Identification of water-related ecosystem services providing units using SWAT model

An input for the design of PES schemes in the Andes

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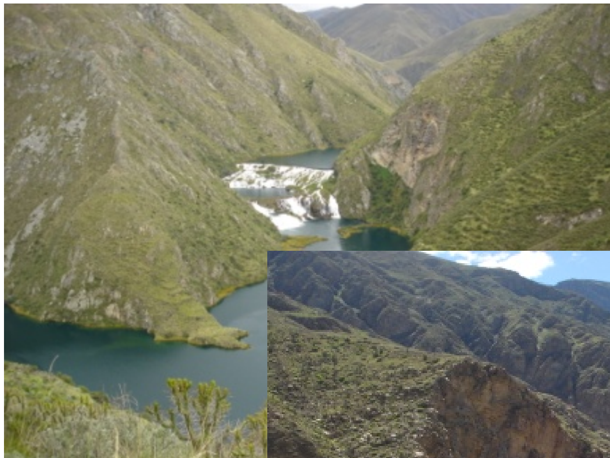
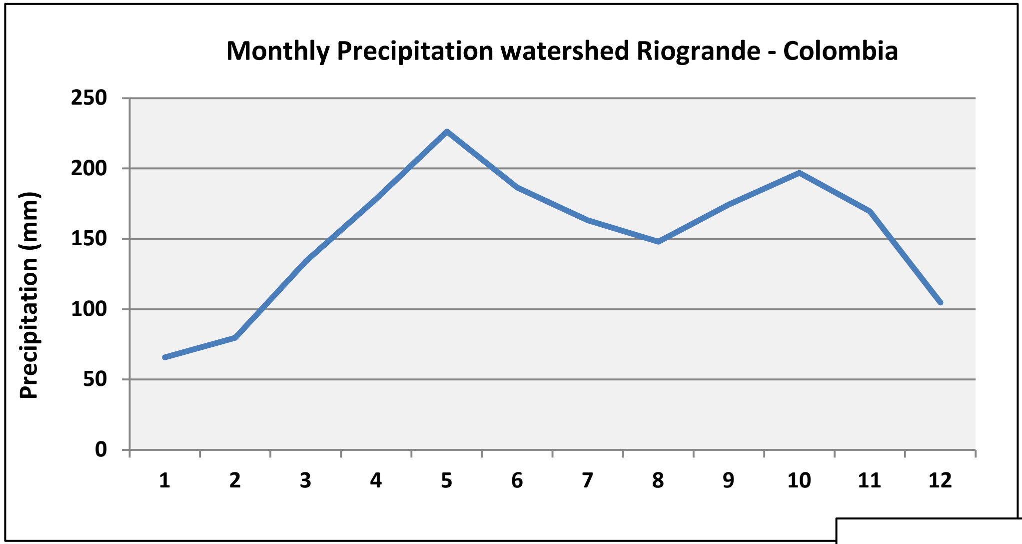
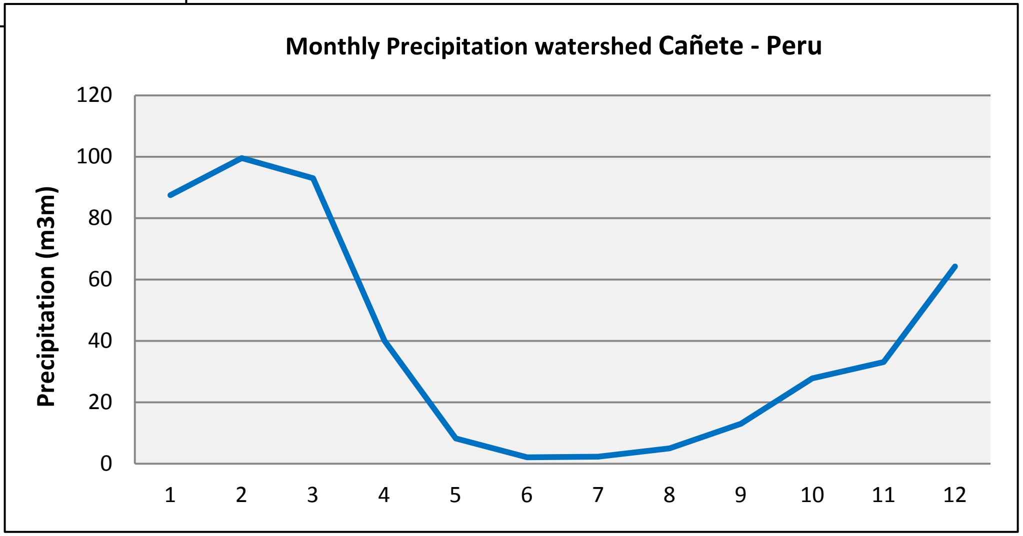
Andean watershed characteristics



The Andean basins are characterized by significant landscape diversity, resulting from a wide variety of soil types, land uses and angles of slopes which, in turn, combined with changes in climate along the altitudinal gradient, create different hydrological responses within the same basin.

Watershed characteristics





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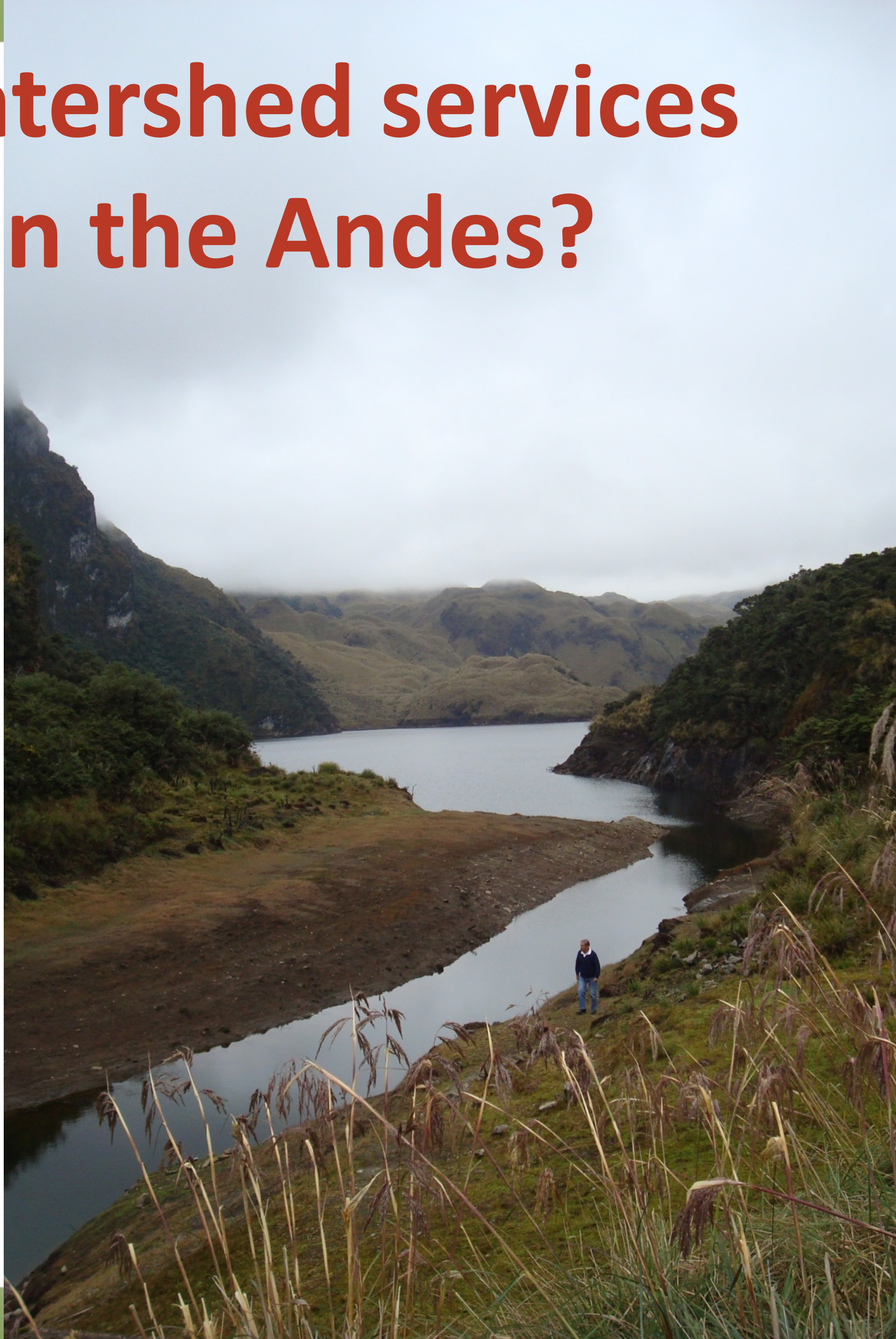
What kind of watershed services are relevant in the Andes?

- Total water yield
- Improvement/ maintenance of hydrological regime (base flows and peak flows)
- Retention of sediments



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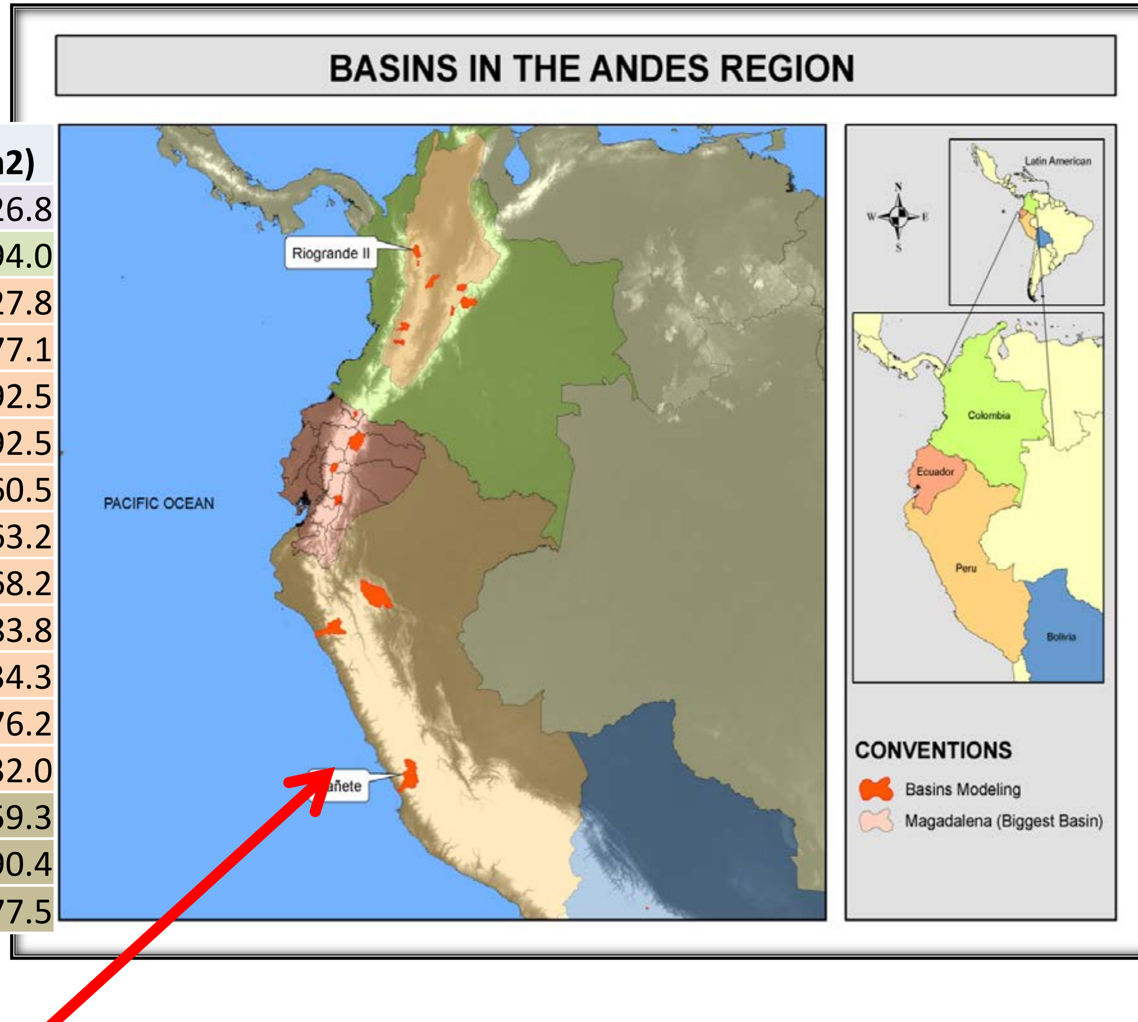
Main research needs

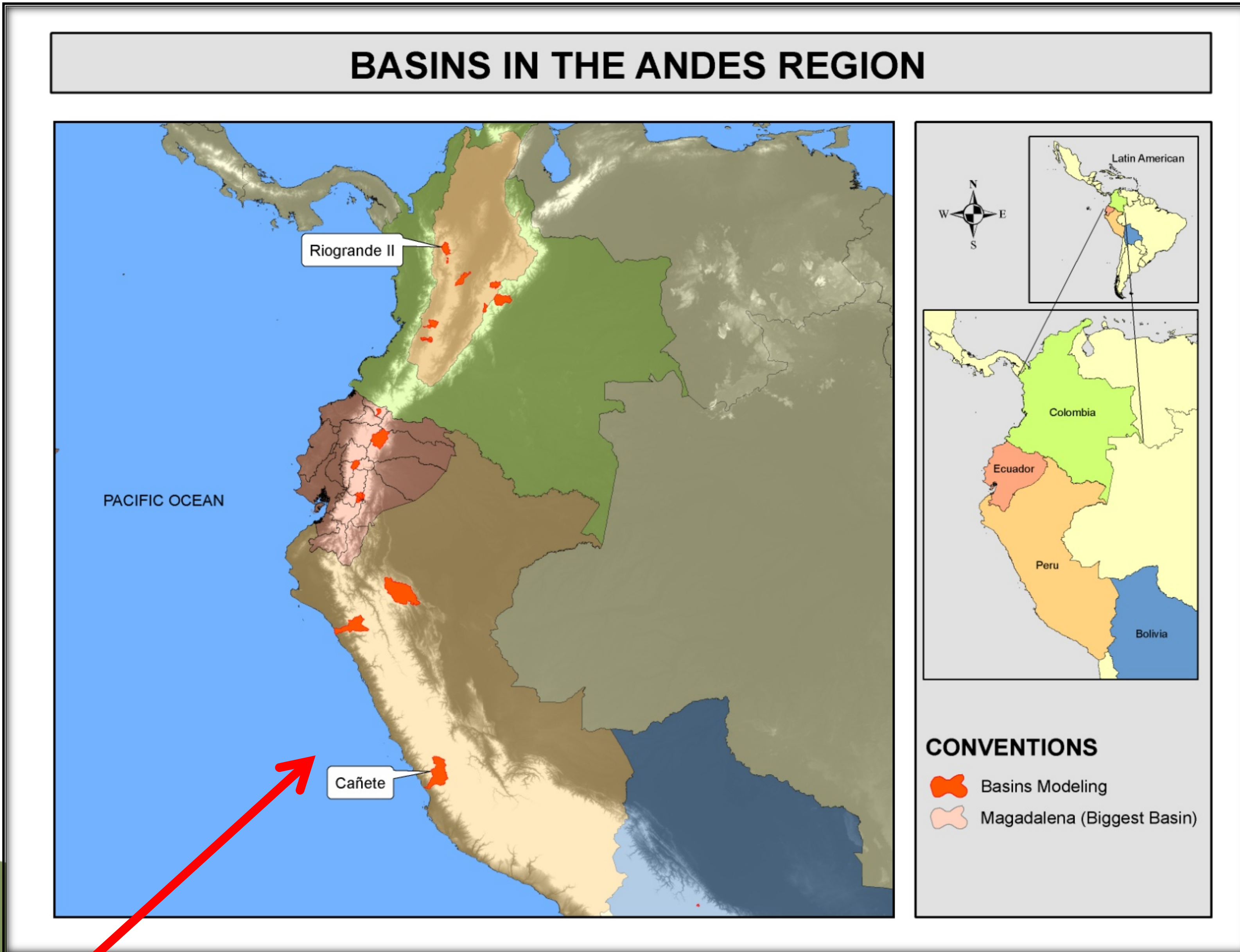
- Identification of priority areas for the provision of WES
- Impact of land use changes and management practices promoted by Payment for Ecosystem Services Schemes
- Economic benefits and costs of improving/maintaining the water-related ecosystem services
- Impact of climate change on water-related ecosystem services

Study sites

COUNTRY	WATERSHED	AREA (Km2)
Ecuador	Quijos	2426.8
Peru	Cañete	5794.0
Colombia	Piedras Blancas	27.8
	La Fe	77.1
	Guabas	192.5
	Desbaratado	192.5
	Tunjuelo	360.5
	Fraile	363.2
	Tulua	768.2
	Fuquene	783.8
	Riogrande II	1034.3
	Guavio	1476.2
	Magdalena	259232.0
Mexico	Valles	3859.3
	Axtla	890.4
	Necaxa	877.5



Study sites



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Peruvian case study, Canete River watershed – **Current situation**

Extension: 5794 km2

Water and land uses

Upper basin (4000-5800)

Extensive degrading grazing, subsistence agriculture

Middle basin (350 – 4000)

Hydropower company
Shrimp growers

Lower basin (0-350)

Urban dwellers
Water inefficient commercial agriculture
Tourists (rafting)

Desired situation

Upper basin
(4000-5800)

Investment in land use alternatives (high water yields, high economic performance)

Middle basin
(350 – 4000)

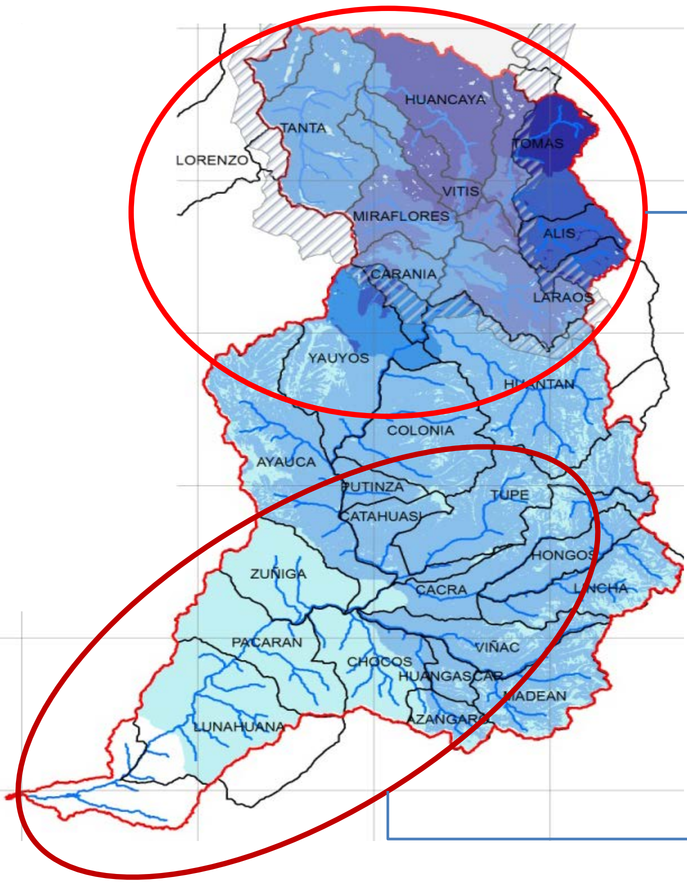
Ecosystem conservation

Transfer part of their benefits

Lower basin
(0-350)

Watershed's socioeconomic asymmetries might be balanced by this benefit-sharing mechanism

Putting the pieces for designing a PES together



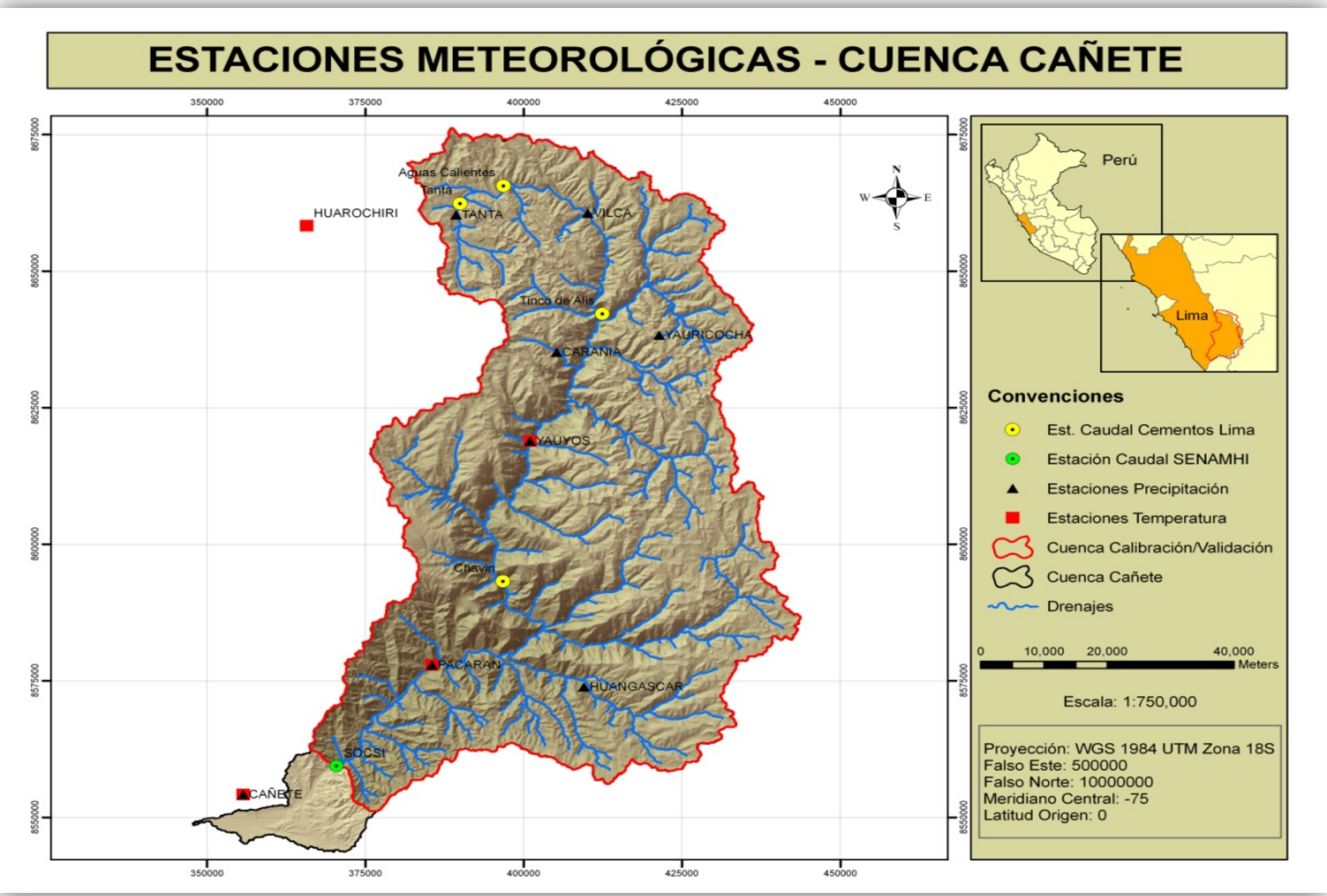
Where payments should be targeted to?
Identification of service providing areas using hydrological modeling

How payments should be used?
Ex-ante assessment of likely eco-efficient land use alternatives; ecosystem conservation measures and social development projects.

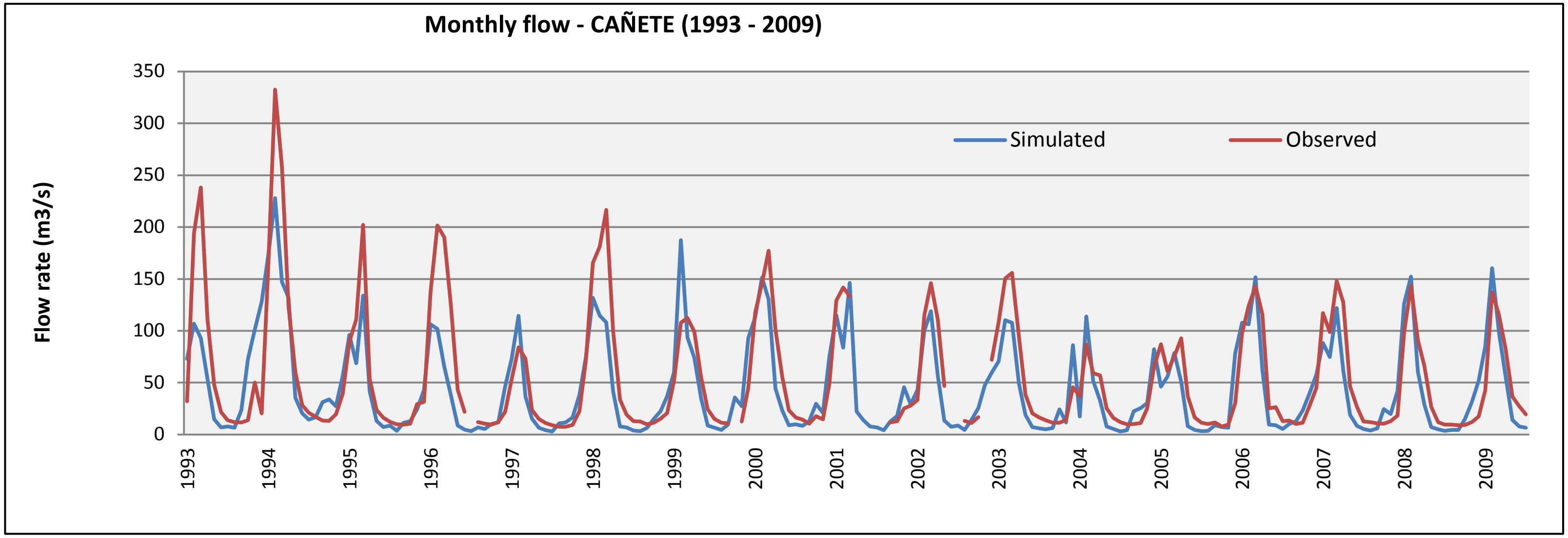
What should be the payments amount to be made by ES beneficiaries?
Estimation of economic value of watershed services for different ES users:

Valuation of water-related ecosystem services*		
Type of downstream water user	**Value of the WES**	**Current price of water**
Irrigated Agriculture (US$ m³)	0.29512	0.023664
Tourism (US$/ind)	15.75	n.a.
Urban users		
Domestic (US$ mon^{-1})	3.5	3.1 - 15
Commercial (US$ mon^{-1})	5	6.3 - 44.4

Hydrological and metereological data

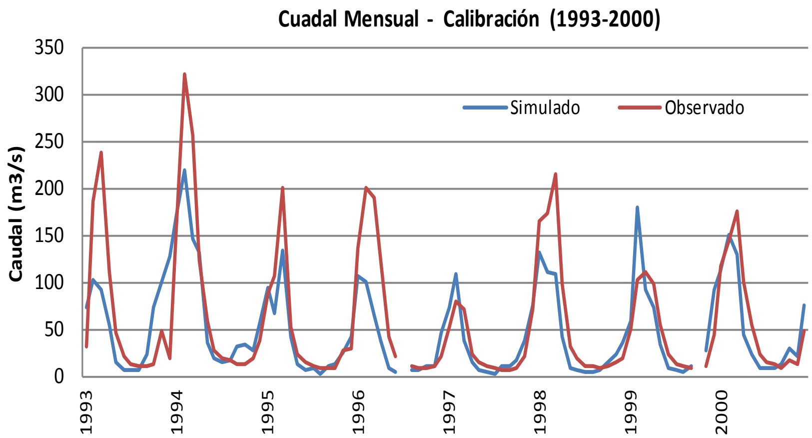


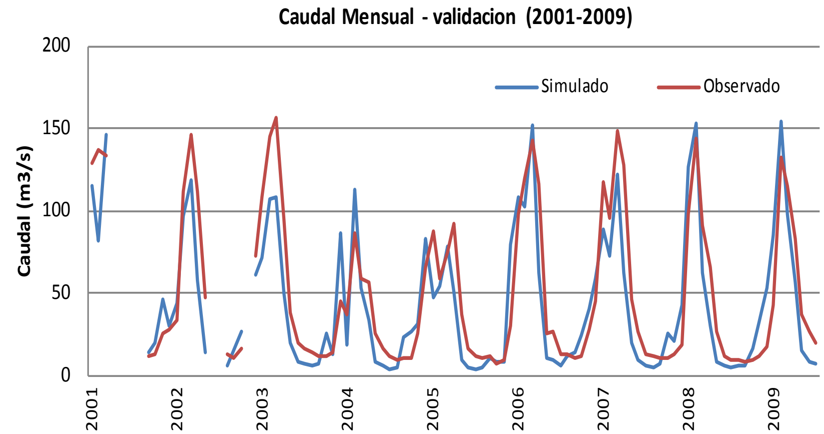
Hydrological modeling results

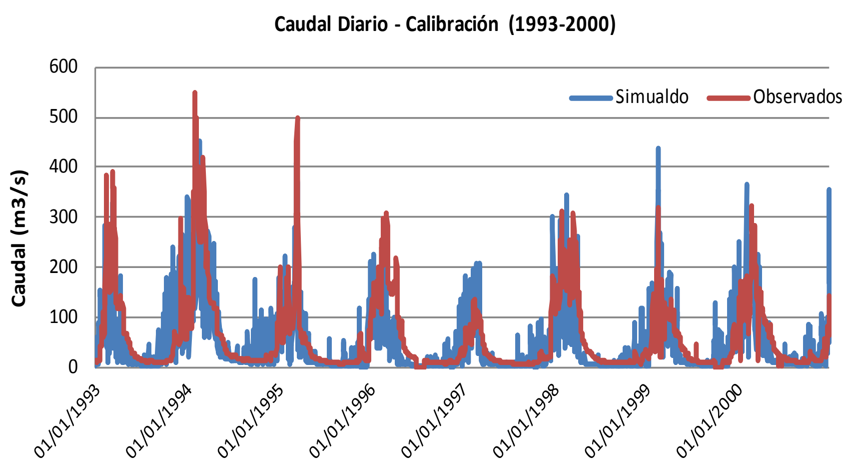


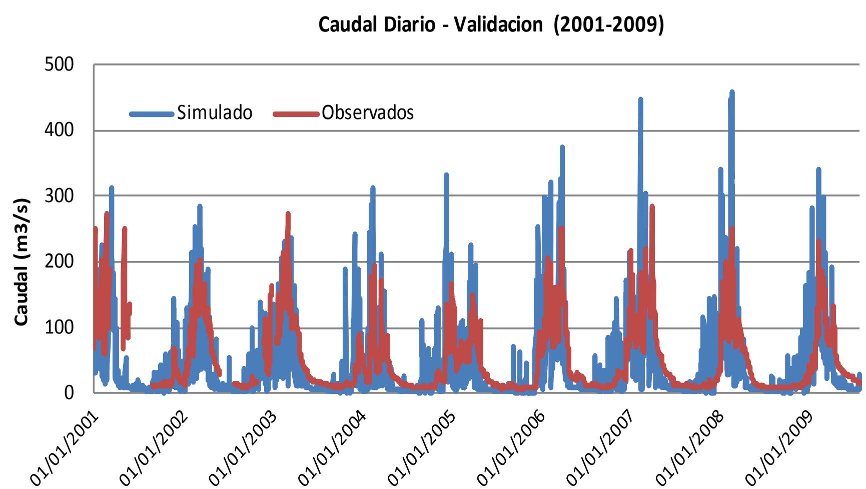
Statistics	Basin Cañete (5794 km2)	
	Simulated monthly flow (m3/s)	Observed monthly Flow (m3/s)
$\overline{Q}_{obs}$	44.1	55.9
NS		0.65
r		0.83

$\overline{Q}_{obs}$ = Average flow
NS = Coeficiente de Nash-Sutcliffe
R = Correlation coefficient









Statistics	Daily Flow		Monthly Flow	
	Calibrated	Simulated	Calibrated	Simulated
NS	0.39	0.15	0.59	0.73
r	0.66	0.64	0.78	0.88

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Calibration: Parameters adjusted

PARAMETRO	NOMBRE VARIABLE EN SWAT	RANGO	VALOR DEFULT	VALOR OBTENIDO CALIBRACION MANUAL
Baseflow alpha factor [days]	ALPHA_BF.gw	0 - 1	0.048	0.01
Groundwater delay [days]	GW_DELAY.gw	0 - 500	31	25
Groundwater "revap" coefficient	GW_REVAP.gw	0.02 - 0.2	0.02	0.02
Threshold water depth in the shallow aquifer for flow [mm]	GWQMN.gw	0 - 5000	0	1
Threshold water depth in the shallow aquifer for "revap"	REVAPMN.gw	0 - 500	1	50
Soil evaporation compensation factor	ESCO.hru	0.01 - 1	0.95	1
Plant uptake compensation factor	EPCO.hru	0.01 - 1	1	1
Maximum canopy storage [mm]	CANMX.hru	0 - 100	0	0
Average slope steepness [m/m]	SLOPE.hru	0 - 0.6	Varia por HRU	Varia por HRU
Average slope length [m]	SLSUBBSN.hru	10 – 150	Varia por HRU	Varia por HRU
Snow pack temperature lag factor	TIMP.bsn	0.01 - 1	1	0.5
Melt factor for snow on June 21 [mm H2O/ºC-day]	SMFMX.bsn	0 - 10	4.5	3.5
Melt factor for snow on December 21 [mm H2O/ºC-day]	SMFMN.bsn	0 - 10	4.5	1
Snowfall temperature [ºC]	SFTMP.bsn	± 5	1	1
Snow melt base temperature [ºC]	SMTMP.bsn	± 5	0.5	2
Surface runoff lag time [days]	SURLAG.bsn	1 - 24	4	8
Available water capacity [mm H20/mm soil]	SOL_AWC.sol	0 - 1	Varia por suelo	Varia por Suelo
Saturated hydraulic conductivity [mm/hr]	SOL_K.sol	0 - 2000	Varia por suelo	Varia por Suelo
Moist soil albedo	SOL_ALB.sol	0 - 0.25	Varia por suelo	Varia por Suelo
Channel effective hydraulic conductivity [mm/hr]	CH_K2.rte	0 - 150	0	0
Manning's nvalue for main channel	CH_N2.rte	0 - 0.3	Varia por HRU	Varia por HRU
Initial SCS CN II value	CN2.mgt	20 - 90	Varia por HRU	Varia por HRU
Temperature lapse rate [°C/km]	TLAPS.sub	-5 - 50	0	-6.5

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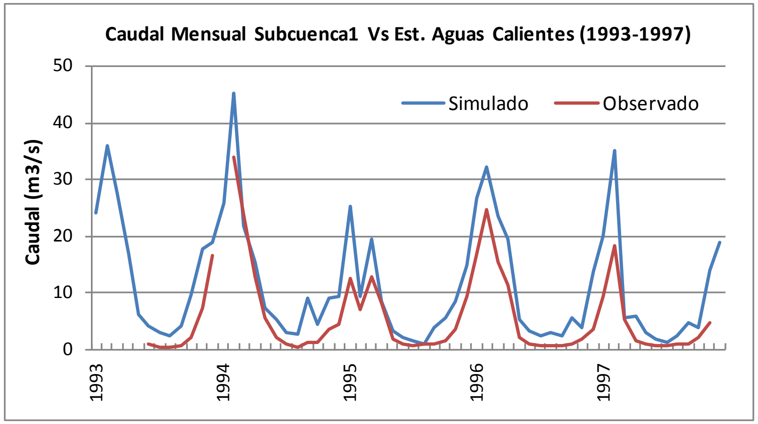

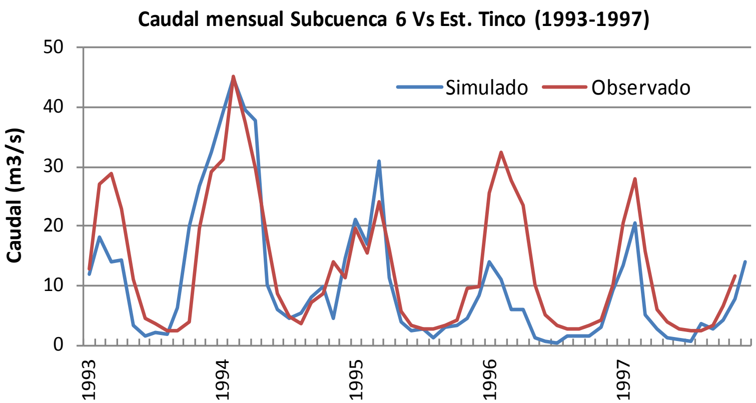

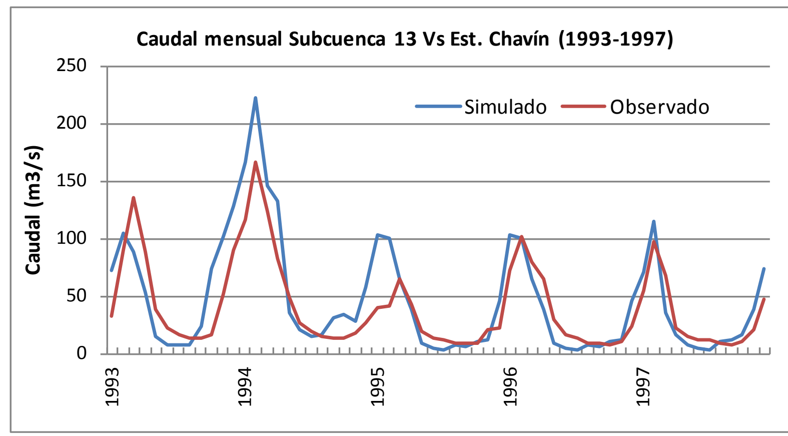

Stadistica	Caudal Mensual (1993-1997)			
	Aguas Calientes	Tinco	Chavín	Regantes
NS	0.01	0.80	0.66	0.62
r	0.97	0.95	0.93	0.81

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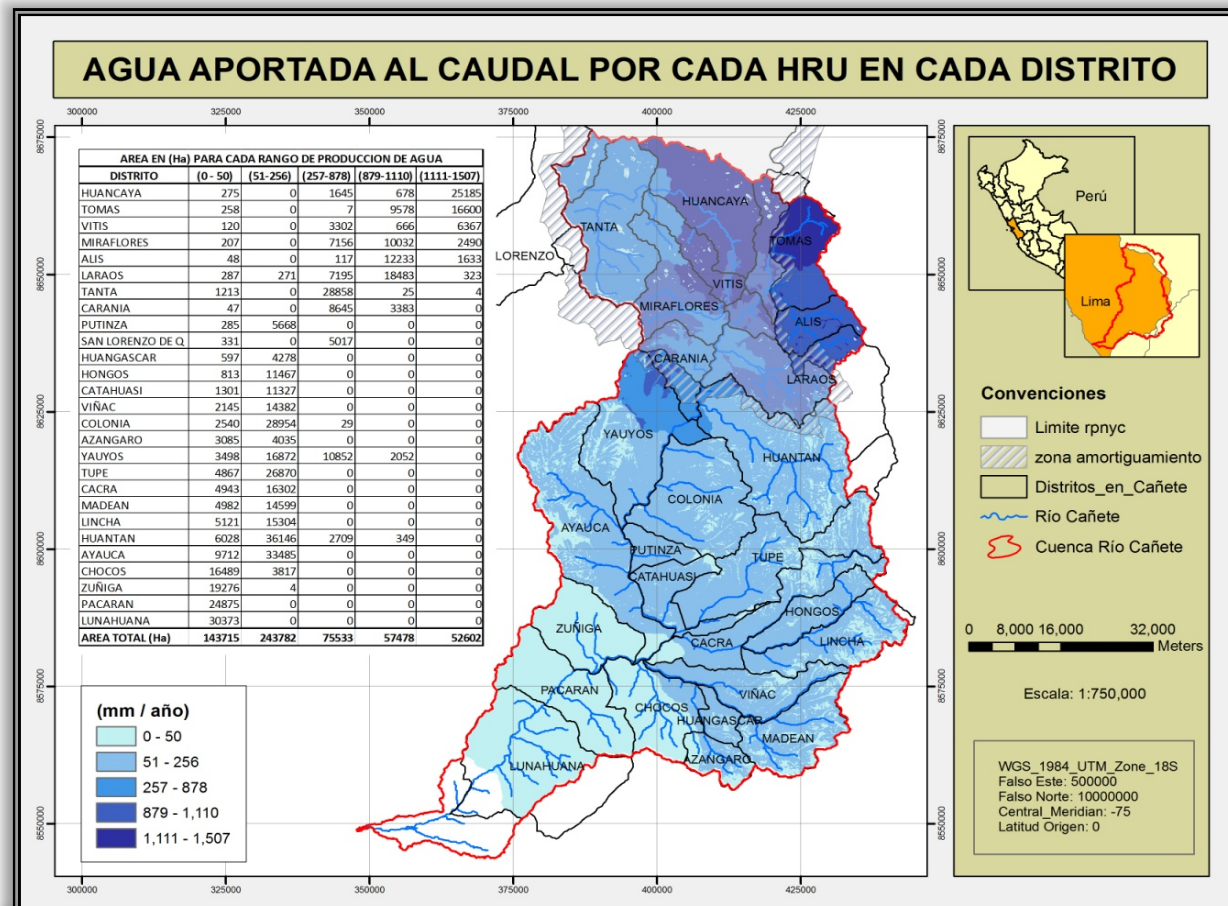
Prioritization of HRU



AREA EN (Ha) PARA CADA RANGO DE PRODUCCION DE AGUA

DISTRITO	(0 - 50)	(51-256)	(257-878)	(879-1110)	(1111-1507)
HUANCAYA	275	0	1645	678	25185
TOMAS	258	0	7	9578	16600
VITIS	120	0	3302	666	6367
MIRAFLORES	207	0	7156	10032	2490
ALIS	48	0	117	12233	1633
LARAOS	287	271	7195	18483	323
TANTA	1213	0	28858	25	4
CARANIA	47	0	8645	3383	0
PUTINZA	285	5668	0	0	0
SAN LORENZO DE Q	331	0	5017	0	0
HUANGASCAR	597	4278	0	0	0
HONGOS	813	11467	0	0	0
CATAHUASI	1301	11327	0	0	0
VIÑAC	2145	14382	0	0	0
COLONIA	2540	28954	29	0	0
AZANGARO	3085	4035	0	0	0
YAUYOS	3498	16872	10852	2052	0
TUPE	4867	26870	0	0	0
CACRA	4943	16302	0	0	0
MADEAN	4982	14599	0	0	0
LINCHA	5121	15304	0	0	0
HUANTAN	6028	36146	2709	349	0
AYAUCA	9712	33485	0	0	0
CHOCOS	16489	3817	0	0	0
ZUÑIGA	19276	4	0	0	0
PACARAN	24875	0	0	0	0
LUNAHUANA	30373	0	0	0	0
AREA TOTAL (Ha)	**143715**	**243782**	**75533**	**57478**	**52602**

Next Steps

- Part of design of a PES scheme in Peru
- Design of an endowment fund is underway
- Targeting intervention and investment
- Ex-ante analysis of land use/conservation alternatives

Table 7
Prioritized hydrologic response units in the Mishquiyacu watershed (Peru) under the "business as usual" scenario.

HRU code #	Area size (ha)	Sediments over 7 years		%Contribution to total sediments produced in micro watershed
		(t ha^{-1})	(t)	
18	9.1	903	8217	16.5
02	5.8	500	2902	5.8
06	0.9	396	356	0.7
09	0.9	323	291	0.6
12	1.2	261	313	0.6
22	2.2	374	823	1.7
03	1.9	292	555	1.1
19	1.1	239	263	0.5
Total	23.1	3289	13720	27.6

Table 8
Integrating environmental and socioeconomic assessments of land-use scenarios in Mishciyacu watershed, Peru.

Indicator	Land use system			
	Traditional ("business as usual")[a]	Traditional[a] with live barriers	Shade-grown coffee planted on pastures	Forest planted on pastures
NPV (US$), 10 year horizon[b]	12,949	9,668	32,057	967
Marginal income[c]	n.a.	−3,281	19,108	−11,982
Initial cash investment (US$)	9	13	176	470
Sediments (t ha^{-1})	21,247	10,623	11,766	10,620
Marginal sediments (%)[c]	n.a.	−50	−44	−50
Water production (m^3)	2,707,711	2,707,711	2,395,627	2,334,858
Marginal change (%)[c]	n.a.	0	−11	−14
Use of work days	5			
Marginal change[c]	n			

n.a.—not applicable.
[a] Burning-maize-pastures land-use cycle.
[b] Includes labor cost. Discount rate = 15%. Co
[c] Vis-à-vis baseline of traditional slash and b

Table 9
Unit costs of reducing sediment yields under different land-use scenarios in Mishquiyacu watershed, Peru.

Parameter	Current scenario, with live barriers	Shade-grown coffee	Forest plantation
Cost of reducing one ton of sediments (US$/t)	0.36	1.16	1.10
Cost of reducing erosion on one hectare of land (US$/ha)	16.6	47.4	51

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Quintero et al. (2009)

How uncertain are these assessments? Are they reliable for designing PES schemes?

- "Essentially, *all models* are *wrong*, but *some* are *useful*" (Box, 1919)
- **How wrong do they have to be for not being useful?**
- Uncertainty analysis
- PES decisions are not taken based on absolute values of the result but in the result itself
- SWAT targets well the most important ES providing areas in relative terms
- Good performance of results regarding stream flows simulation. Useful for economic valuation analysis
- Very useful to provide arguments during the design and negotiation of PES schemes (where, why?)

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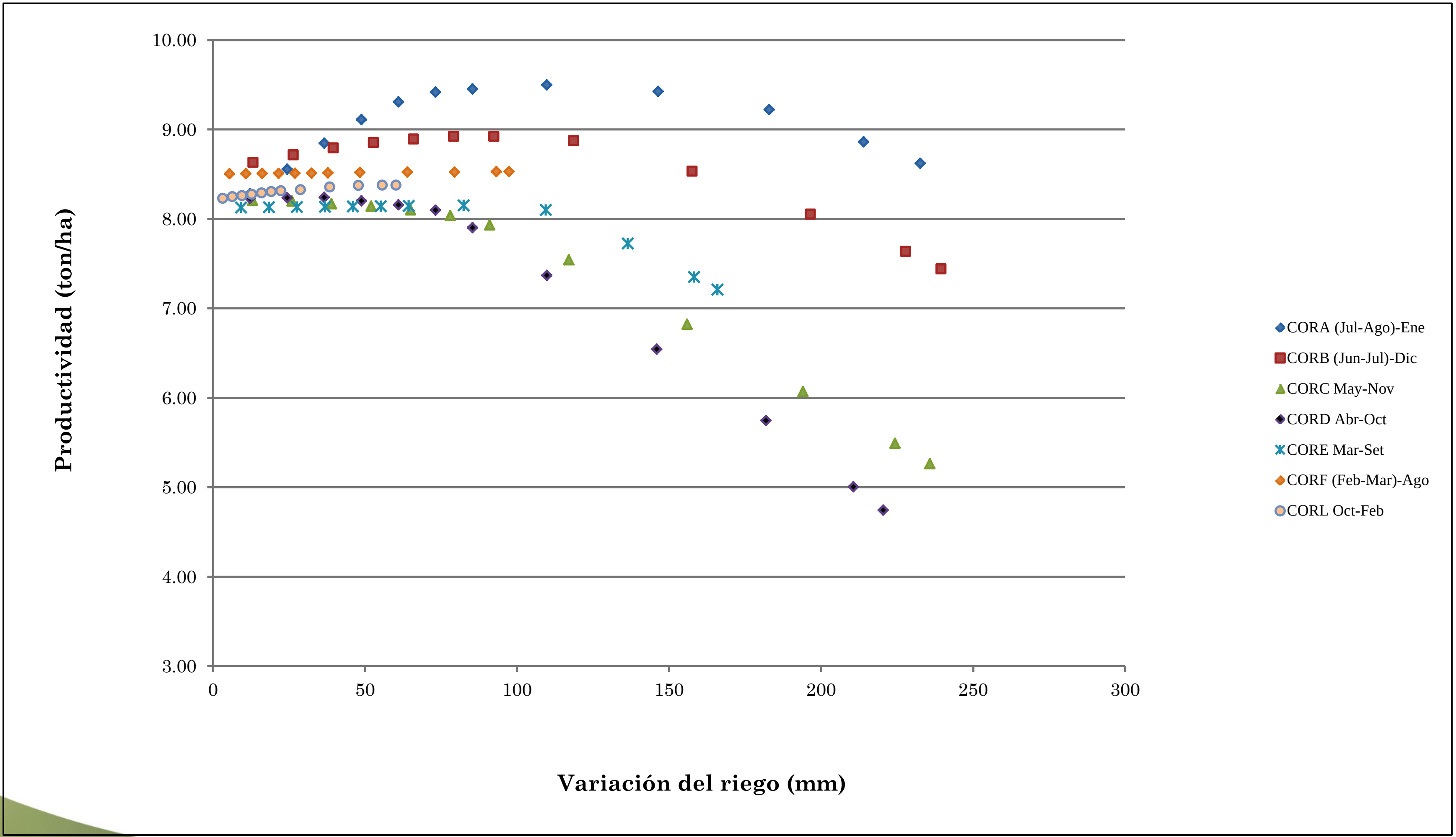
Agricultura:
Relación entre la productividad y el riego



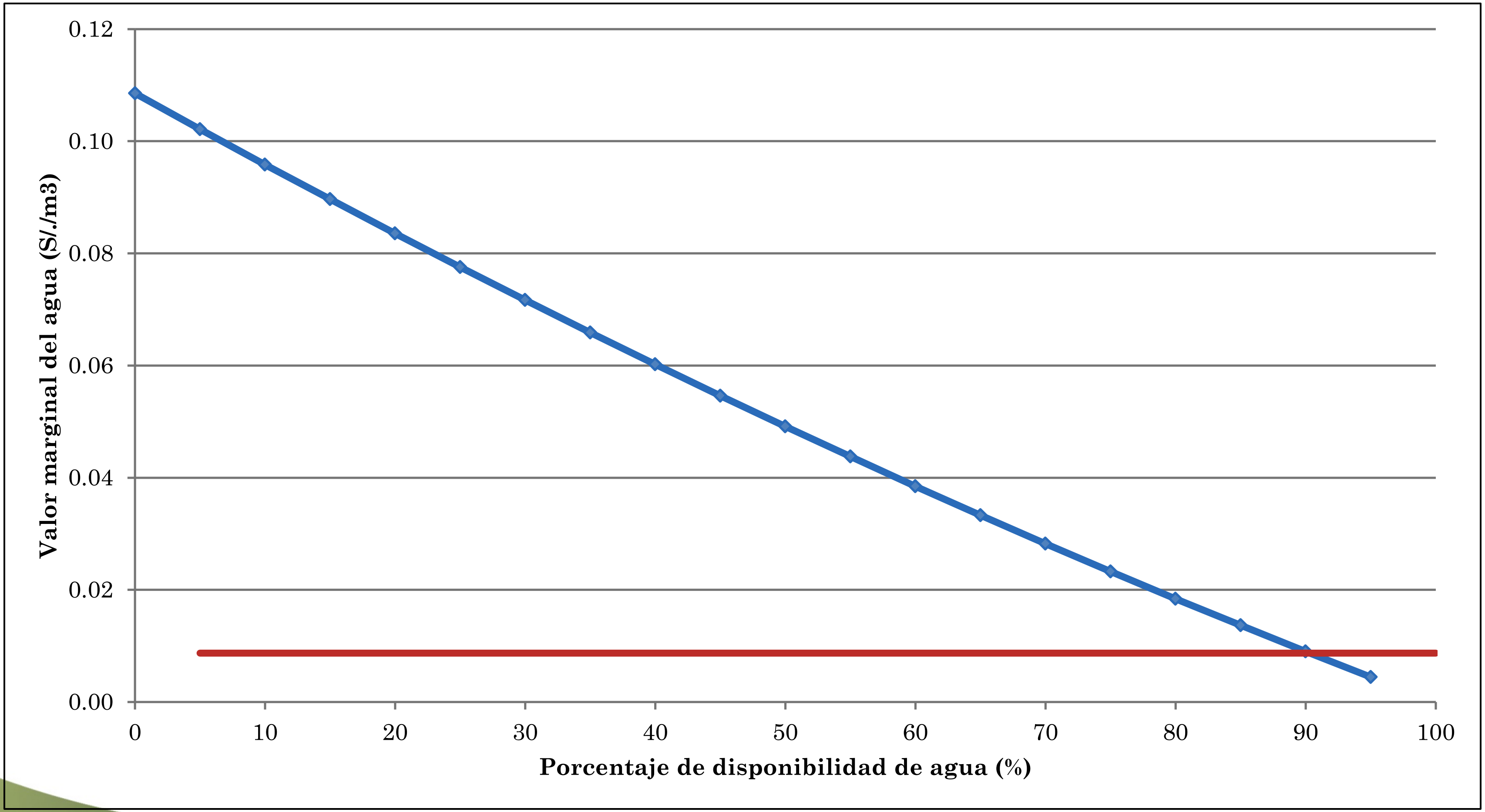
(Pareja, 2011)

Agricultura: Valor marginal del agua en el escenario menos favorable

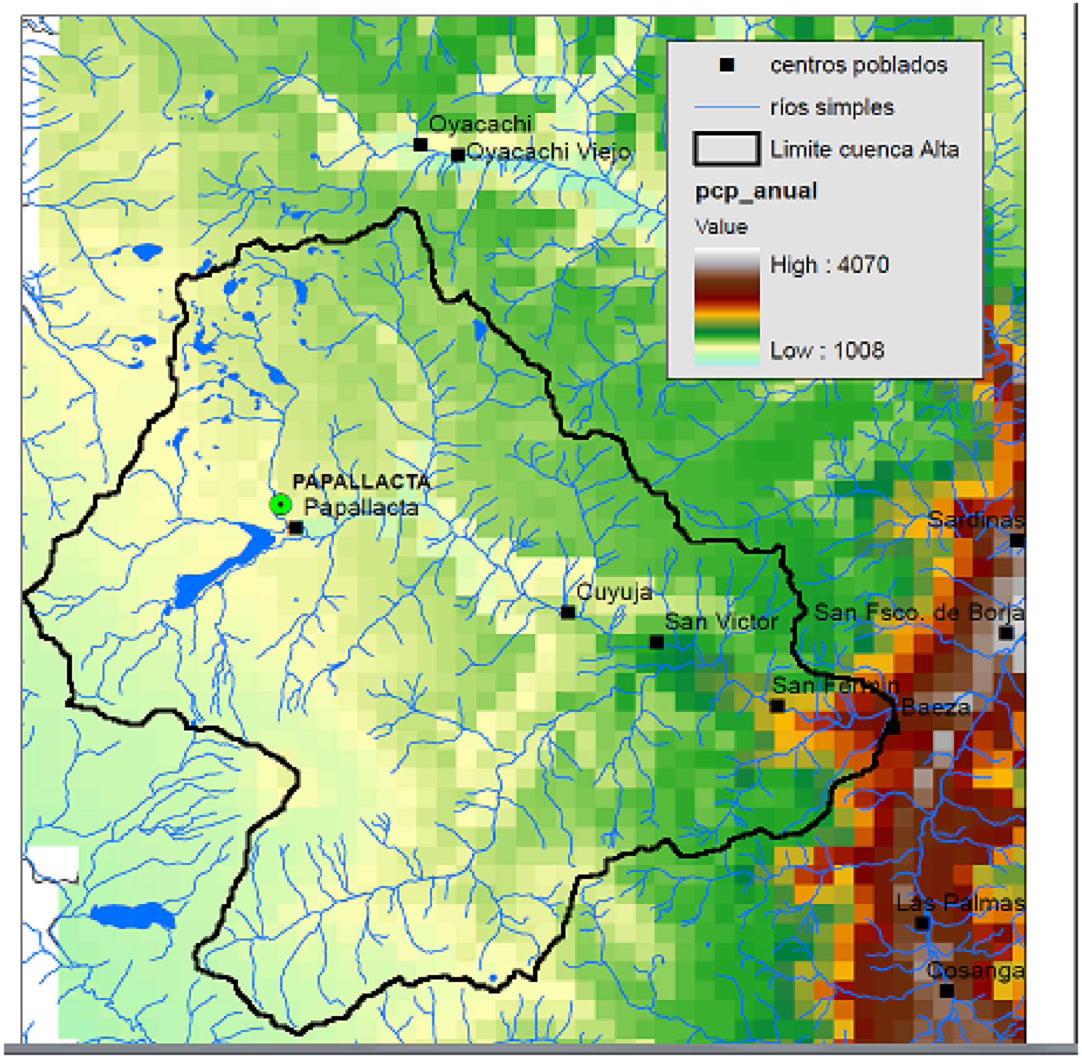
Fecha de cosecha	Variacion de la productividad (kg)	Precio de venta del maiz (S/. / kg)	Variación de la rentabilidad (S/.)	Agua aplicada (m3)	Valor marginal del agua ajustado (S/./m3)	Area cosechada por periodo (ha)	Valor marginal del agua ponderado (S/./m3)
ENE	546.42	0.75	409.38	6081.28	0.07	761.43	0.01
DIC	2331.64	0.83	1927.42	5940.17	0.32	575.29	0.03
NOV	3870.81	0.82	3184.91	5680.08	0.56	406.29	0.03
OCT	3662.38	0.82	3005.24	5737.26	0.52	369.14	0.03
SET	928.11	0.83	770.20	6223.03	0.12	487.14	0.01
AGO	41.08	0.81	33.17	6287.58	0.01	562.43	0.00
JUL	0.00	0.76	0.00	5501.43	0.00	664.14	0.00
JUN	0.00	0.76	0.00	7224.39	0.00	629.57	0.00
MAY	0.00	0.77	0.00	4935.22	0.00	534.00	0.00
ABRI	0.00	0.75	0.00	5135.47	0.00	446.29	0.00
MAR	0.00	0.73	0.00	5302.77	0.00	558.86	0.00
FEB	0.00	0.73	0.00	5386.24	0.00	660.00	0.00

VALOR MARGINAL DEL AGUA PROMEDIO	S/./m3	0.11

Agricultura: Variación del valor económico del agua según cada escenario



(Pareja, 2011)


centros poblados
ríos simples
Limite cuenca Alta
pcp_anual
Value
High : 4070
Low : 1008
Oyacachi
Oyacachi Viejo
PAPALLACTA
Papallacta
Cuyuja
San Victor
San Fsco. de Borja
Sardinas
San Fermin
Baeza
Las Palmas
Cosanga

Watershed characteristics