Today, Wednesday July 17

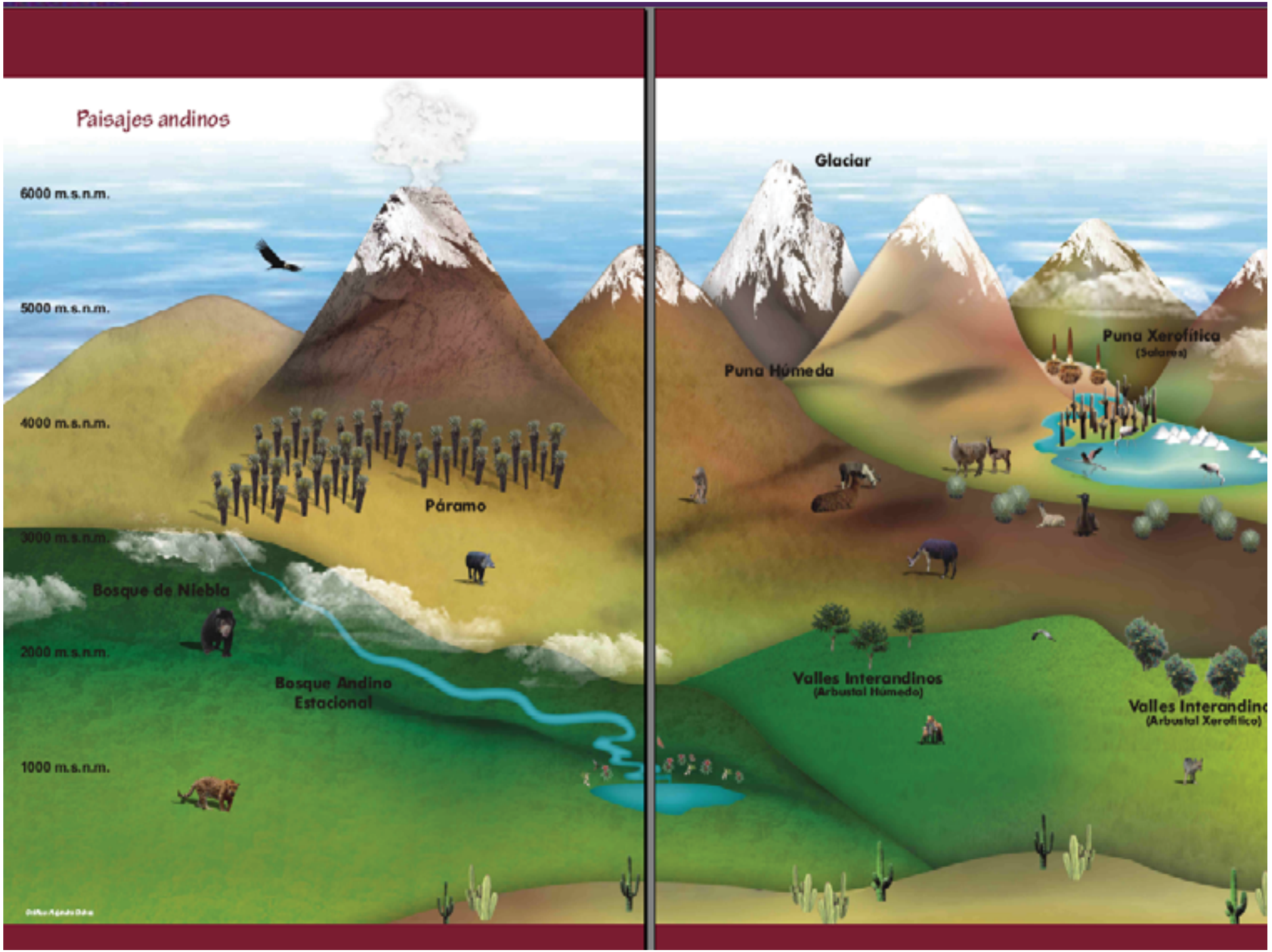
1. Andean ecosystems: introduction to climate, hydrology, drivers of change
2. Effects of land use change and climate change on the hydrology of a high mountain ecosystem
3. Benefit sharing mechanisms in watersheds.

CONDESAN

Consorcio para el Desarrollo Sostenible de la Ecorregión Andina

Andean ecosystems: introduction to climate, hydrology, drivers of change

Tropical Andes


Paisajes andinos
6000 m.s.n.m.
5000 m.s.n.m.
4000 m.s.n.m.
3000 m.s.n.m.
2000 m.s.n.m.
1000 m.s.n.m.
Páramo
Bosque de Niebla
Bosque Andino Estacional
Glaciar
Puna Húmeda
Puna Xerofítica
(Salares)
Valles Interandinos
(Arbustal Húmedo)
Valles Interandino
(Arbustal Xerofítico)

Páramos

Bosque de Niebla

Valles interandinos

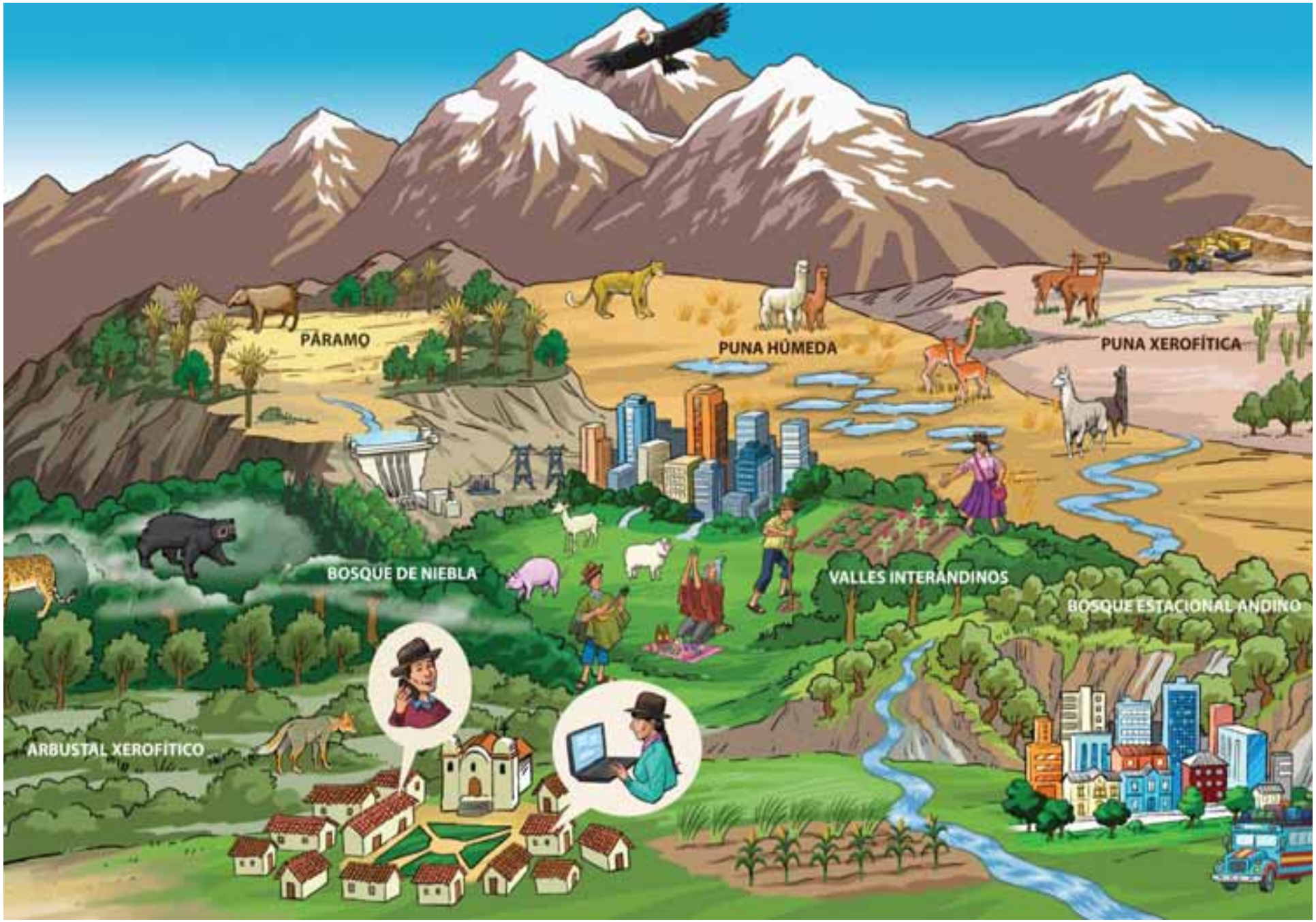
Bosque Andino Estacional

Paisajes culturales

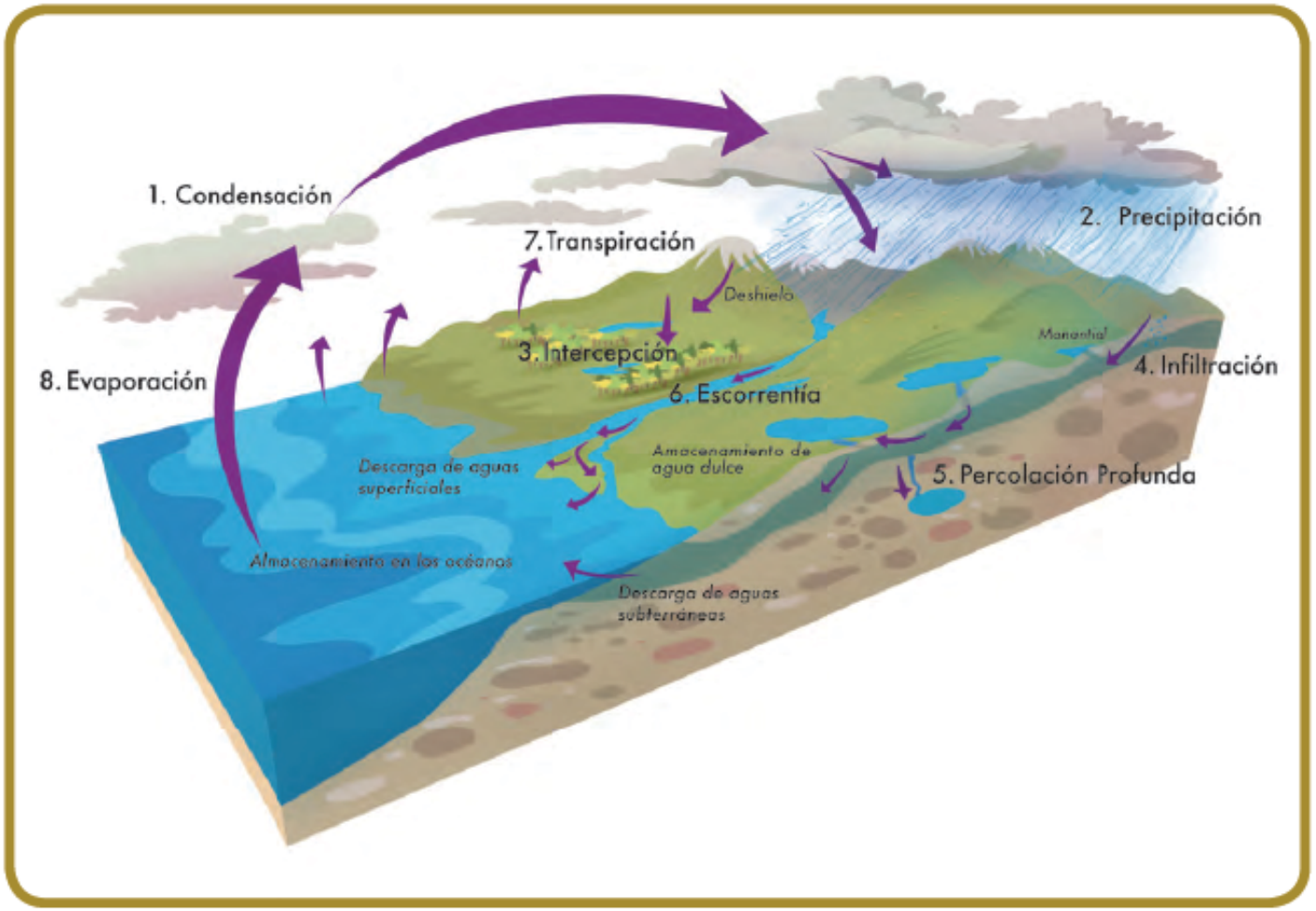
Puna Húmeda

Puna Xerofítica: Puna Xerofítica y Salares

Bosque Andino Xerofítico


PÁRAMO
PUNA HÚMEDA
PUNA XEROFÍTICA
BOSQUE DE NIEBLA
VALLES INTERANDINOS
BOSQUE ESTACIONAL ANDINO
ARBUSTAL XEROFÍTICO

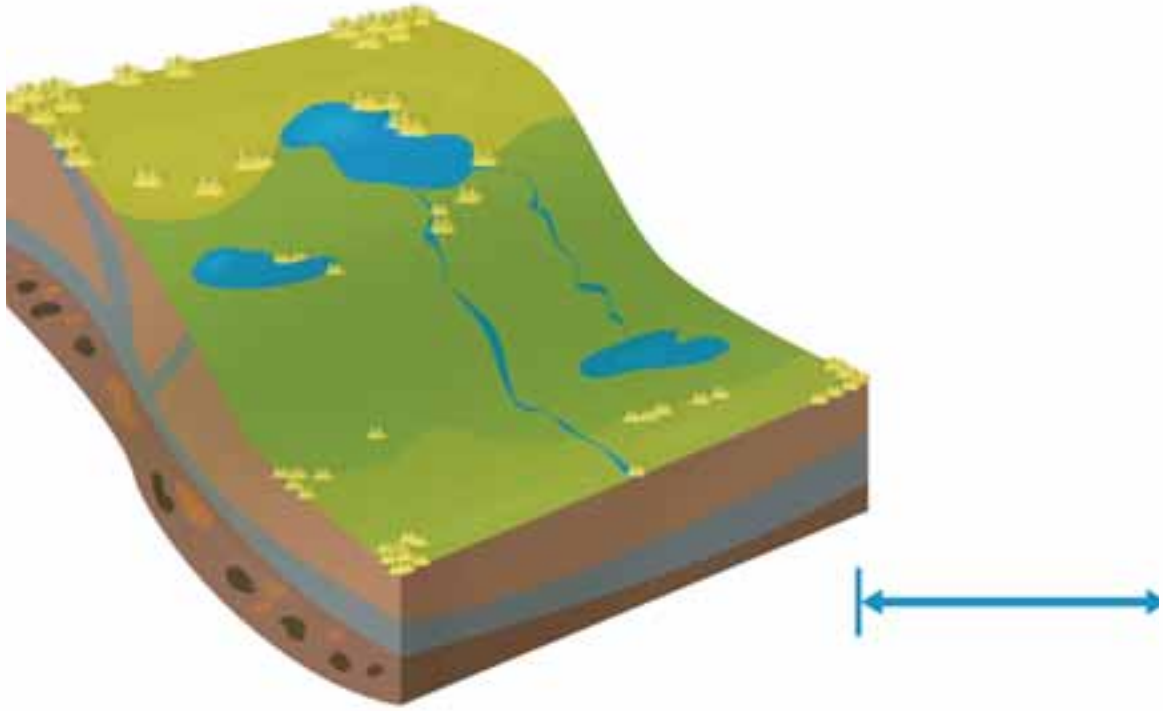
Componentes del ciclo hidrológico



Hydrological cycle

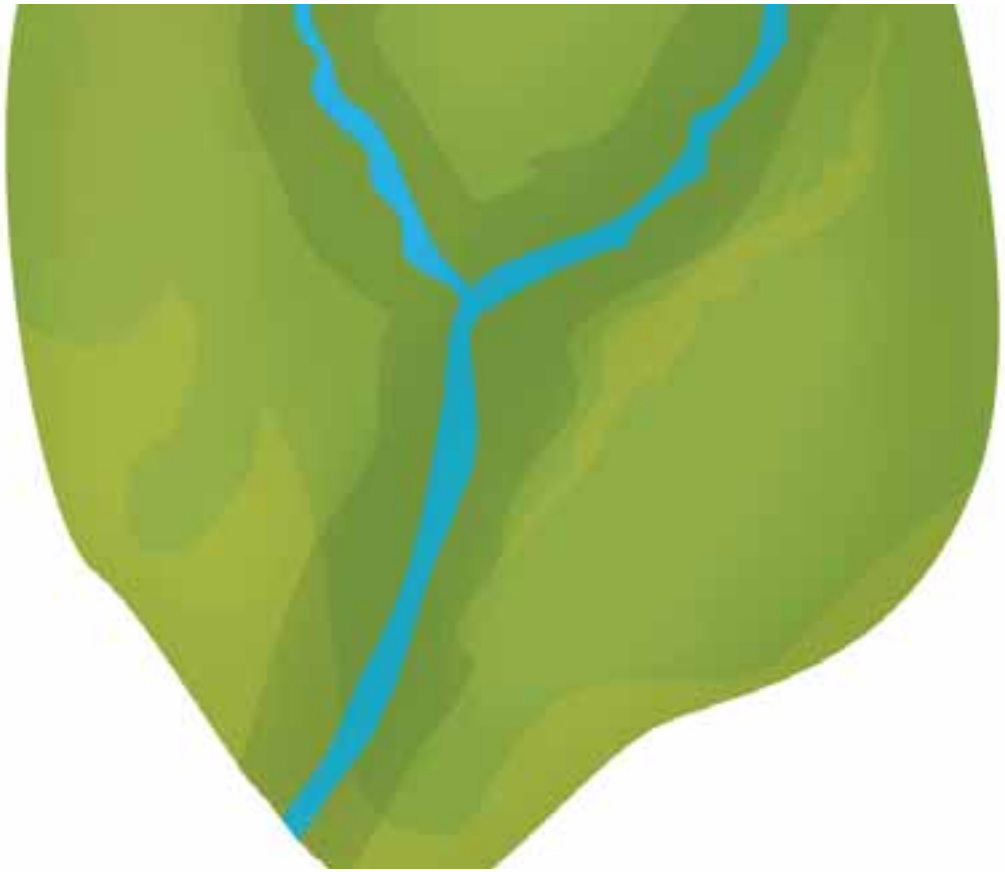
Mountain specificiities

Precipitation in Andes:
- Amazone origin
- Pacific origin
- Caribean origin



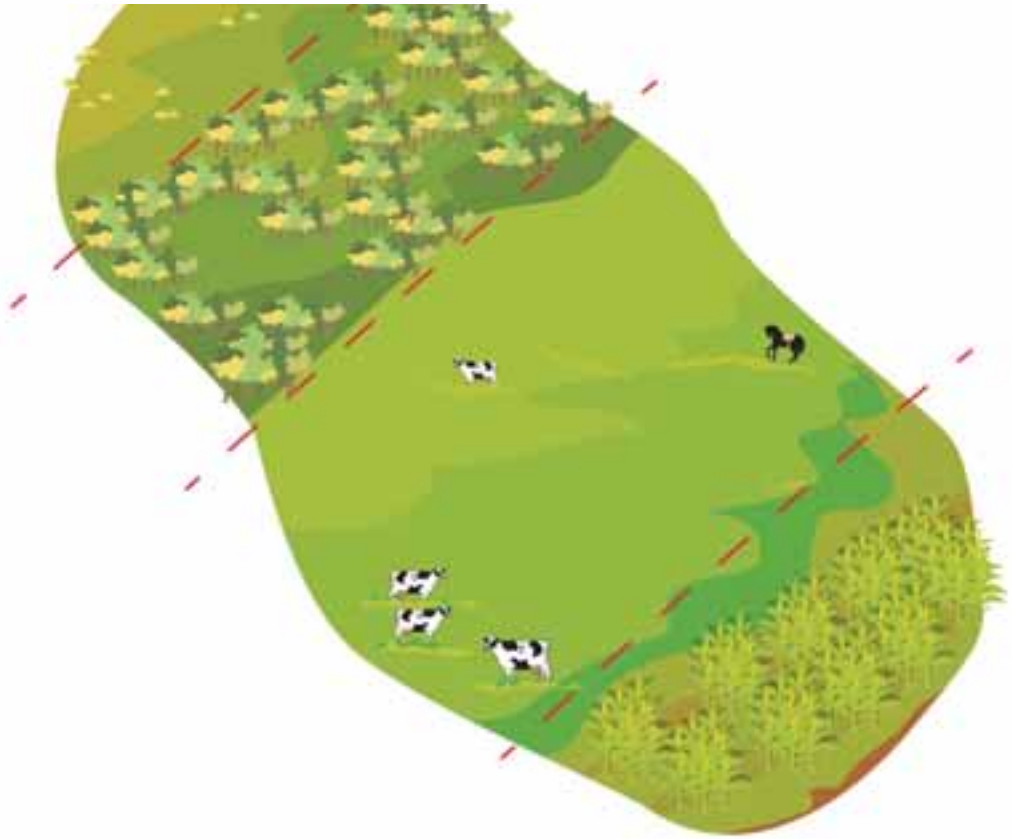
Scales of hydrological processes

Hillslope scale



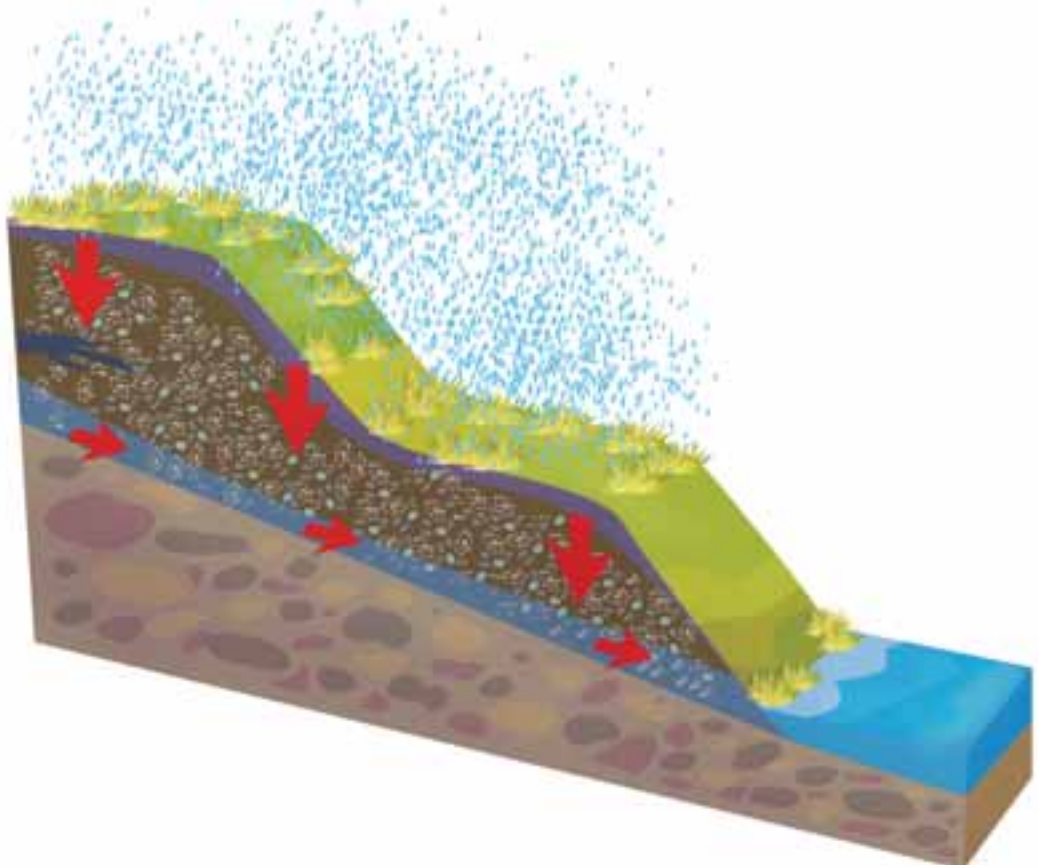
Scales of hydrological processes

Microwatershed scale

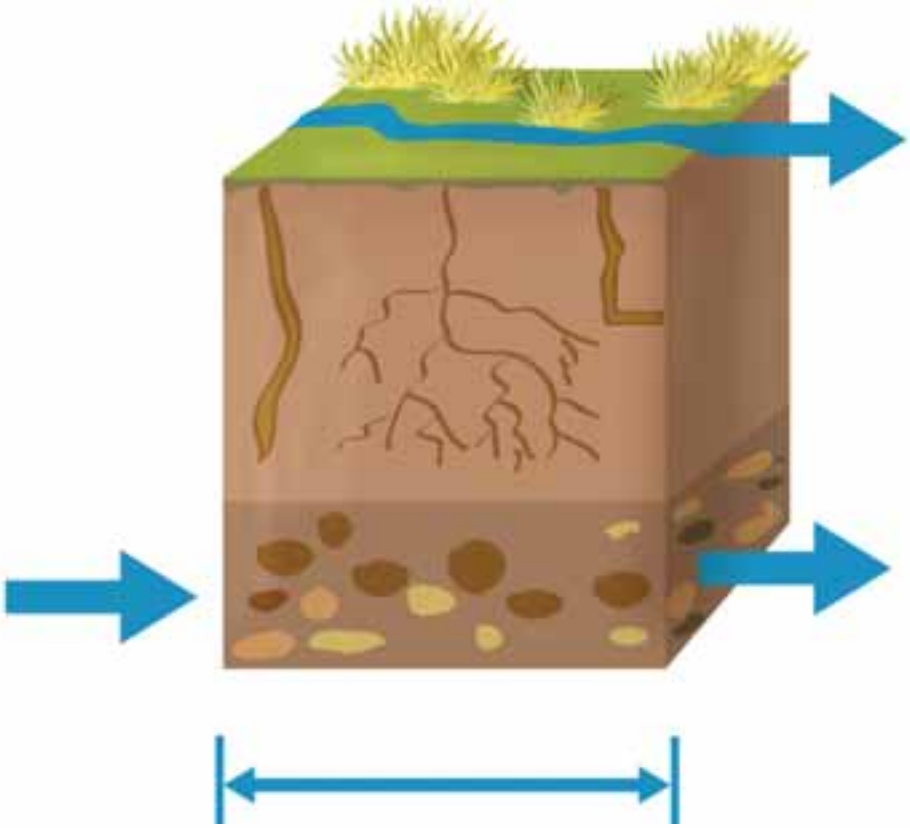


Scales of hydrological processes

Catchment scale



Hillslope process: importance of subsurface runoff



Scales of hydrological processes

Plot scale

Relevant conditions in Andes (1)

- (very) high mountains with a lot of people in them

INDICATOR	BOLIVIA	COLOMBIA	ECUADOR	PERÚ	CAN (2005)
Population (millions)	9,4	44,9	13,2	27,3	94,8
Urban (%)	64	77	63	73	72
Rural (%)	36	23	37	27	28

Data from CEPALSTAT (CEPAL, 2008)

- Extremely variable conditions

Altitude range	*0 - 6746 (masl)*	*Bolivia*	252 - 6542
		Colombia	0 - 5750
		Ecuador	0 - 6267
		Perú	0 - 6746
Precipitation range	*31 – 9000 (mm/year)*	*Bolivia*	200 - 5000
		Colombia	300 – 9000
		Ecuador	125 - 6000
		Perú	31 – 3838

Source: Principales indicadores de la Unión de Naciones Suramericanas1998 – 2007 **(SGCA, 2008c), (PNUMA & SGCA, 2003), Fondo Mundial para la Conservación de la Naturaleza (WWF)**

Relevant conditions in Andes (2)

- Mountain rivers with limited regulation capacity

Very high temporal variability of water availability in sources:

- **Small catchments in case of high altitude offtakes**
- **High dependence on few regulation mechanisms: peatlands, glaciers**
- **Little regulation infrastructure**

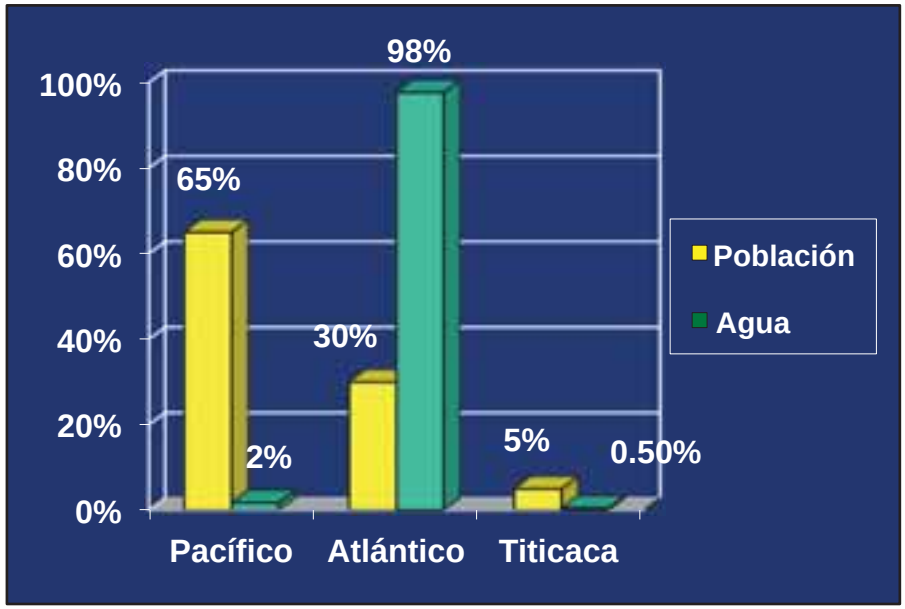
Relevant conditions in Andes (3)

- Water demand at high altitudes

Dependent on regulation mechanisms at even higher altitude, where groundwater regulation is almost unexistent

Relevant conditions in Andes (4)

- Water demand in lower river reach very variable (Peru's coastal desert: very high, Amazon tributaries: very low)



Source: ANA Perú 2010

Relevant conditions in Andes (5)

- Traditional knowledge and technologies to manage natural resources

Important drivers in Andes

Important drivers in Andes (1)

- Urbanization: drastic increase in urban population, rural population more or less stable. Causes geographical concentration of water demand

Source: Presentation "Water Management and Climate Change", by Axel Dourojeanni, Lima 2010.

Source: Estrategia Andina para GIRH, CAN 2010.

Important drivers in Andes (2)

- Free trade agreements boost agroindustry for export, but large differences between countries

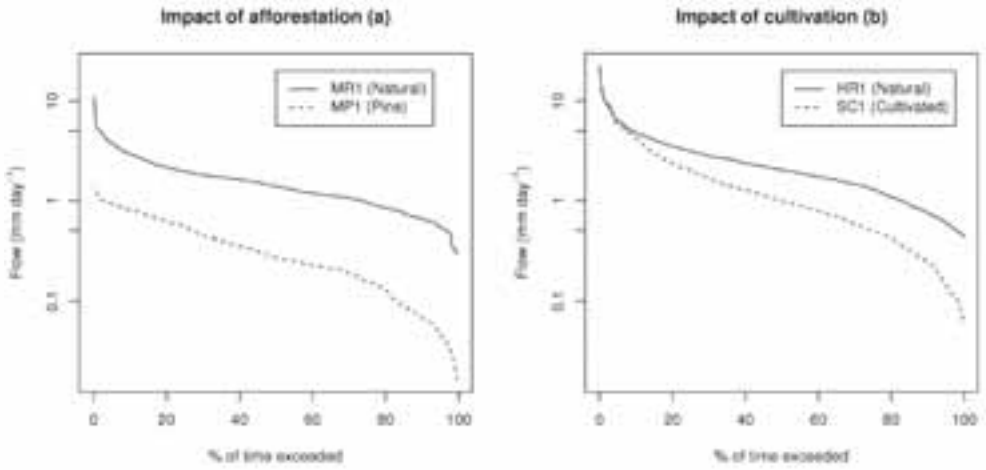
Important drivers in Andes (3)

- Land degradation: loss of regulation capacity in mountain catchments

- **Some spontaneous recuperation in abandoned land (migration)**
- **Doubts on reversibility**

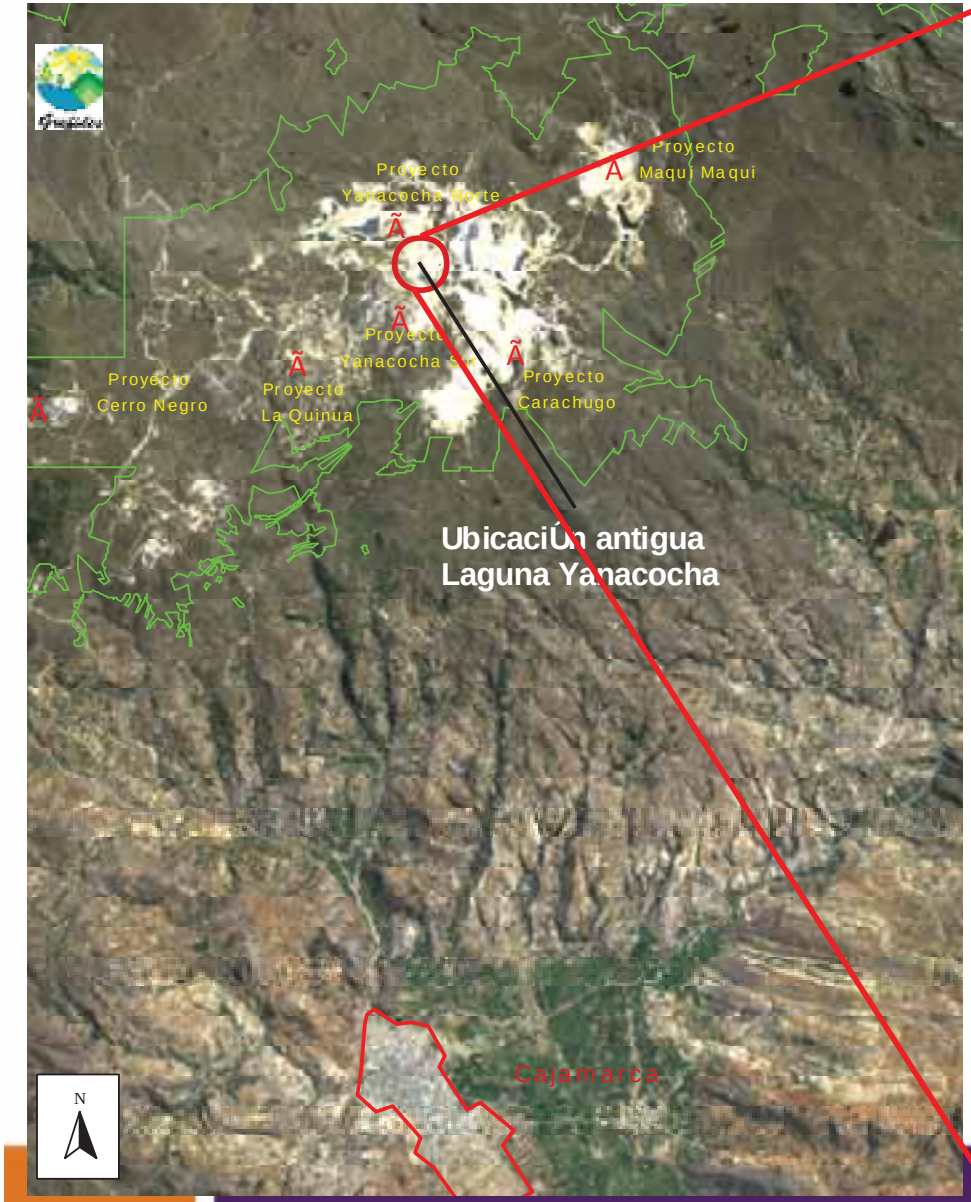
Important drivers in Andes (3)

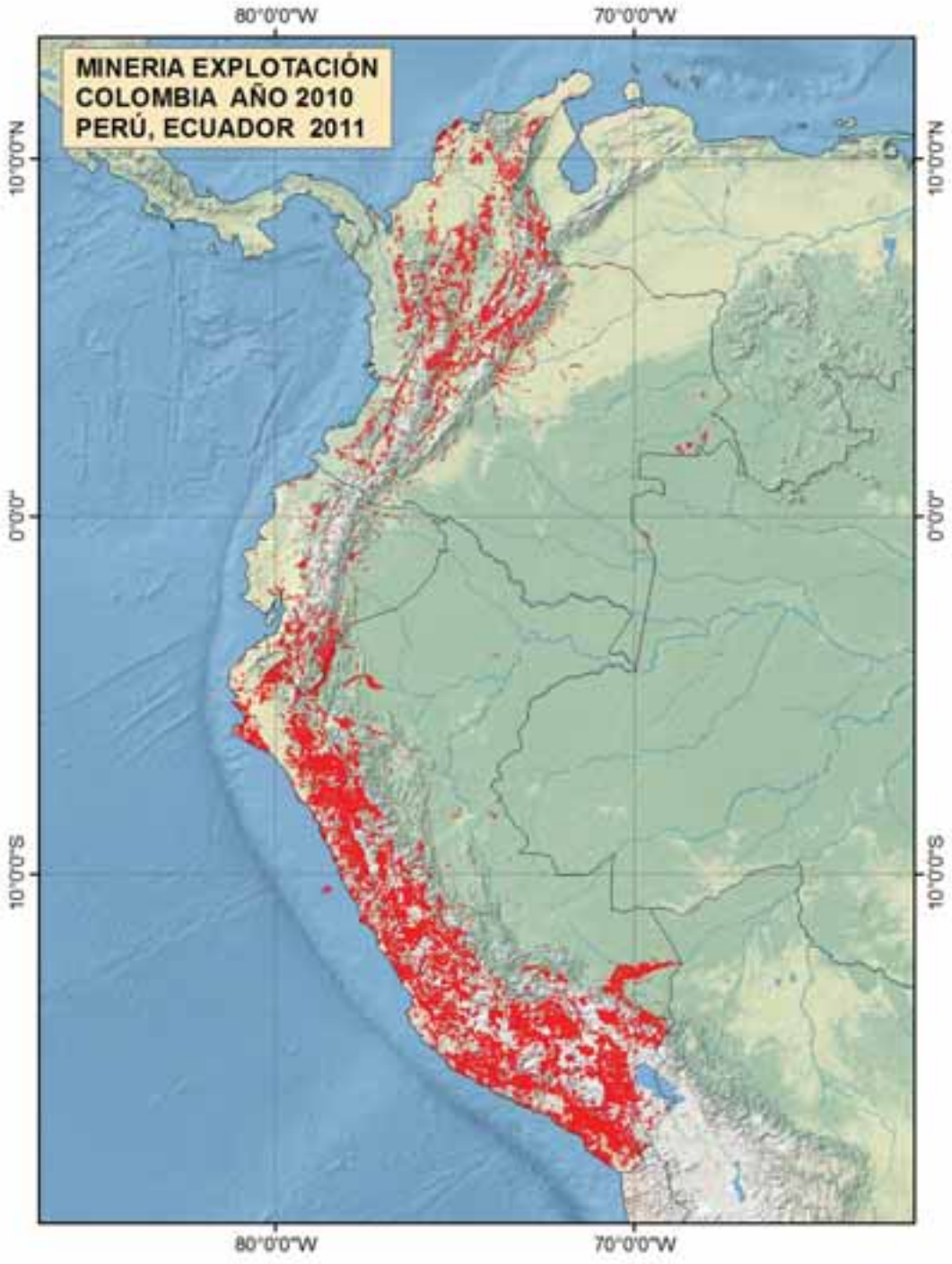
- Land degradation: loss of regulation capacity in mountain catchments



Source: Wouter Buytaert, 2010.

Important drivers in Andes (4)




MINERIA EXPLOTACIÓN
COLOMBIA AÑO 2010
PERÚ, ECUADOR 2011
80°0'0"W
70°0'0"W
10°0'0"N
0°0'0"
10°0'0"S

Effects of land use and climate change on water yield and water regulation in a high mountain ecosystem

Bert De Bièvre

CONDESAN

Proyecto Páramo Andino

Conservación de la Diversidad en el Techo de los Andes

The “páramo”

- 35,000 km^2 in the Tropical Andes between 11º North and 8º South)

- Grasslands above treeline, usually above 3000-3300 masl, and below permanent snowline, 4700-5000 masl

- 900-2500 mm annual rainfall, high solar radiation, cold tropics but huge daily temperature variation

GEF UNEP CONDESAN ICAE HUMBOLDT ECOCIENCIA Instituto de Montaña

Proyecto Páramo Andino

Conservación de la Diversidad en el Techo de los Andes

Páramo area

Country	km^2	% country
Costa Rica	80	0.2
Venezuela	2460	0.4
Colombia	14200	1.3
Ecuador	18400	5
Peru	600-1 1000	

GEF UNEP CONDESAN ECOCIENCIA Instituto de Montaña

Importance of páramo water

- Water for domestic use, urban and rural
  - High altitude cities (Bogotá, Quito, ...)
- Irrigation water in interandean valleys
- Water for hydropower
- Water for biodiversity conservation in páramo itself, ecological flows

What is needed for a good water supply “service” from páramo?

Good water supply "service" from ecosystem

Total water yield

"Water Factory"

Regulation (flow as constant as possible)

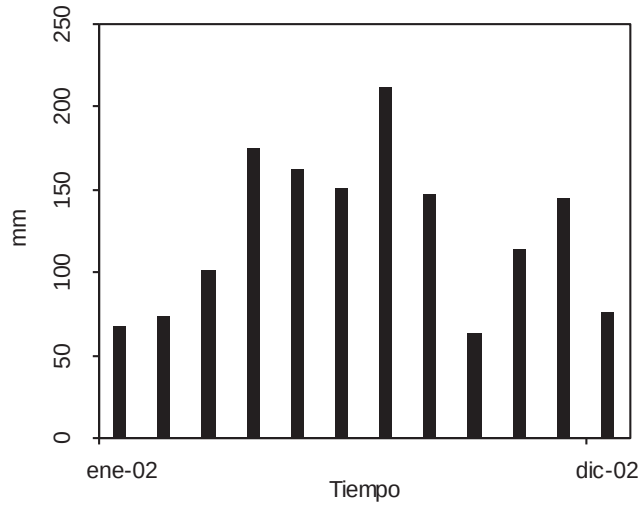
"The Sponge"

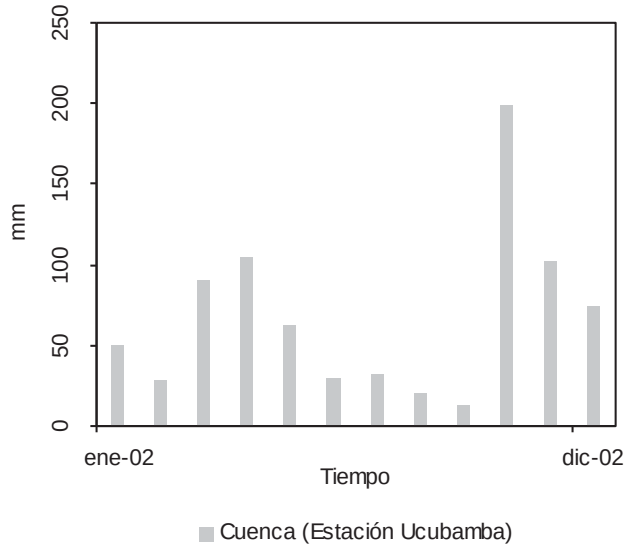
Good water supply "service" from ecosystem

Total water yield

"The water Factory"

- Rainfall





Good water supply "service" from ecosystem

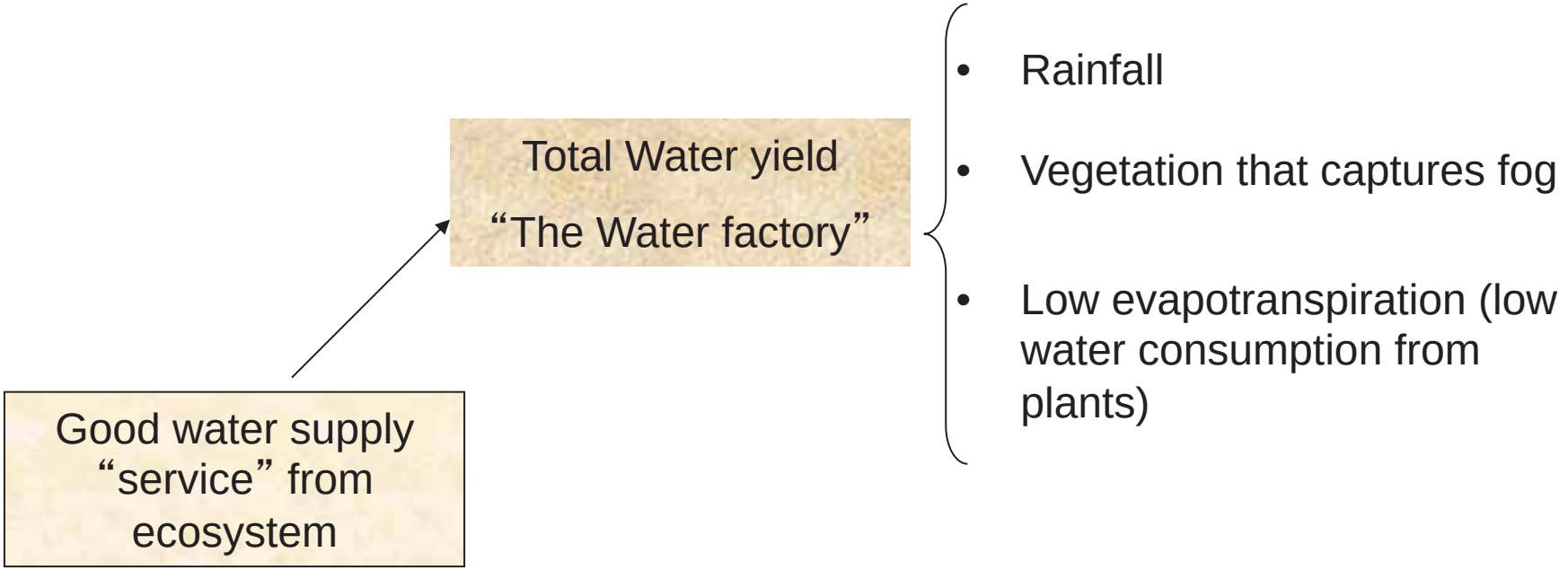
Total water yield

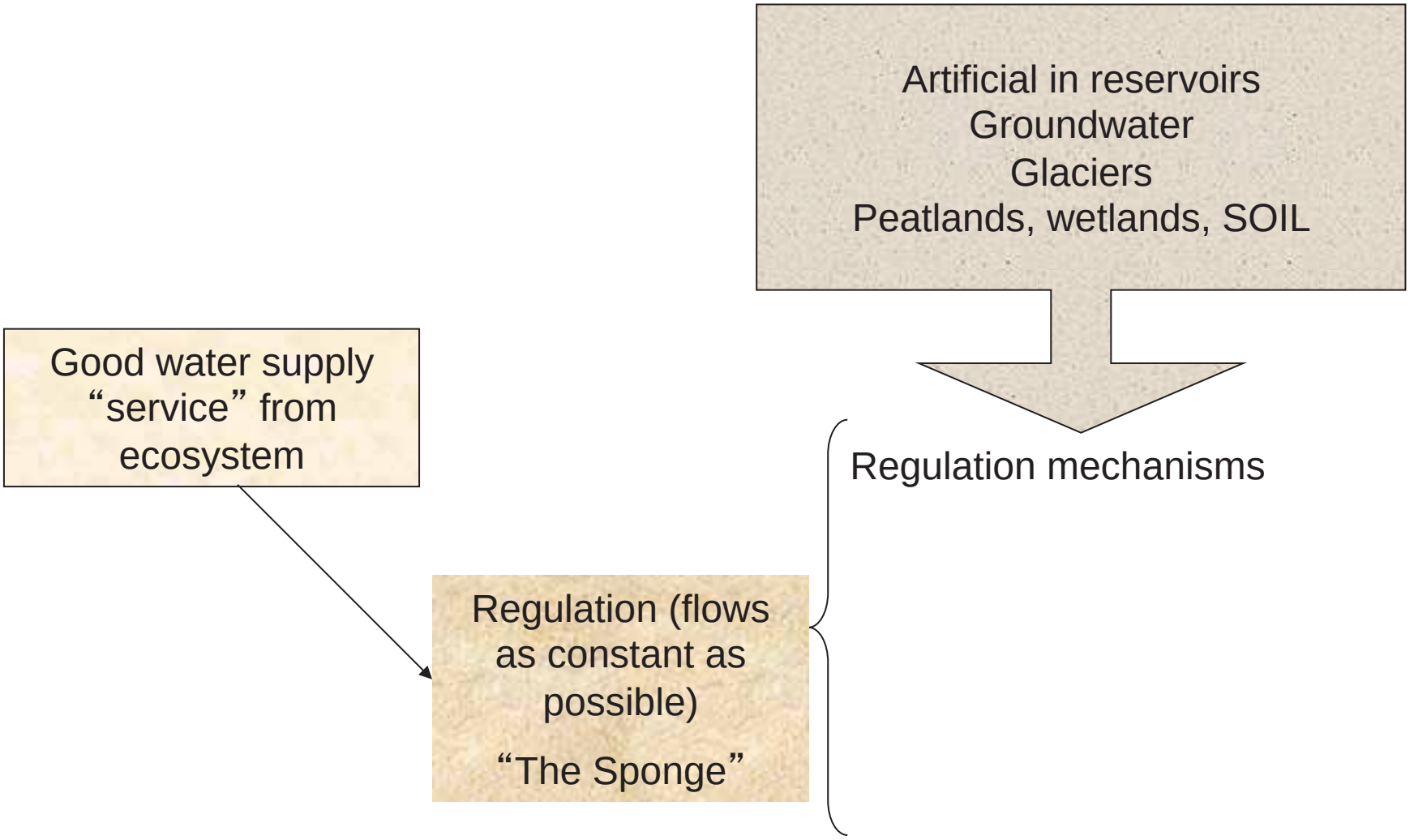
"The Water Factory"

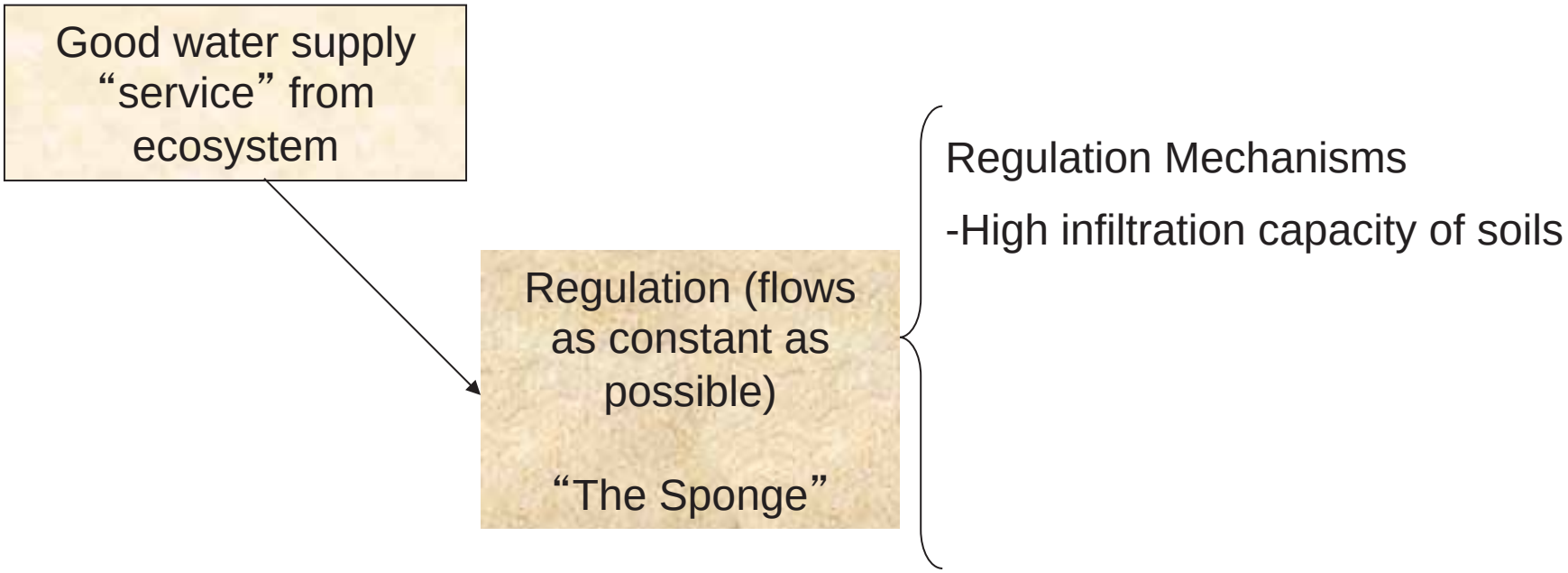
- Rainfall
- Vegetation that captures fog

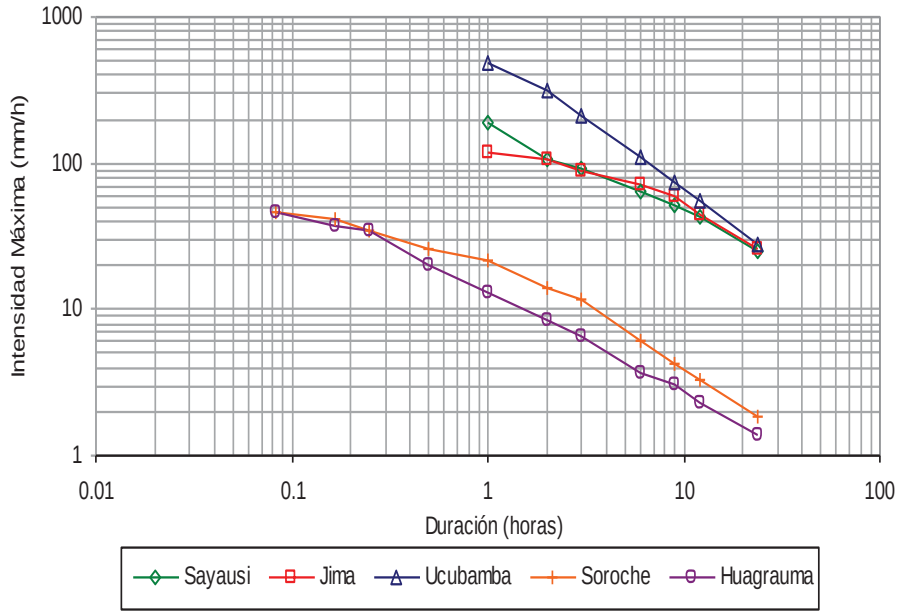
Intercepción de la lluvia en el pajonal

Foto: Rolando Célleri


Total Water yield
“The Water factory”
Good water supply “service” from ecosystem
• Rainfall
• Vegetation that captures fog
• Low evapotranspiration (low water consumption from plants)


Artificial in reservoirs
Groundwater
Glaciers
Peatlands, wetlands, SOIL
Good water supply "service" from ecosystem
Regulation mechanisms
Regulation (flows as constant as possible)
"The Sponge"


Good water supply "service" from ecosystem
Regulation (flows as constant as possible)
"The Sponge"
Regulation Mechanisms
-High infiltration capacity of soils



Good water supply "service" from ecosystem

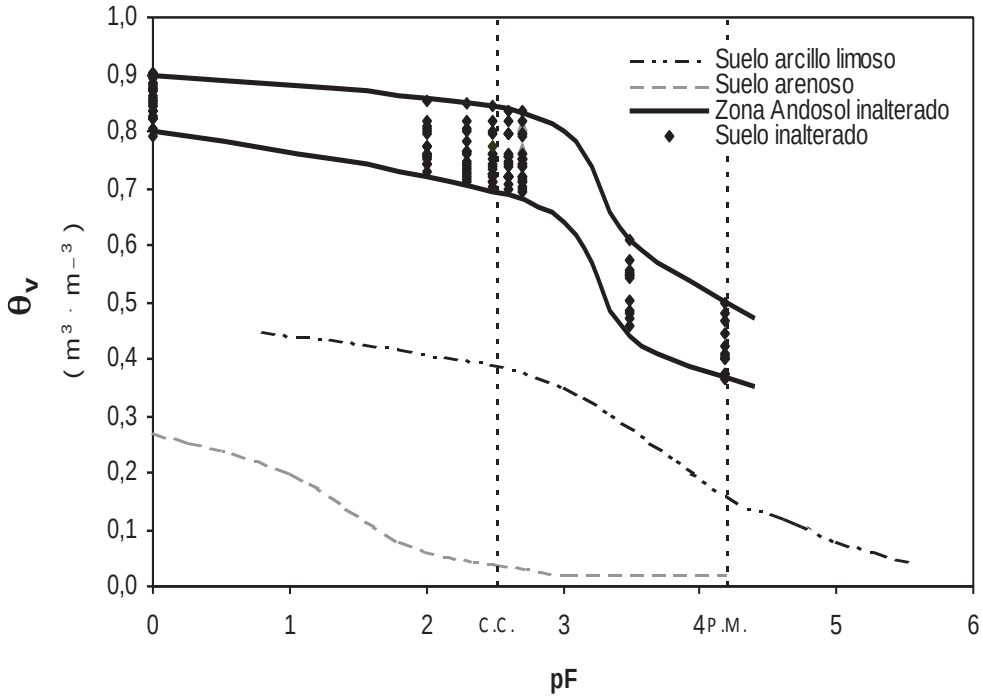
Regulation (flows as constant as possible)

"The Sponge"

Regulation mechanisms

-High infiltration capacity of soils

-Low rainfall intensity



Good water supply "service" from ecosystem

Regulation (flows as constant as possible)

"The Sponge"

-High infiltration capacity of soils

-Low rainfall intensity

-High water holding capacity of soils

Examples of Human Impact

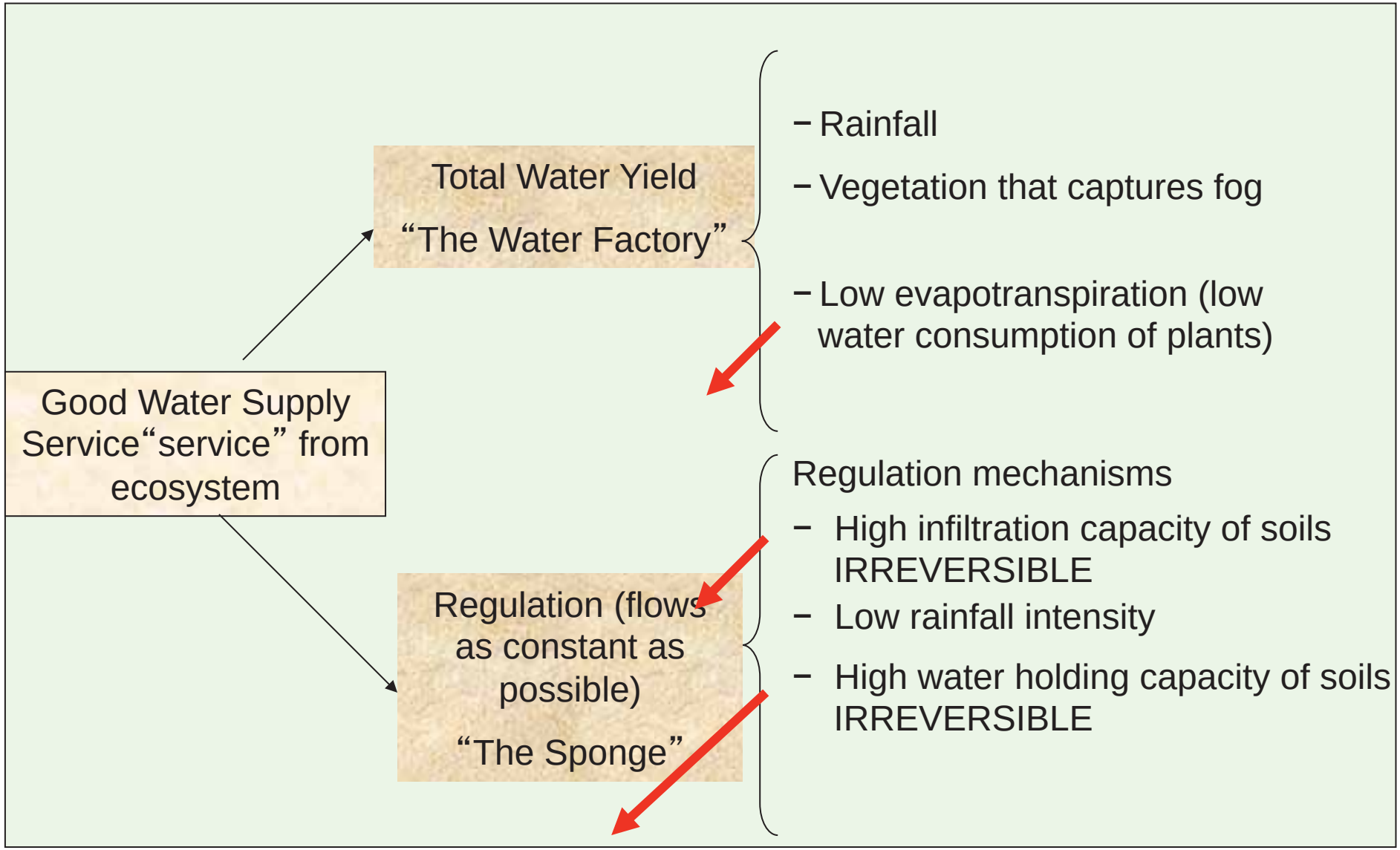
Burning

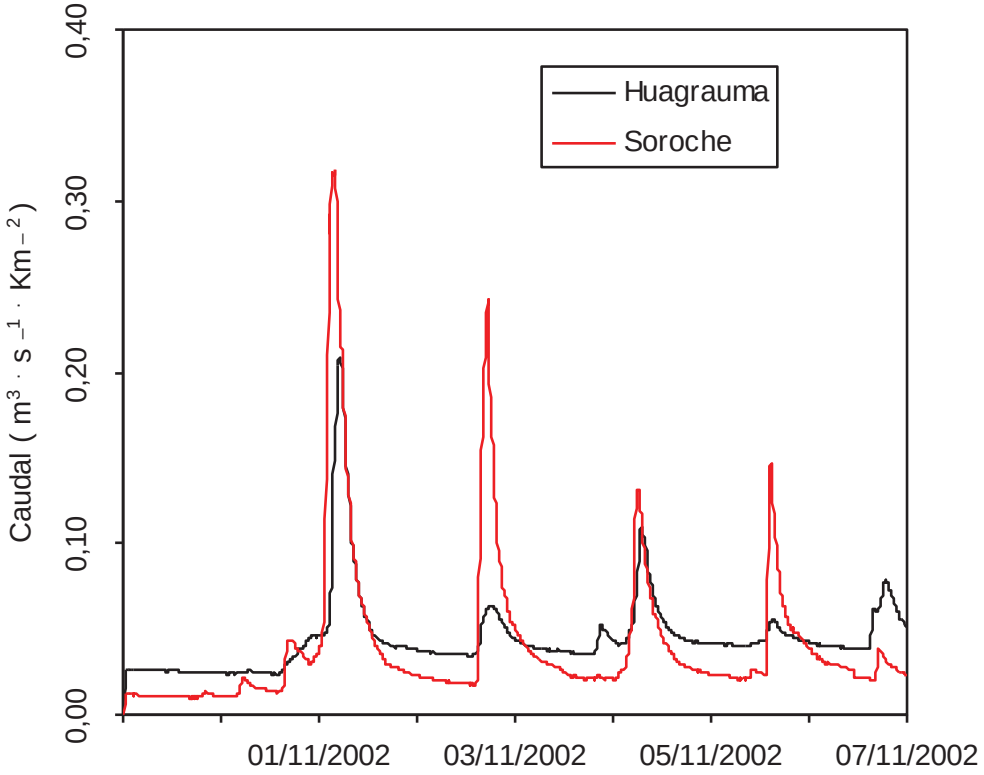
Foto: Pablo Borja.

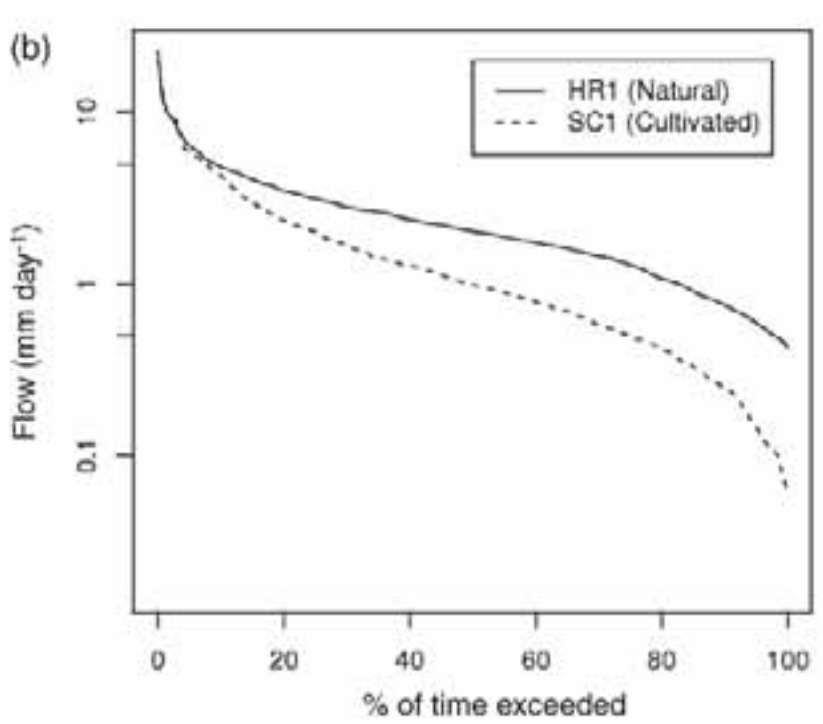

Cultivos
Foto: Boris Ochoa Tocachi.


Pastoreo
Foto: Boris Ochoa Tocachi.

Agriculture (incl. Intensive grazing)

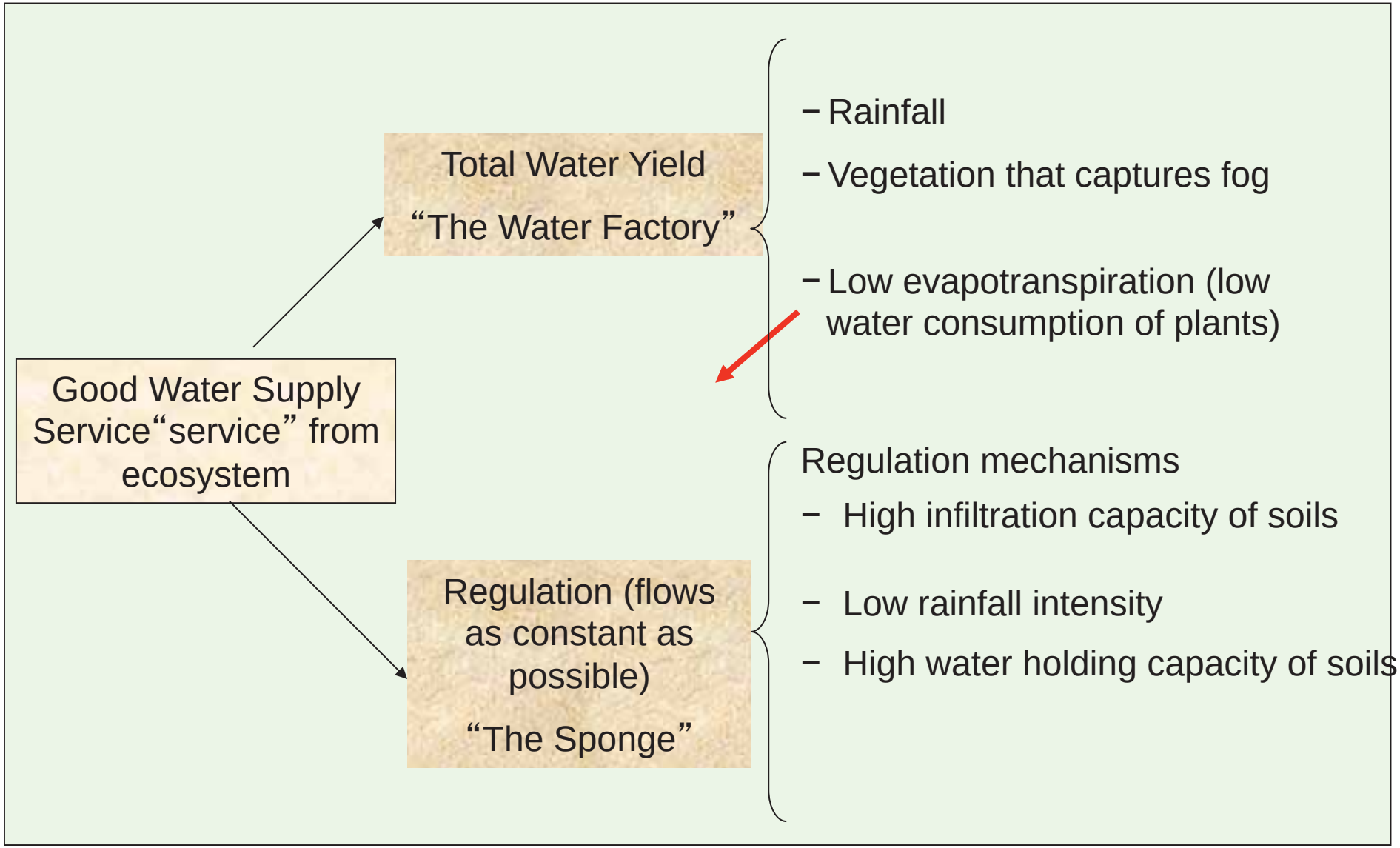


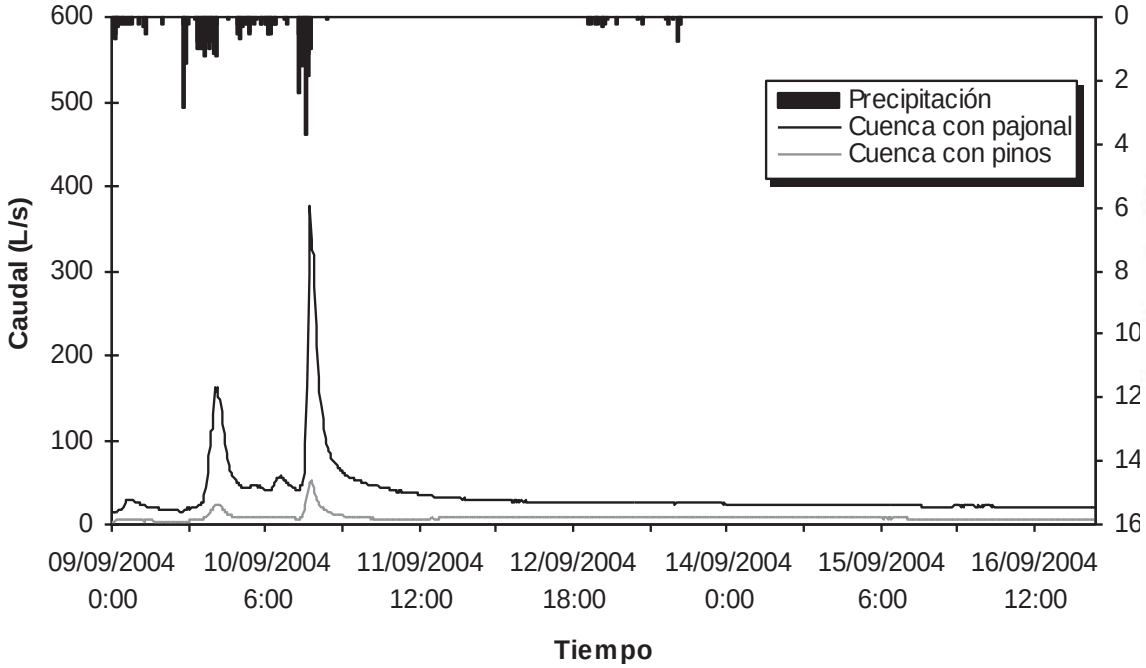


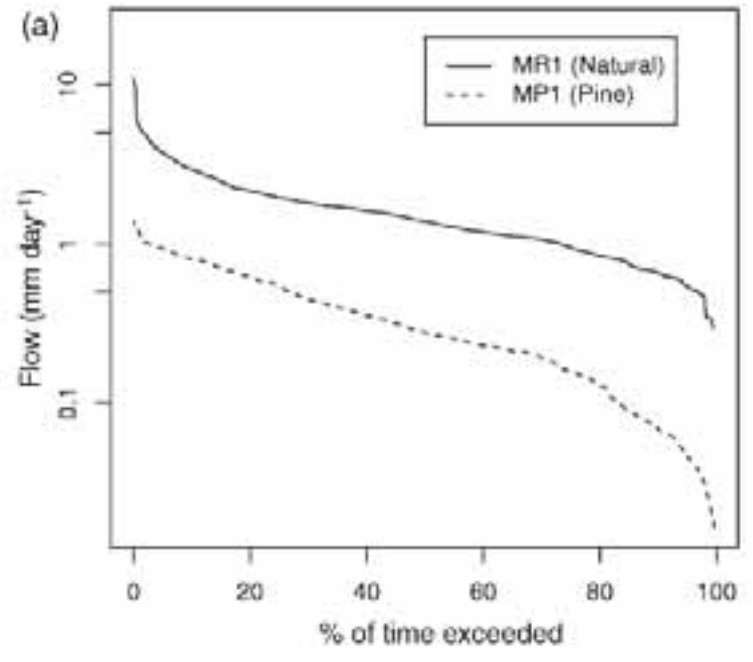


Buytaert, Célleri, De Bièvre ..., 2006, Human impact on the hydrology of the Andean páramos, Earth Science Reviews 79:53-72.

Forestation with Pines

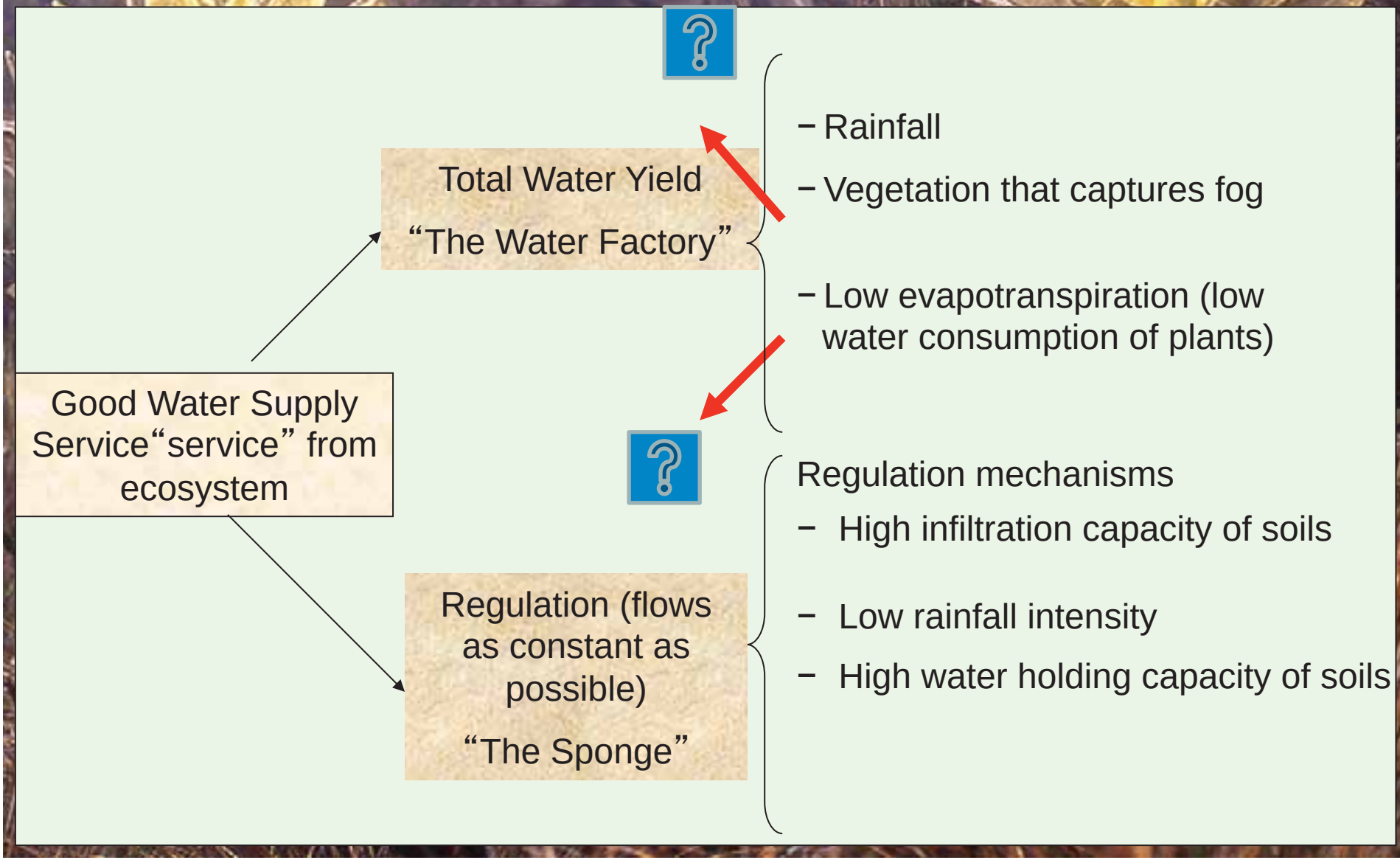






Buytaert, Iñiguez, De Bièvre, 2007, The effects of afforestation and cultivation on water yield in the Andean paramo, Forest Ecology and Management 251(1-2): 22-30

Forestation with native species



On de-, re-, and afforestation

- Benefits do not depend on type of action undertaken, depends on combination of **preceding state** and action
- Be clear on objectives and priorities:
  - Timber/wood
  - Water conservation
  - Barrier against something worse
- Reforestation ≠ $(\text{Deforestation})^{-1}$

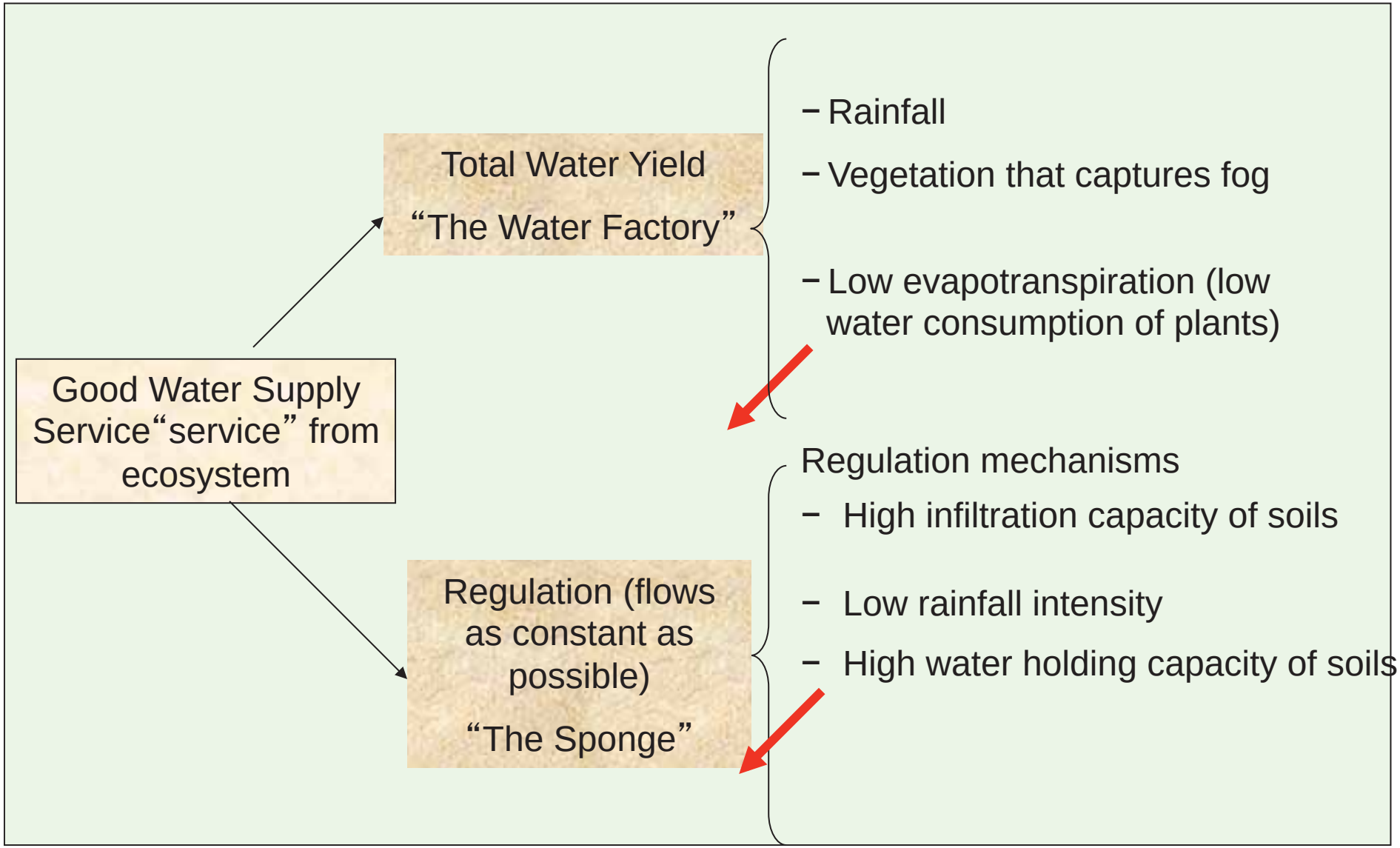
Land use impacts

Crespo et al., 2013

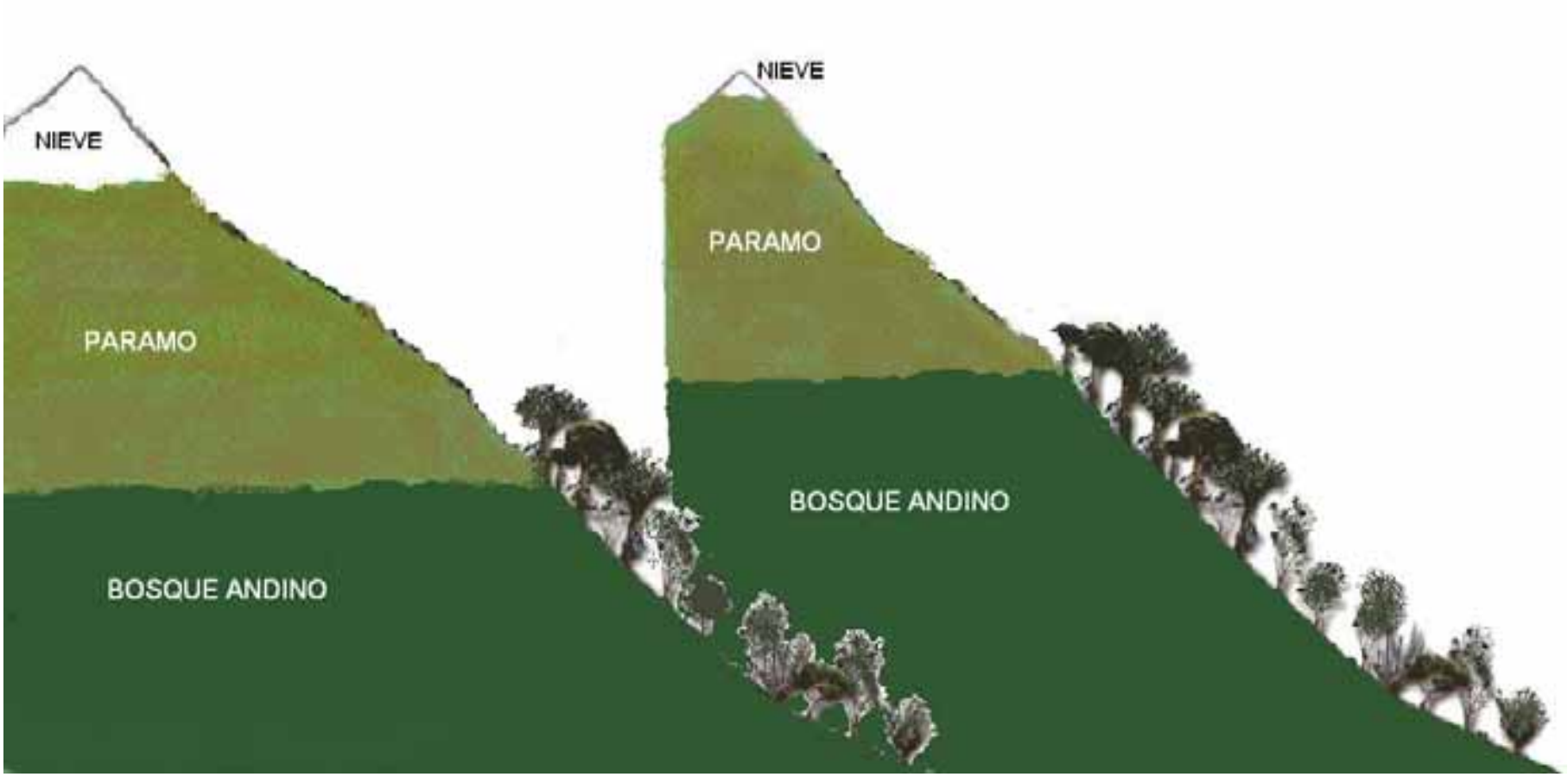
Cuenca	Unidades	Paute		Paute		Jubones	Paute	
Micro cuenca		Huagrahuma (M1)	Soroche (M2)	Quinahuaycu (M3)	Calluancay (M4)	Zhurucay (M5)	Marianza 1 (M6)	Marianza 2 (M7)
Área	km²	2.58	1.59	5.01	4.39	1.34	0.84	0.63
Suelos		Andosol	Andosol	Andosol Histosol	Andosol Histosol	Andosol Histosol	Andosol Histosol	Andosol Histosol
Cobertura vegetal	%	TG(100)	P(30), TG(70)	TG(78), S(02), CP(20)	TG(69), S(20), CP(11)	TG(71), S(02), CP(26)	TG(86), S(14)	PF(>90), TG
Uso del suelo		EG	P, IG	N	EG	EG	N	PF
Geología		Saraguro Fm.: lavas andesíticas y depósitos volcanoclásticos		Quimsacocha Fm.: rocas volcánicas y volcanoclásticas.			Saraguro Fm: lavas andesíticas y depósitos volcanoclásticos.	
Pendiente	%	45	20	22	19	21	42	37
Altura	msnm	3690 - 4100	3520 - 3720	3590 - 3880	3585 - 3870	3680 - 3900	2980 - 3810	3230 - 3710
Forma		SO	SO	SO	CO	SO	SO	CO

Micro cuenca	Unidades	M1	M2	M3	M4	M5	M6	M7
Características hidrometeorológicas								
Inicio periodo monitoreo	Fecha	16/10/01	29/10/01	10/11/06	10/11/06	10/11/06	29/02/04	08/05/04
Final periodo monitoreo	Fecha	30/10/08	23/01/04	12/11/08	12/11/08	12/11/08	23/09/08	23/09/08
Caudal máximo	l/s/km²	614.98	873.25	1019.38	971.35	992.84	445.70	285.32
Caudal mínimo	l/s/km²	3.33	0.67	2.78	4.35	2.01	2.33	0.15
Caudal promedio	l/s/km²	32.09	20.50	25.52	26.05	28.82	19.30	8.30
Componentes del balance hídrico								
Inicio periodo balance	Fecha	13/08/03	29/10/01[a]	11/11/06	11/11/06	11/11/06	23/09/07	23/09/07
Final periodo balance	Fecha	29/10/08	22/01/04	11/11/08	11/11/08	11/11/08	23/09/08	23/09/08
Precipitación	mm/año	1451	1126	1143	1383	1254	1417	1407
Caudal total	mm/año	1064	649	908	824	911	685	389
Evapotranspiración	mm/año	387	477	235	559	343	732	1018
Coeficiente de escorrentía		0.73	0.58	0.79	0.60	0.73	0.48	0.28

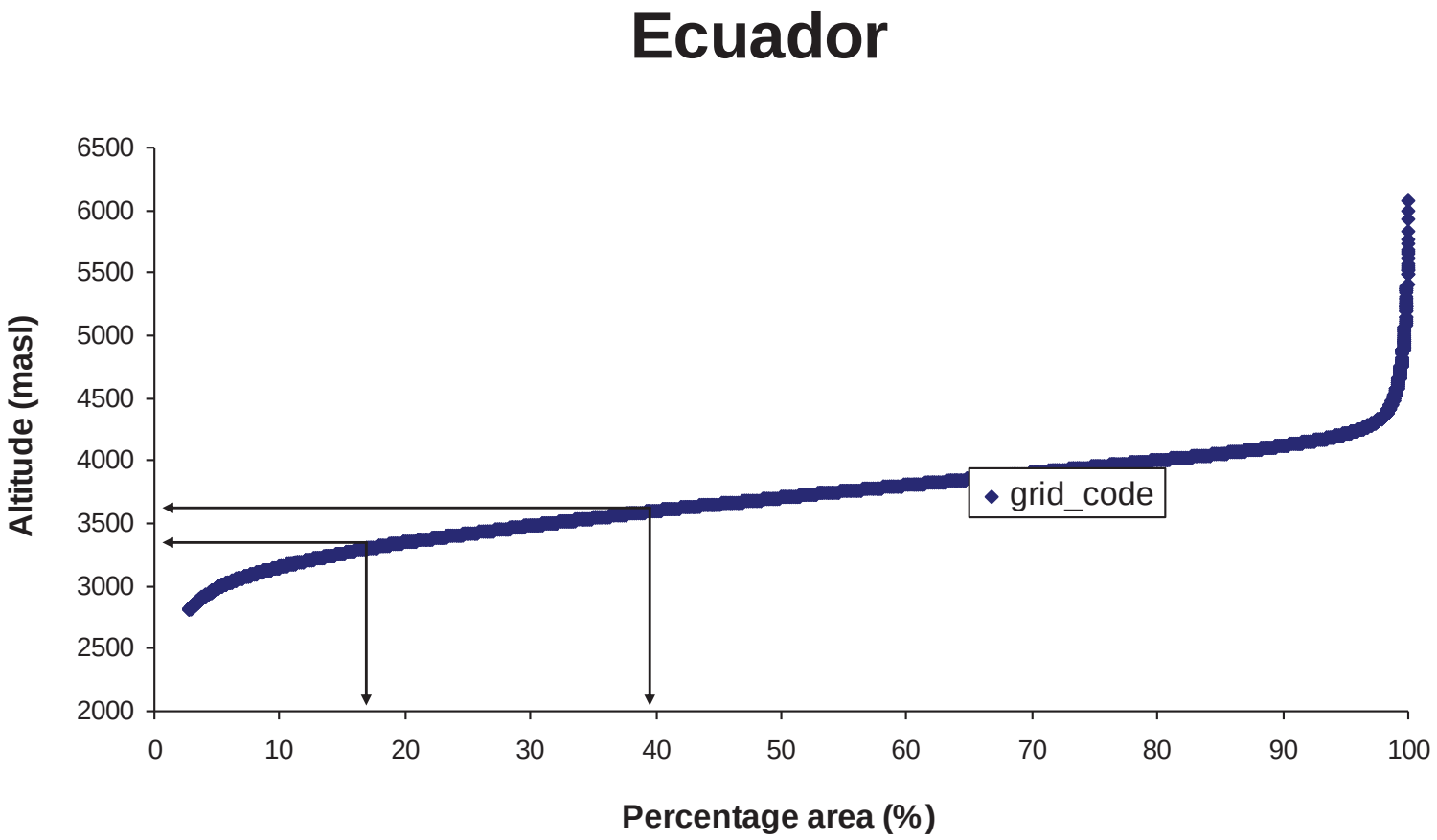
Climate change



Climate change: ecosystems are climbing uphill and with them their precious hydrological properties



Vulnerability of the total páramo area to global warming



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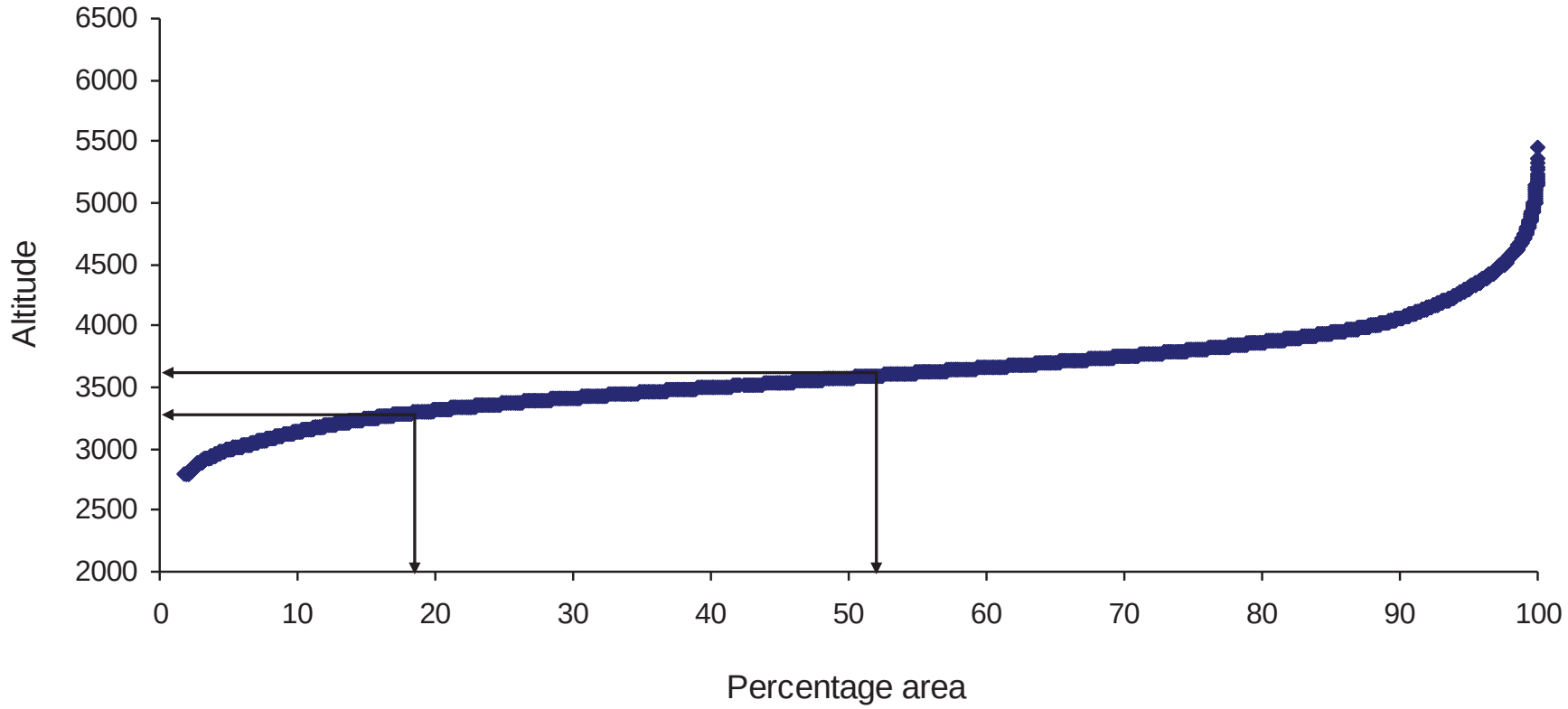
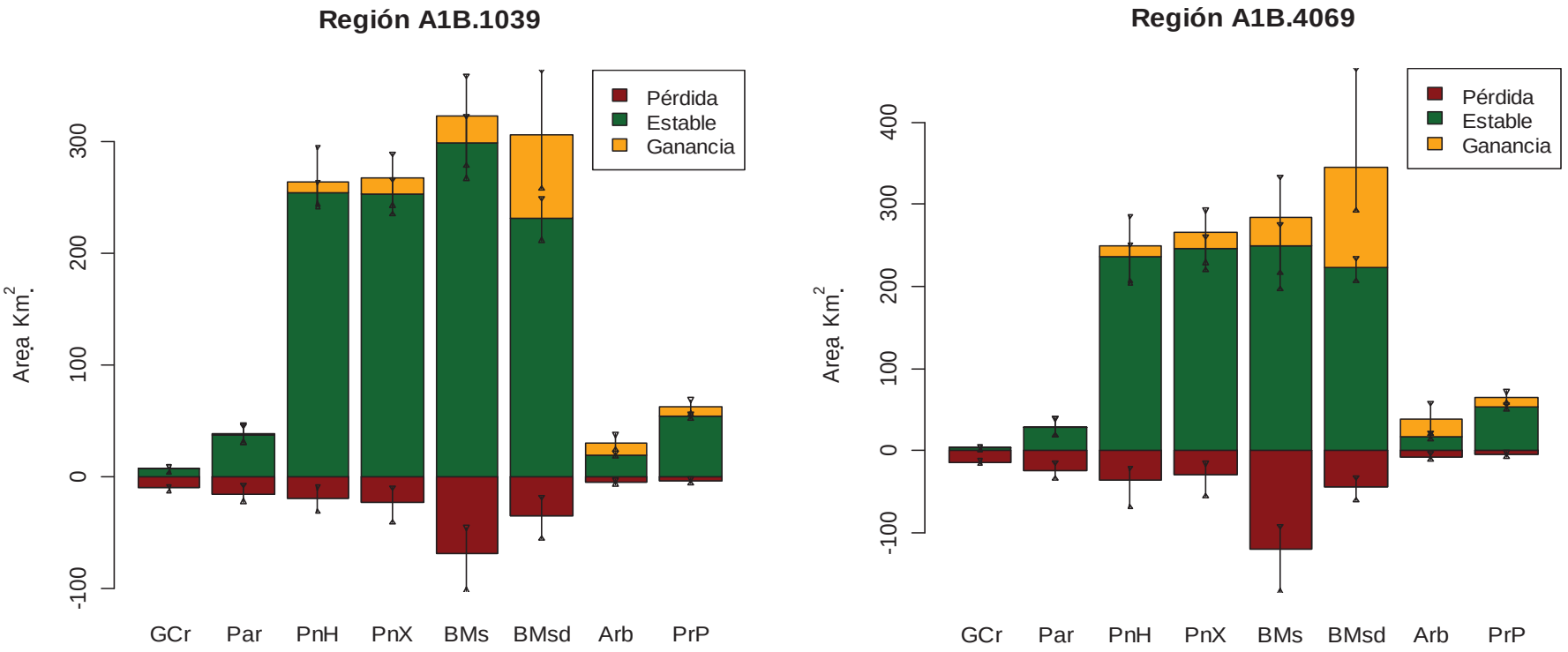


Biome shifts in the Andes

- Climate change: vertical altitudinal moves certain, everything else very uncertain



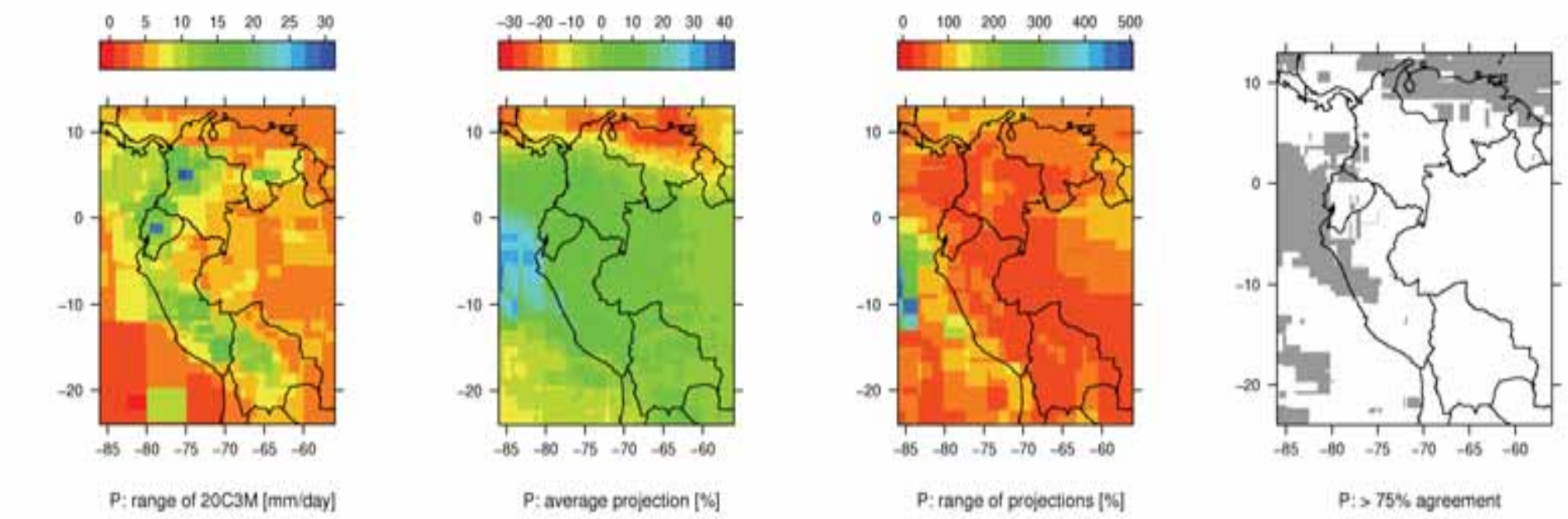
Projected changes in ecosystems area: the higher ecosystems only loose, the lower ones loose and gain (Tovar et al., 2013)

Climate Change Models

- Different models agree on:
  - Significant increase in temperature
  - Higher increase at high altitude than at sea level (at 3500 masl double)
- Models do NOT agree on
  - Changes in total rainfall and its seasonal distribution

- Climate change: vertical altitudinal moves certain, everything else very uncertain

Range of projected annual rainfall



And then … is it annual rainfall that matters?

Concluding remarks

- In the tropical Andes, páramo is THE water regulating source, glaciers of secondary importance.

  Buytaert, De Bièvre, Cuesta, Célleri, Hofstede, Sevink, 2007, E-letter response to "Threats to water supplies in the tropical Andes" (Bradley et al. Science 2006; 312: 1755-1756), Science.
- Human intervention that affect soils directly have high impact on hydrology and are irreversible
- Human interventions that affect vegetation only can have high impact but reversible

How to upgrade rapidly our knowledge on high altitude tropical hydrology?

- Minimum hydrological monitoring approach: rainfall and discharge
- More policy relevant to have minimal data on many sites than detailed data on few sites
- Partner with local stakeholders with their specific interest in catchment
- Paired design (natural catchment vs catchment with intervention) where feasible: conclusions with one year of data, as opposed to conclusions based on statistical analysis of long records

.

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Cordillera Tropical Fundación

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Fondo de Páramos Tungurahua

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The Nature Conservancy

Instituto de Montaña

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Universidad de los Andes

Ciencias de la Tierra y del Ambiente

Universidad de Cuenca

Universidad Nacional de Colombia

Escuela Politécnica Nacional

Universidad del Cauca

Imperial College London

Proyecto Páramo Andino
Conservación de la Diversidad en el Techo de los Andes

Programa Regional ECOBONA

natural cooperation

CGIAR Challenge Program on WATER & FOOD

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Agencia Suiza para el Desarrollo y la Cooperación COSUDE

Hydrological response of overgrazing in paramos in Plura?

Hydrological response of overgrazing in puna in Huaraz?

Hydrological response of pine forestation combined with infiltration ditches in puna inTambobamba – Apurimac?

Hydrological response of potato cultivation in puna in Cochabmaba?

Monitoring and Modelling

- The “modeller”
- Hydrological Modelling advanced a lot in the 90s with “physically based models”
- “Physical” basis proved weak because not enough based on solid information: lack of knowledge of hydrological processes
- Please have clear the questions you want to get answers to with the modelling exercise! Maybe you need something else than a model!
- The best model does not exist, nor the universal one!
- Always include a proper uncertainty analysis, if uncertainty range very high, admit it!
- Let’s upgrade our information on processes and then come back to modelling

.

Thank you!

CONDESAN

Consorcio para el Desarrollo Sostenible de la Ecorregión Andina

Benefit sharing mechanisms in watersheds

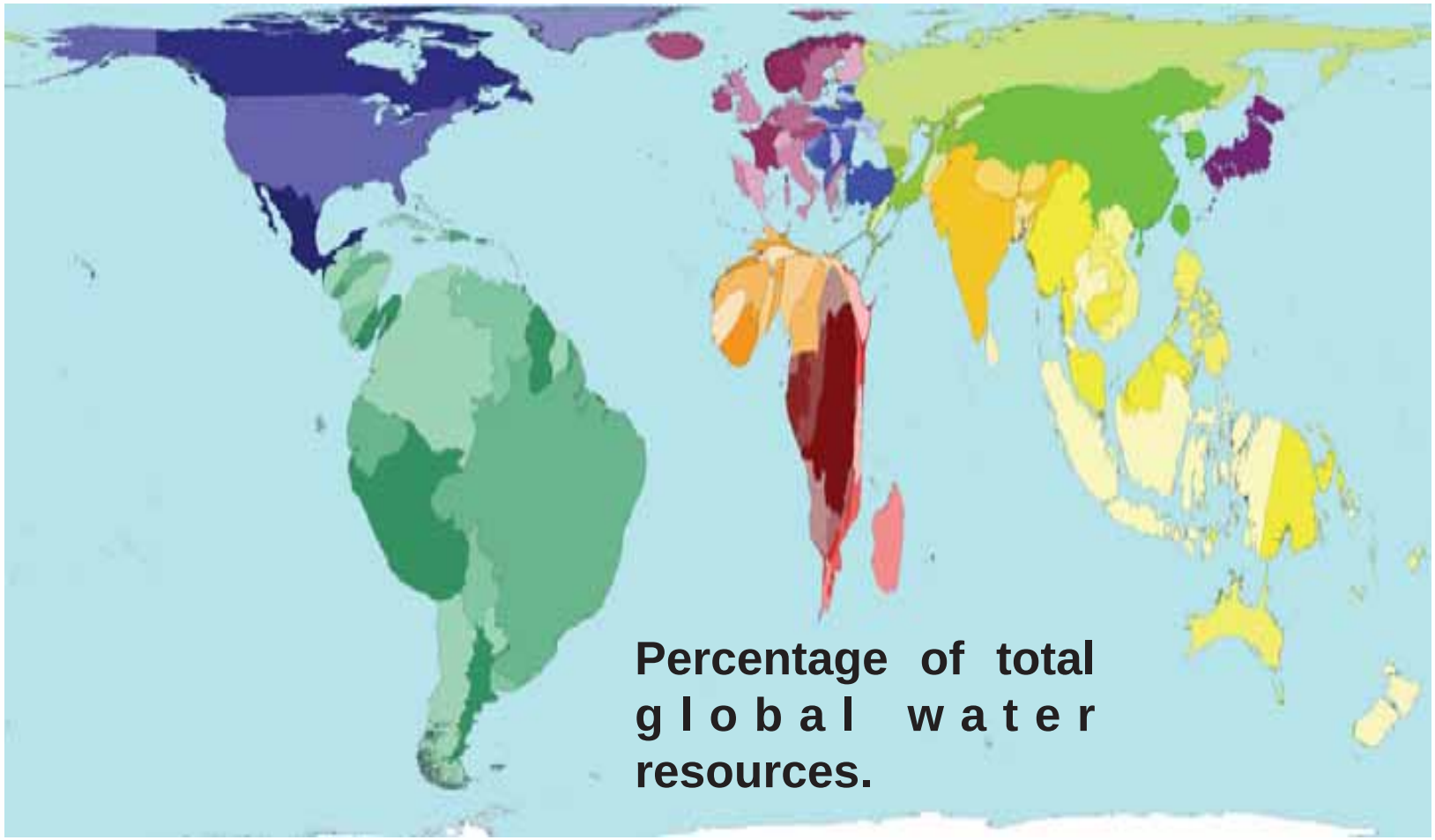
Bert De Bievre, Coordinador Cuencas Andinas, CONDESAN

PERÚ Ministerio del Ambiente

CGIAR Challenge Program on WATER & FOOD

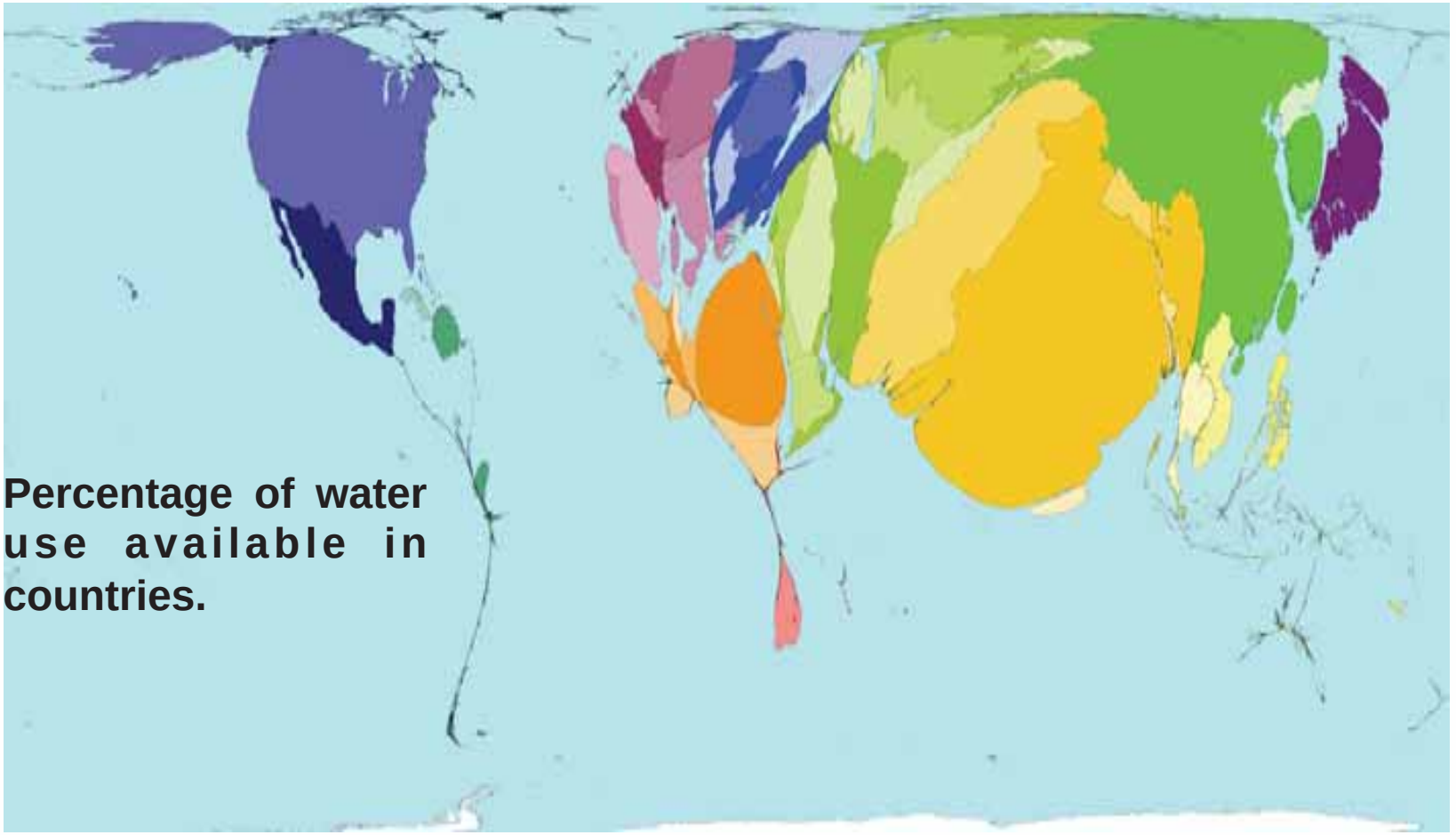
Andes • Ganges • Limpopo • Mekong • Nile • Volta

Water in The Andes



Fuente: Copyright 2006 SASI Group (University of Sheffield) and Mark Newman (University of Michigan)

Water in The Andes



Percentage of water use available in countries.

Fuente: Copyright 2006 SASI Group (University of Sheffield) and Mark Newman (University of Michigan)

We understand BSM as…

"***Processes of collective action, through fair and equitative negotiations and agreements between stakeholders of a catchment, in search of satisfying common needs around water productivity preserving base resources, and in search of quality of life"***

León, J., Lavado, A., Perdomo, D., Carvajal, B., Rubiano, J. 2011. Informe semestral Proyecto COMPANDES. Universidad Nacional de Colombia Sede Palmira – Centro Internacional de Agricultura Tropical.

1990s Payment for Environmental Services

"A voluntary transaction for an environmental service, in which at least one buyer and one seller participate; the environmental service is well defined, and the provider of the service ensures its provision" (Wunder, 1996)

It was assumed there was a big market for PES.

But "PES" schemes in the Andes, are not the result of market forces, but of negotiation and cooperation among different stakeholders.

"PES" schemes rooted in market are less likely to include equity and fight against poverty.

Water is considered a human right in many countries, should include strong social and cultural provisions.

CONDESAN, Panorama Andino on Hydrological Environmental Services, 2007.

Some concerns

1. Pay for what? Not for water, nor for the service itself, but for the activity that improves the service (important for not to delay payments)
2. Who receives? Issues on land ownership.
3. How to pay for intangible service? Issues on attribution of benefits. Amounts mostly determined by negotiations, not by valuation of the service.
4. Additionality, baseline and monitoring
5. How to pay? Cash vs in kind: compensation rather than payment.
6. Equity vs efficiency: “environmental criminal” gets paid, the “saint” does not get anything.

- In view of scarcity of information, adaptively managed.

BSM: A concept based on some criteria…

- Is born from a need of watershed stakeholders.
- Under mutual and voluntary commitment of watershed stakeholders.
- Equitative and fair for everybody. Equity has a lot to do with access to information.
- Improves environmental and socioeconomical conditions in the watershed.
- Is legal and legitimite.
- Participative: all stakeholders involved during each of the steps of the development of mechanism.
- In view of scarcity of information, adaptively managed.

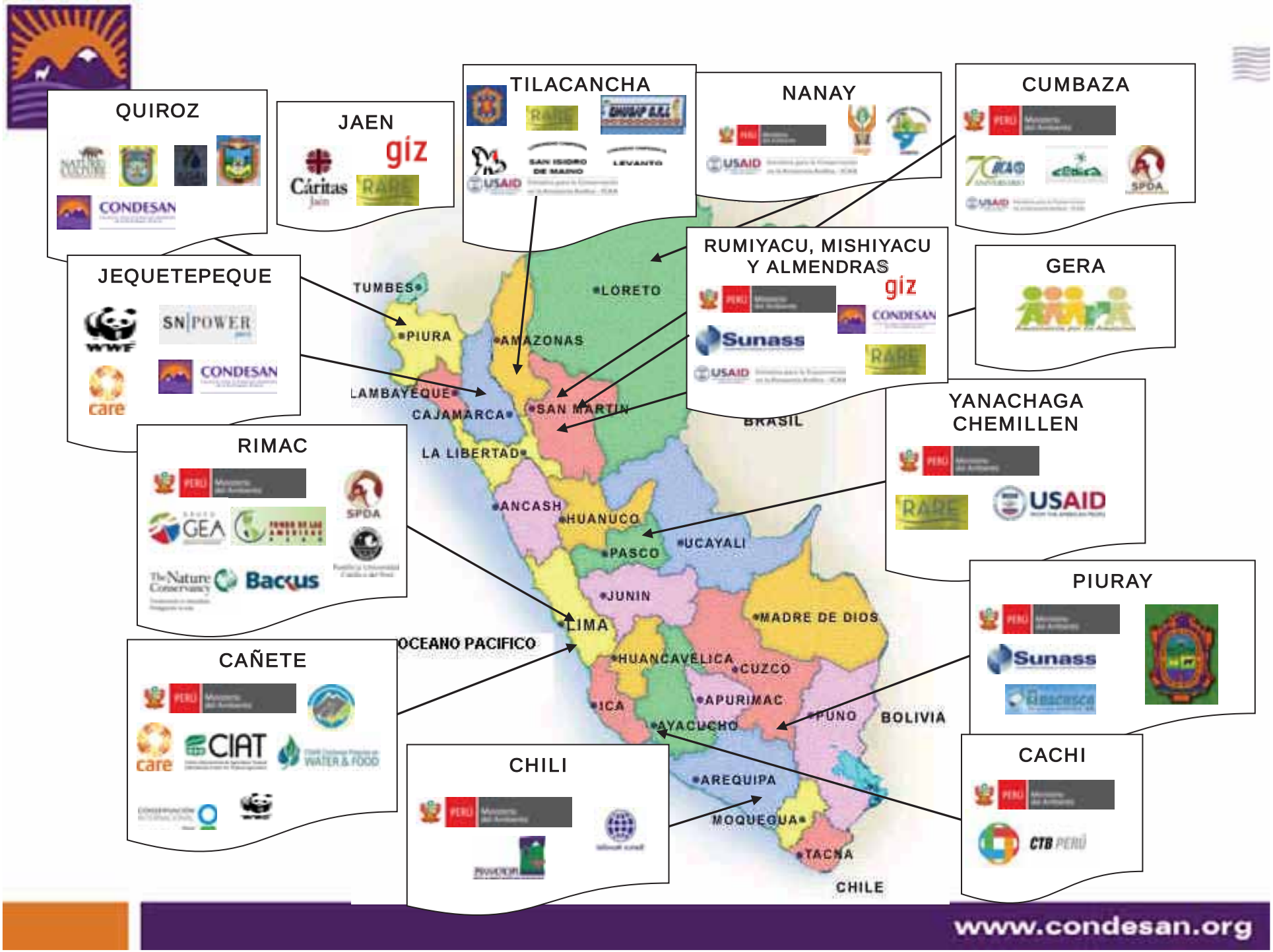
León, J., Lavado, A., Perdomo, D., Carvajal, B., Rubiano, J. 2011. Informe semestral Proyecto COMPANDES. Universidad Nacional de Colombia Sede Palmira – Centro Internacional de Agricultura Tropical.

Recommendations for BSM beyond the market

- Valuation of price of service is just a part of the negotiation.
- Allow for in kind compensation.
- Policies should be more about awareness and incentives, than about regulation. Water is always of public interest, legal framework helps to eliminate uncertainty.
- BSM want to recognize people that are doing “good”, but always recognize water property is from the state.
- Compromise between equity and efficiency: eliminate barriers for the less empowered to participate.

Types of BSMs

- **Depending on the scarcity:**
  - **BSM for conserving present state HES**
    - **More about equity, fairness, poverty alleviation**
    - **Most cases working in practice are here!**
  - **BSM for funding attempts of improving HES**
    - **Difficulties to deliver the service**
    - **Huge difficulties to prove delivery of the service**
- **Funding mechanism**
  - **Private voluntary**
  - **Public**
  - **Mixed**
  - **Water Fund**
- **Type of HES**
- **Scale: usually pops up naturally: which problem brings us together?**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Prioritizing hydrological ecosystem services

Case Main uses HES	Moyobamba Domestic water city	Jequetepeq Irr+hydro big reservoir	Cumbaza Irr+ domestic No reservoir	Gera Hydropower run of river
Water yield	+	++	no	no
Water regulation	+++	Reservoir!	++	+
Less sediments	++	+++	++	+
Less pollution	+	no	+	no
Groundwater recharge	no	no	no	+
Landscape	+	degraded	++	+
Flood control	no	no	no	+++

Prioritizing HES in mountains

- Under many circumstances it is not about water yield!
- Most watersheds in tropical mountains, not regulated by reservoirs, so natural regulation very important
- Sediment is issue many times, look for their origin
- Groundwater recharge minor issue in mountain

Sediments

- Local losses vs downstream accumulation
- Most of sediments accumulated in downstream reservoir has very focused origin
  - in space (very much coming from badlands, not from agriculture by poor farmers on high slopes)
  - in time (more than half from the 3 biggest events in a year)
- Therefore, collect field observations, almost all models based on (R)USLE, which is sheet erosion, specifically not applicable for young mountains, and on slopes of more than 20%!
- But when you only have a hammer, …

Hydropower

- We don’t really have the hydropower sector on board in BSM and PES
- Check your hypothesis on benefits with them. Some surprises might be:
  - Sediment really a problem?
  - Interest only in generating power during peak hours 6-10pm
- It’s not all about dams! Many options to make hydropower more sustainable


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