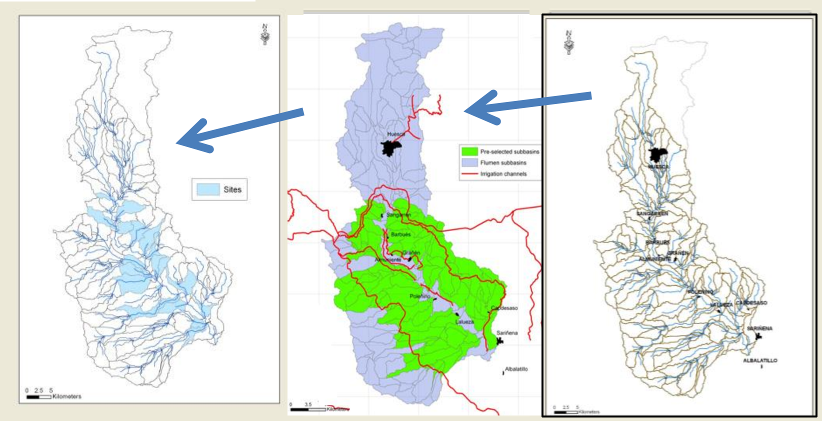
Yes

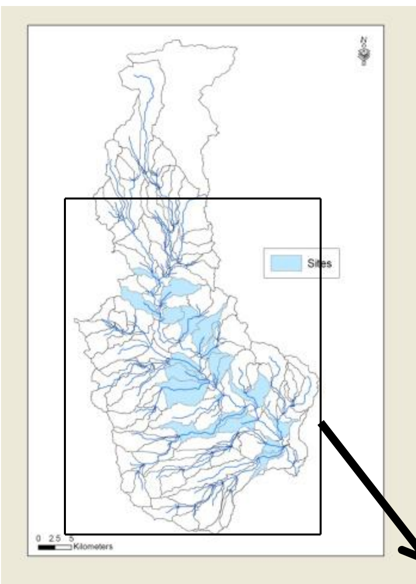
Other constraints

20 wetlands (subbasins-sites) are affordable to be restored/created with this project

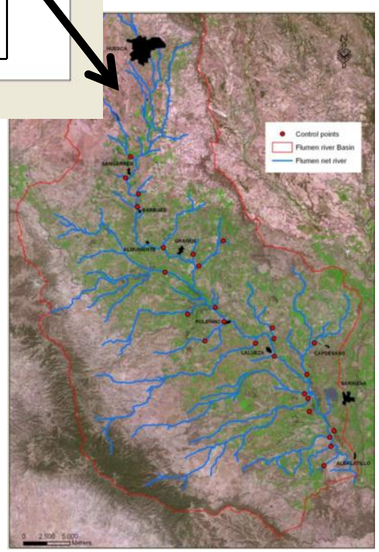
5. (Detailed) **Design restored/created wetlands**

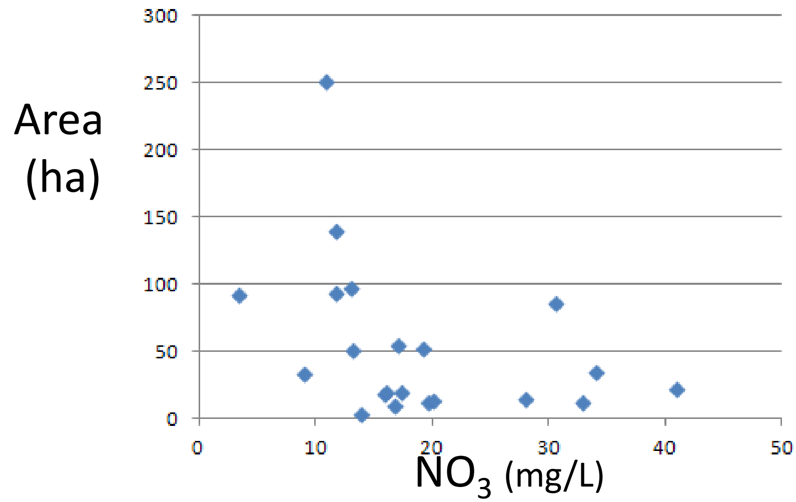
20 wetland sites of 70 selected of 163 potential subbasins

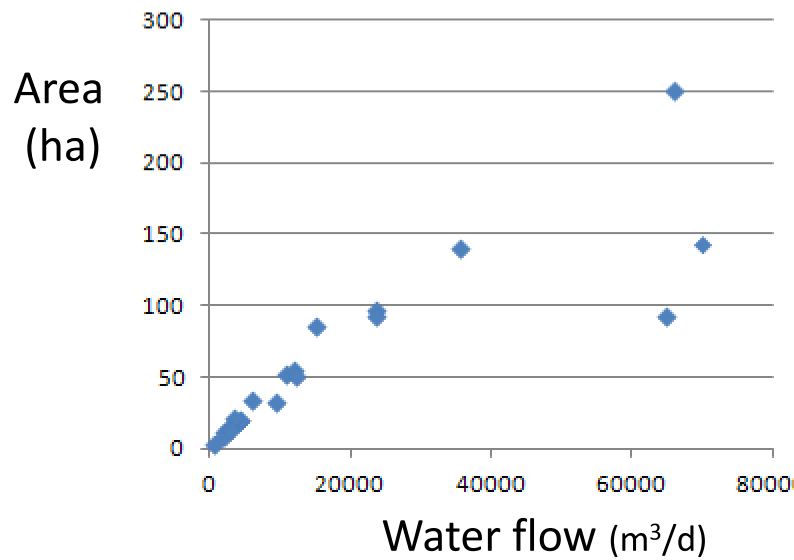




20 wetland sites selected and affordable with this project







Before (2011)

Before (2011)

Sub-basin 76 (35 km^2)

Wetland: 11914 m^3/d; 17 mg/L; 54 ha

After (2012)

9th INTECOL INTERNATIONAL WETLANDS CONFERENCE
WETLANDS IN A COMPLEX WORLD
SWS
JUNE 3-8, 2012
ORLANDO FLORIDA, USA

Before (2011)

Before (2011(

Sub-basin 117 (9,87 km^2)

Wetland:2779 m^3/d; 20 mg/L; 13,5 ha

After (2012)