Landscape patterns and ecosystem service provisioning in a Highland Landscape of northern Ecuador

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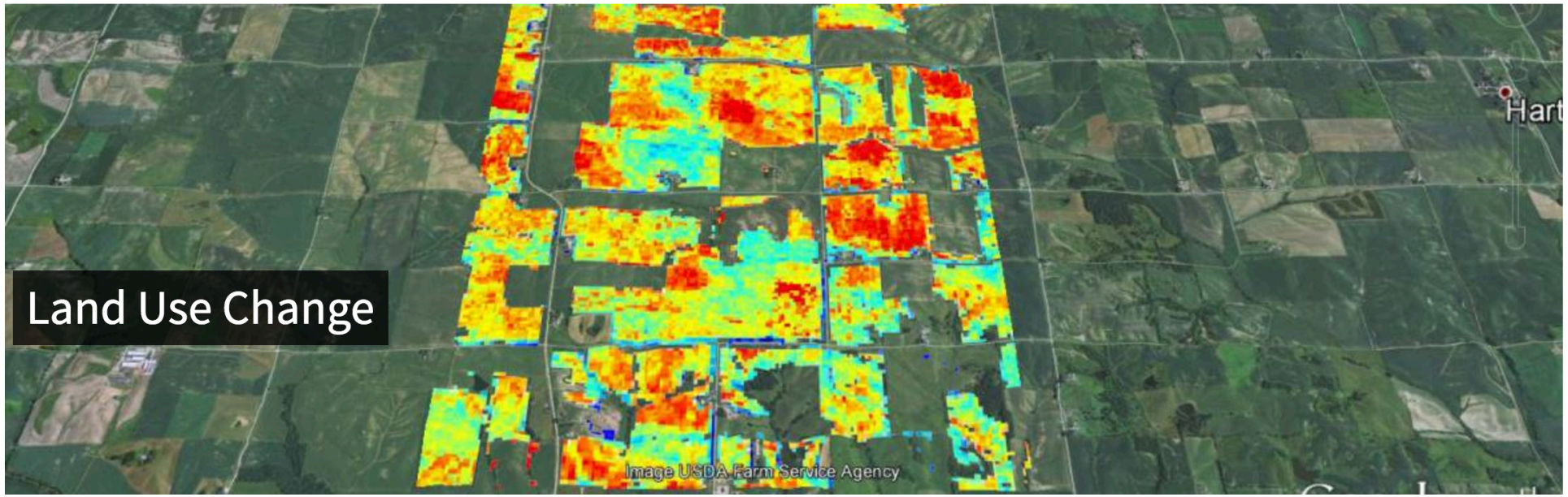
Outline

- Context
- Justification
- Research Question
- Methods
- Preliminary results
- Summary

Context

Land Use Change is the most important variable affecting ecological system

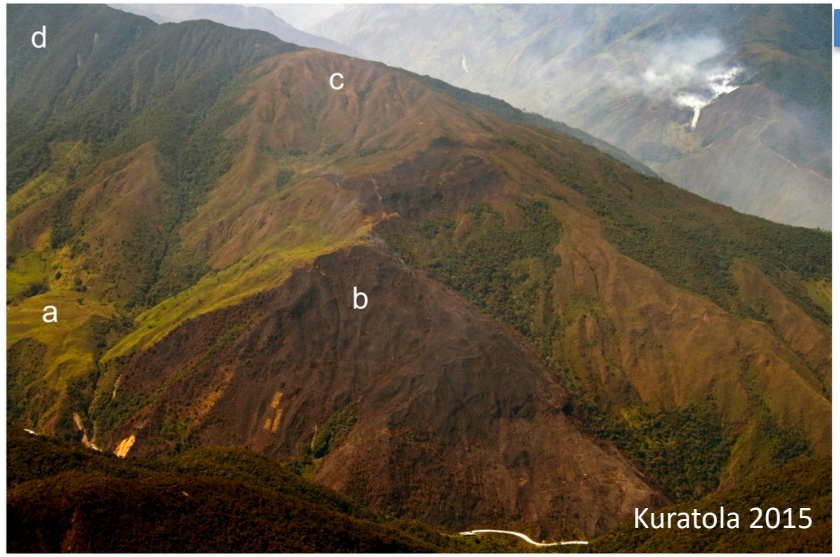


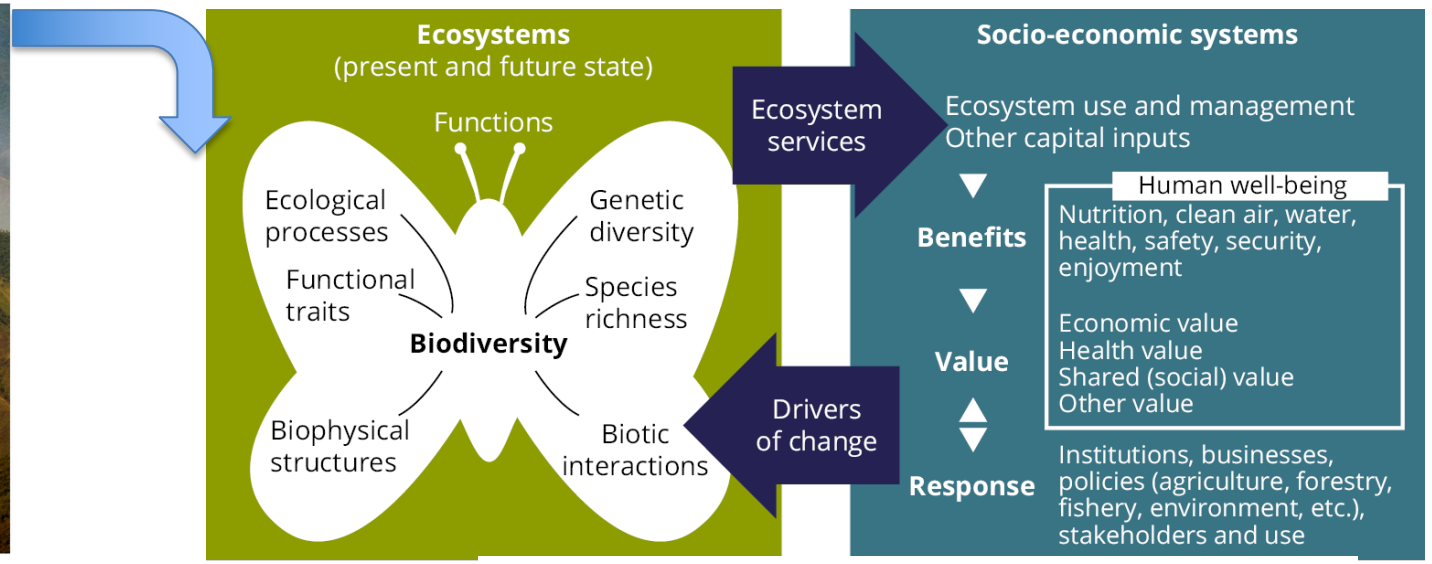
Global carbon cycle
Global, regional and local climates
Hydrologic cycle
Ecosystem degradation
Biodiversity loss
Degradation of soil and water
Overexploitation of native species

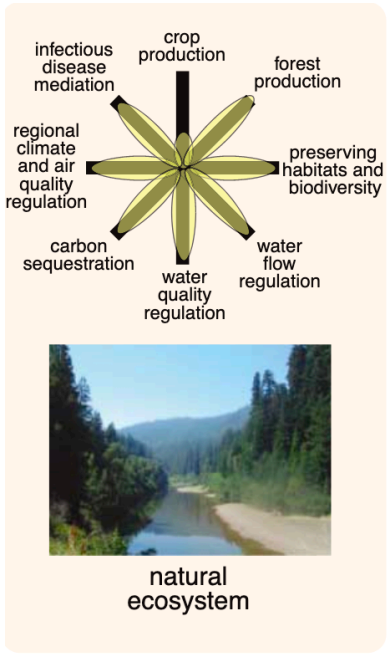
Sala et al 2000, Foley et al 2005

Land use or land cover change impacts on a very diverse array of environmental systems, properties and processes

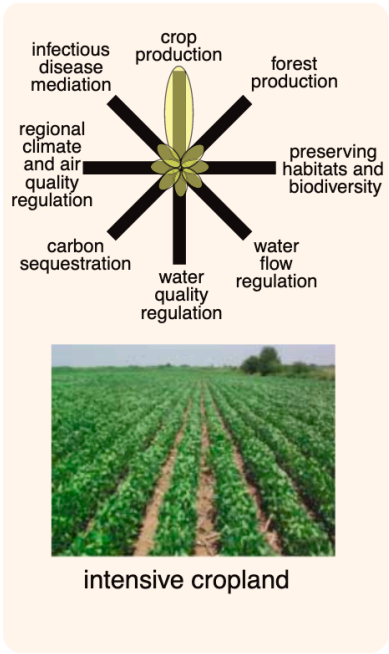
LU change affects the physical and biological properties of landscapes and can impact the provision of multiple ecosystem services



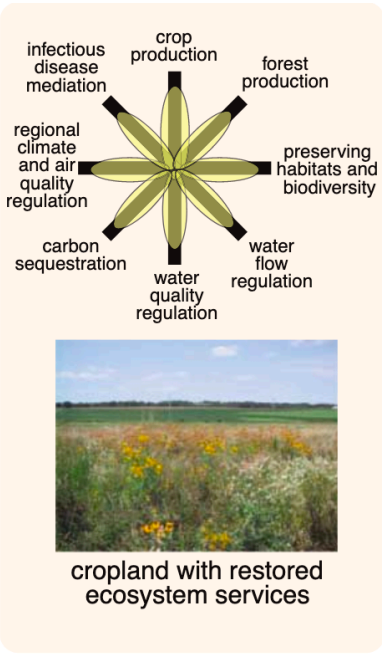




natural ecosystem



intensive cropland



cropland with restored ecosystem services

ROY HAINES-YOUNG AND MARION POTSCHIN

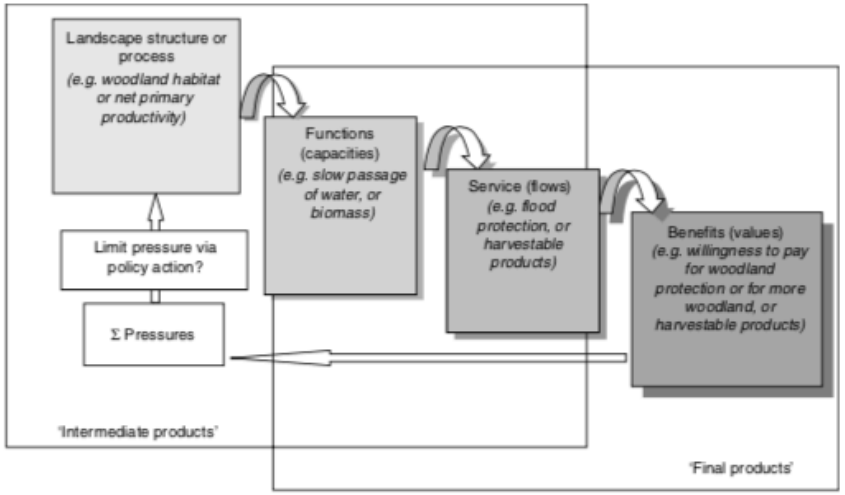


Figure 6.2 The relationship between biodiversity, ecosystem function and human well-being.

Mountain landscapes provide multiple ecosystem services that are continually vulnerable to land-change

- Half of the world population depends on mountain ecosystem resources

  Millenium Ecoystem Assessment, 2005

- Complex land-change dynamics have been documented in the high-Andean region

  Aide et al. 2013

- Land use change may affect ecological processes at different scales, affecting ecosystem services

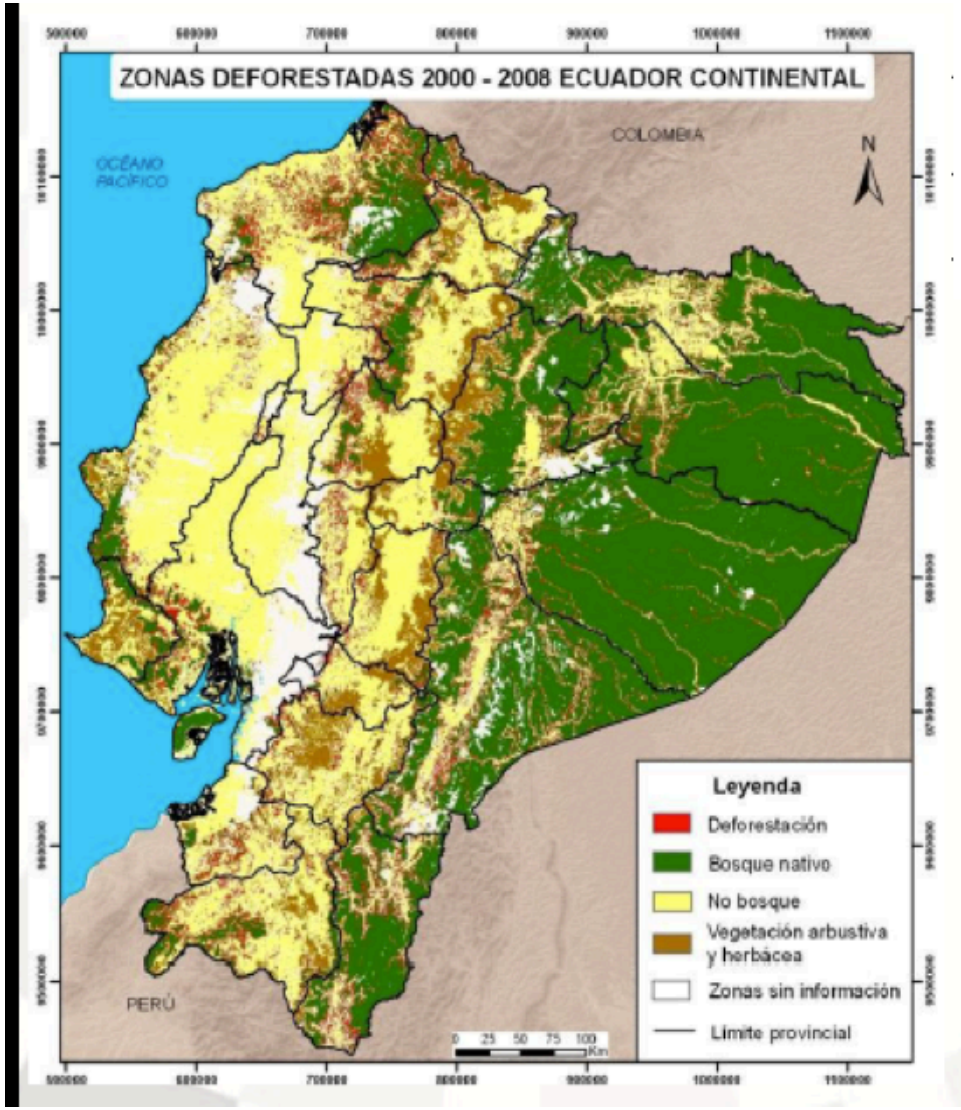
- Qt. assessment of LU changes on the value of ES is one of the research focuses of sustainable development in science

Montane ecosystems of Ecuador have been affected by loss of natural vegetation cover and fragmentation as a result of land use change

- Landscapes of the Ecuadorian highlands are the result of a long-term interaction between people and their natural environment

- Landscape transformation started early on when the Spanish conquered the land to establish different productive systems (agricultural and cattle raising) more than 500 years ago

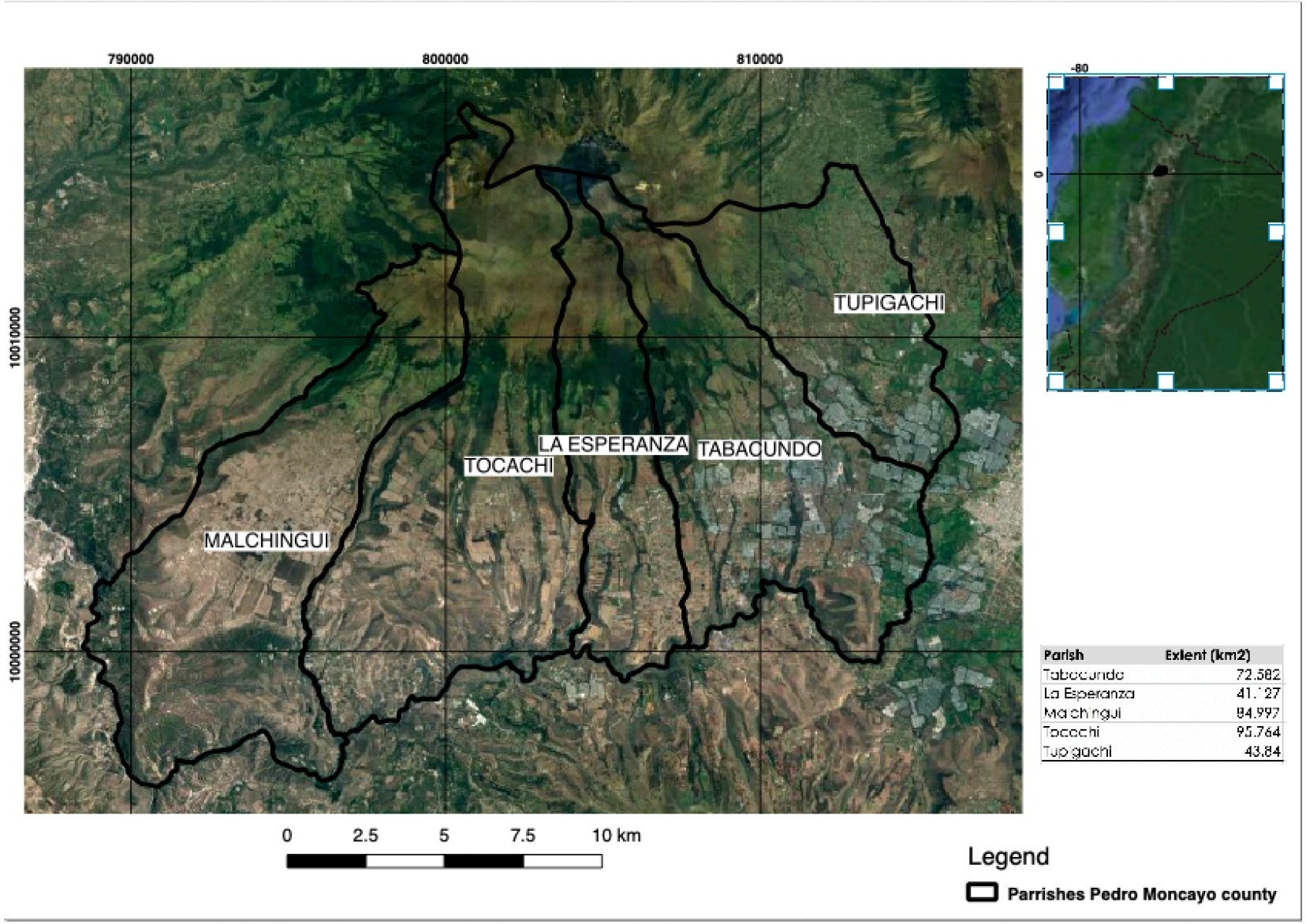
Montane ecosystems of Ecuador have been affected by loss of natural vegetation cover and fragmentation as a result of land use change



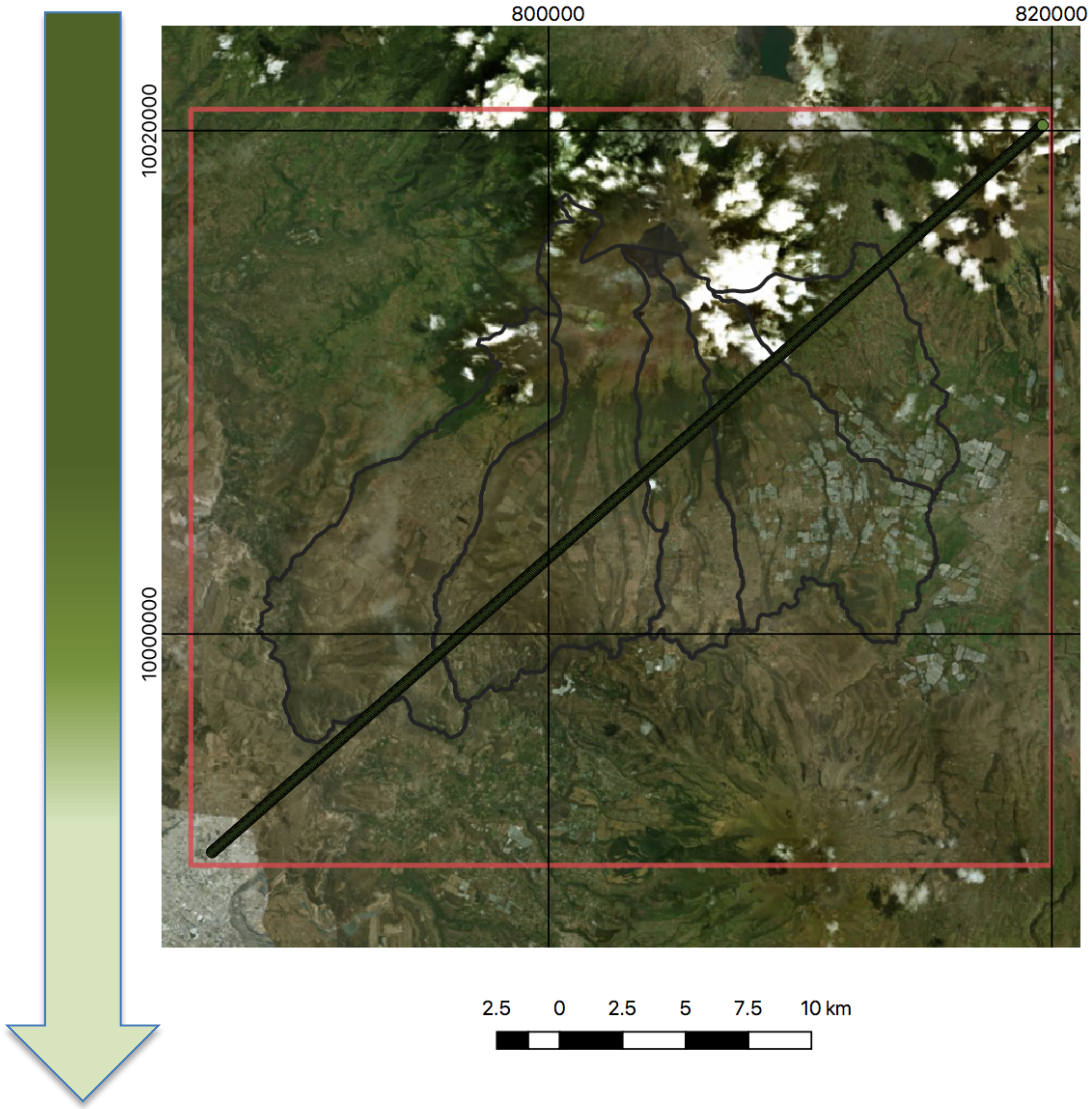
- Mountain native ecosystems in Ecuador are threatened, they are remnant forests in a matrix of agricultural land
- The impact of land use changes on biodiversity and the value of mountain ecosystems in Ecuador has not been evaluated

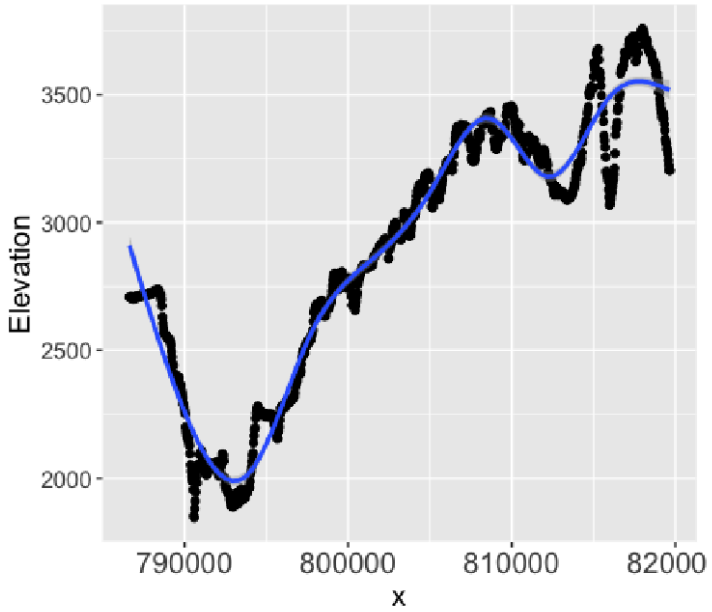
Pedro Moncayo county →Interesting model system to improve our understanding on LULC change and ES

UNIVERSIDAD CENTRAL DEL ECUADOR
Omnium potentior est sapientia



Pedro Moncayo county →Andean landscape with environmental gradients (altitudinal)





Legend

- Study area
- Elevation_profile_PM
- Pedro Moncayo County - parishes

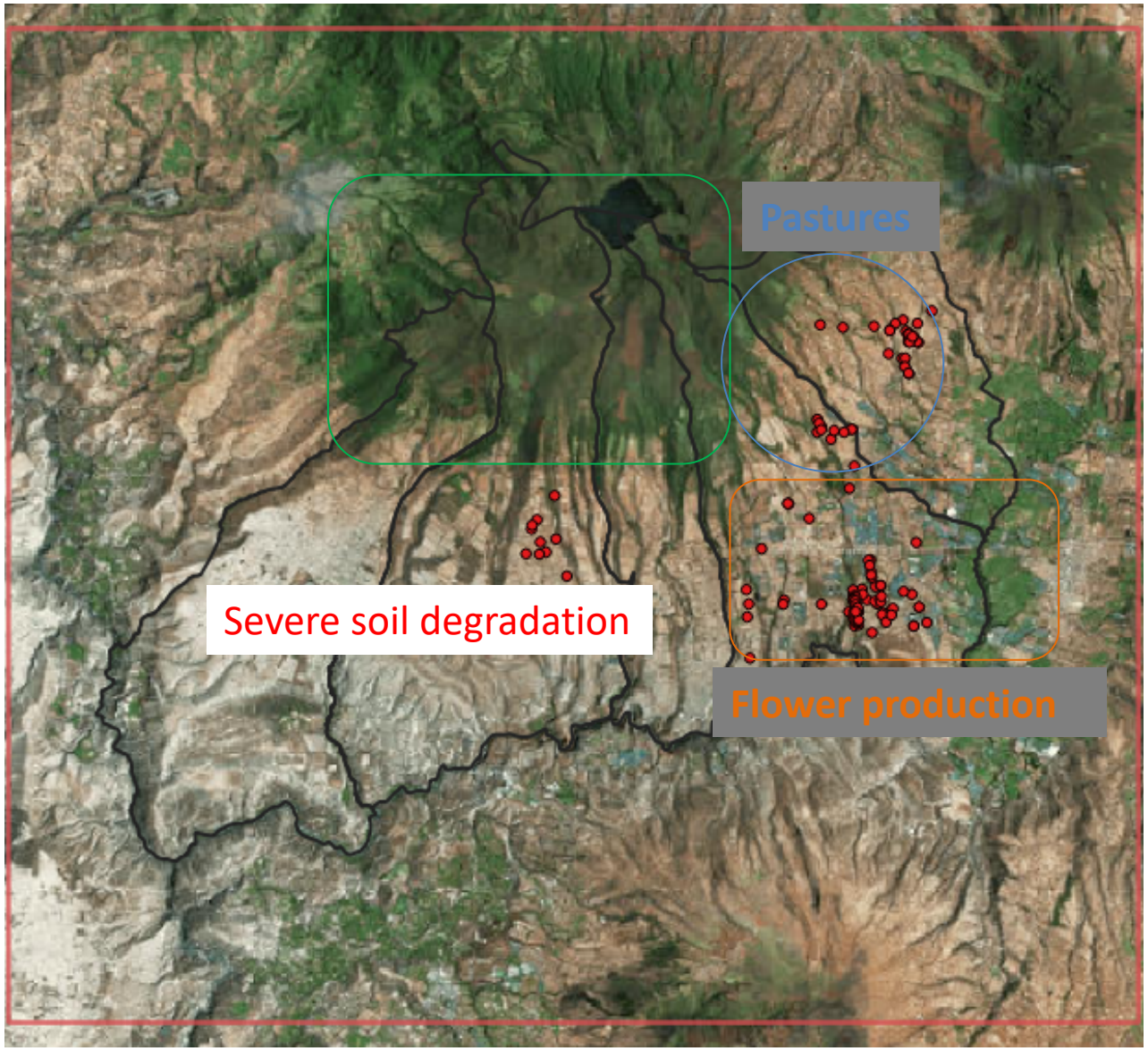
Projection: Universal Trasnsver Mercator
Zone: 17S
Datum: WGS84

Pedro Moncayo county →Andean landscape with a land use intensity gradient – Landscape level

>60%
Ecosystem modif. Agric

Native ecosystems
- **Paramo**
- **Mountain forests**

Agriculture + Pastures + urban areas
- Monoculture farms
- cereals
- tubercules
- Agroecologic farms



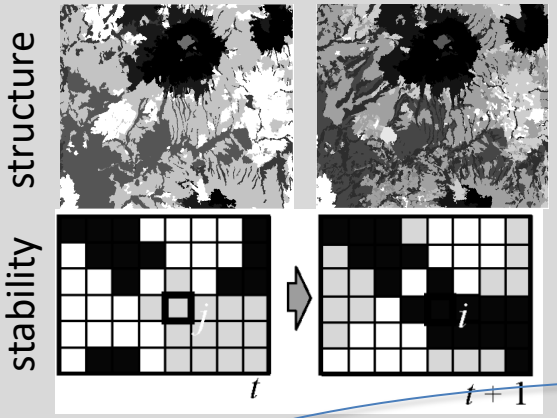
Research question

How land use change has influenced landscape patterns and the capacity of ecosystems to provide services in a highland landscape of northern Ecuador?

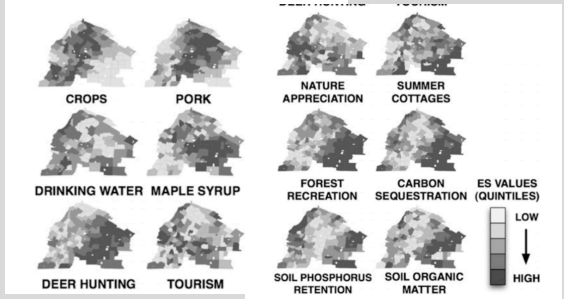
To contribute to the understanding of the impacts of land use changes towards biodiversity, ecosystem services and benefit transfer for the Andean mountain systems of Ecuador

1 **Landscape pattern and ES**

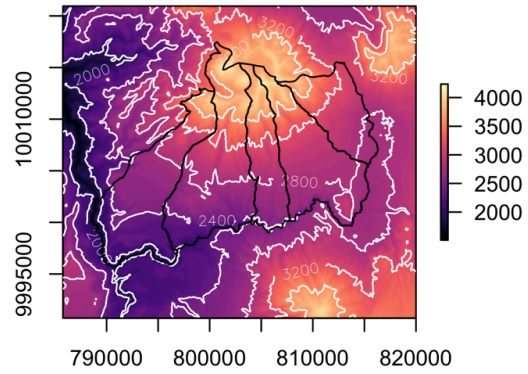
Landscape pattern analysis - time



Map Ecosystem Services



Raudsepp-Hearne et al 2010; Rodríguez-Echeverry et al 2018



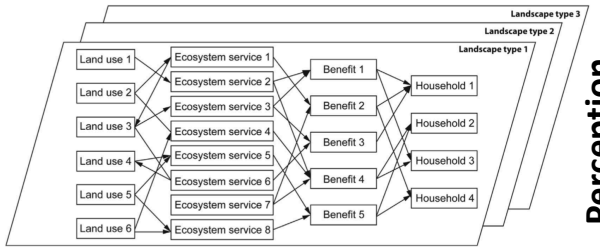
Transfer values - Benefits

Censuses data
Socio-economic surveys

How land use change (LULC) affects biodiversity and ecosystem services in a highland landscape of northern Ecuador?

2 **Perception of stakeholders of ES p**

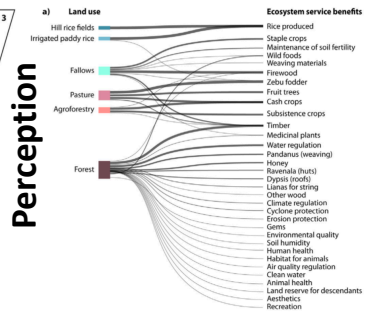
Questionnaires



Zaehringer *et al 2017*

ES supply by LULC

Perception



3 **Functional groups diversity, EF, ES in df. LUlC**

Soil biota
Arthropods
Vegetation
Microorg.

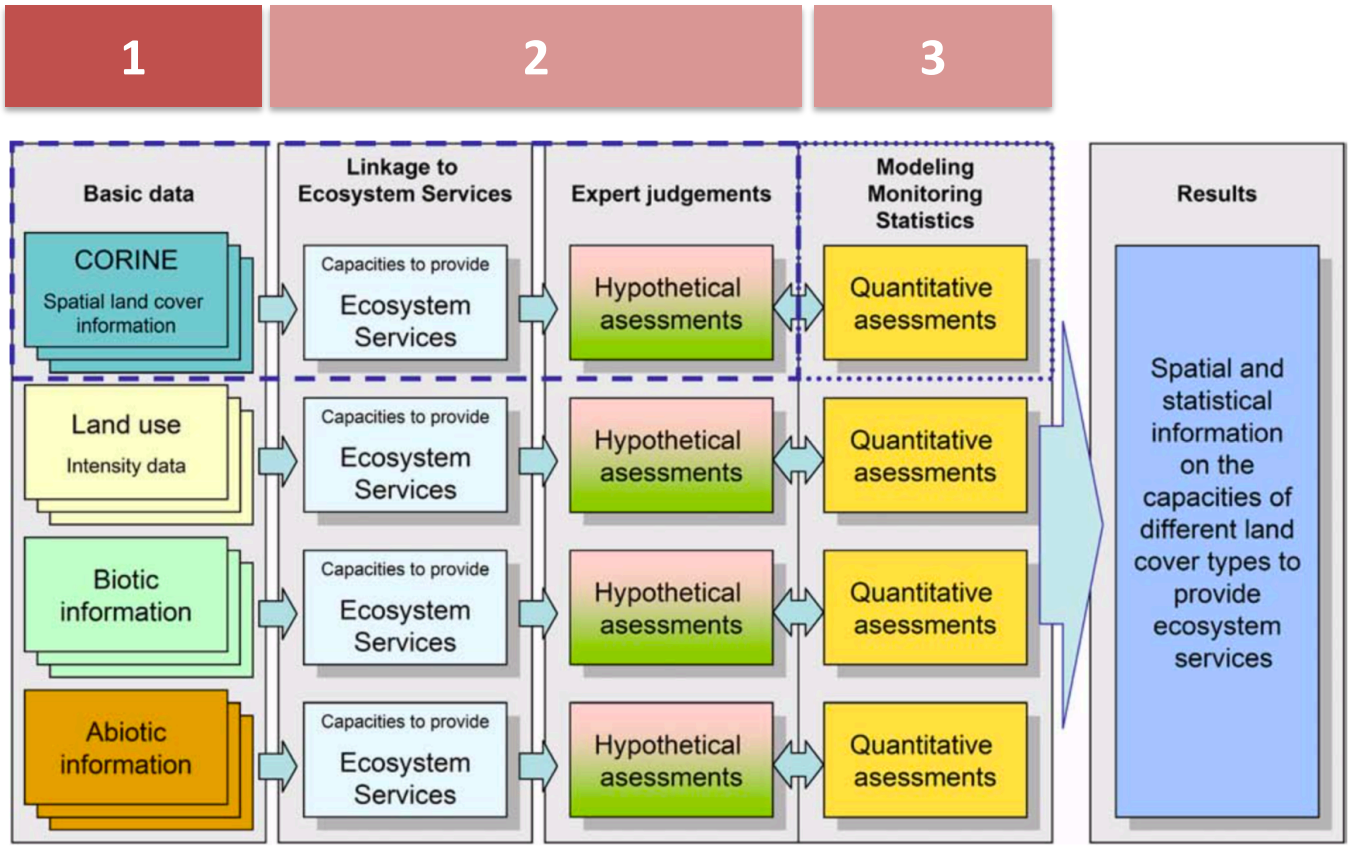
Ec. Function
Mineralization
Soil formation

Soil ES
Soil fertility
Erosion preven.
H_2O hold. Cap.
Microclimate reg.

De VAlençA *et al 2017*

Methods

How LULC change has influenced the capacity of ecosystems to provide ES in the study area ?



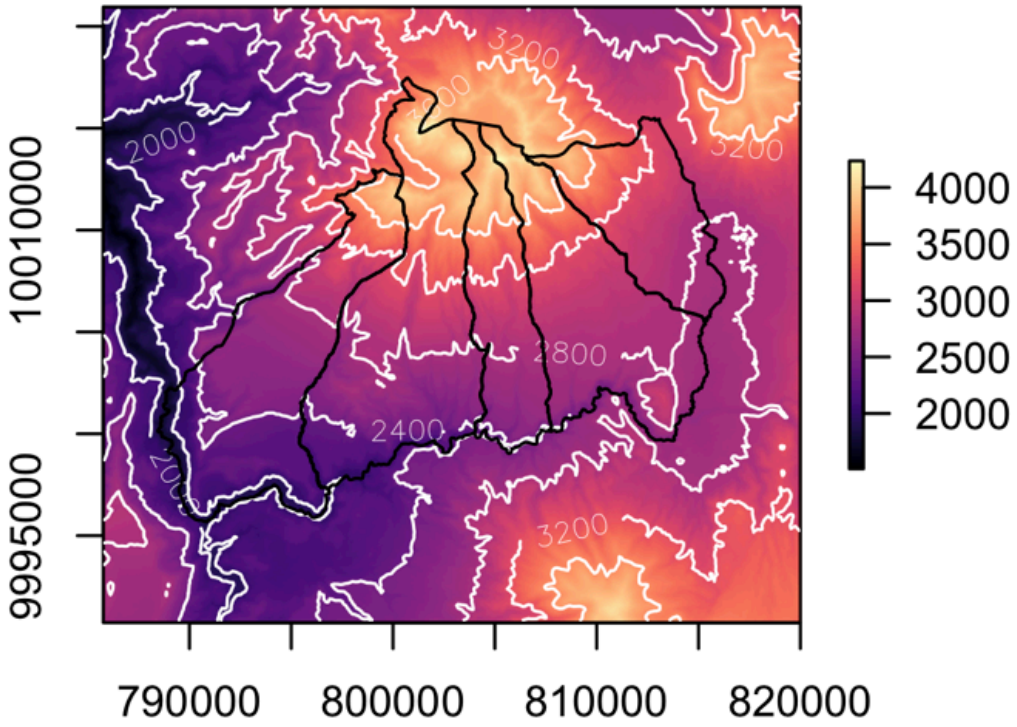
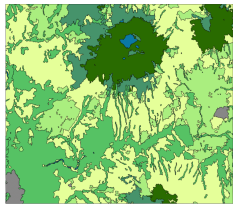


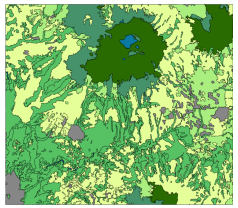
Figure 5: Conceptual framework to assess and quantify landscapes' capacities to provide ecosystem services. The dashed and dotted lines indicate the components presented with examples in this paper.

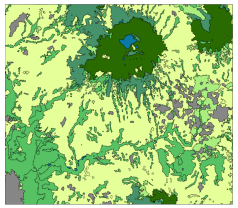
Burkhard (2009, 2012)

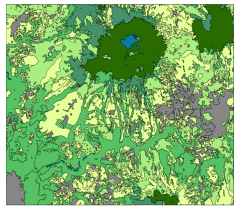
Estimation of land use patterns and dynamics through time

Official Source of LULC data:
Ecuadorian Ministry of Environment

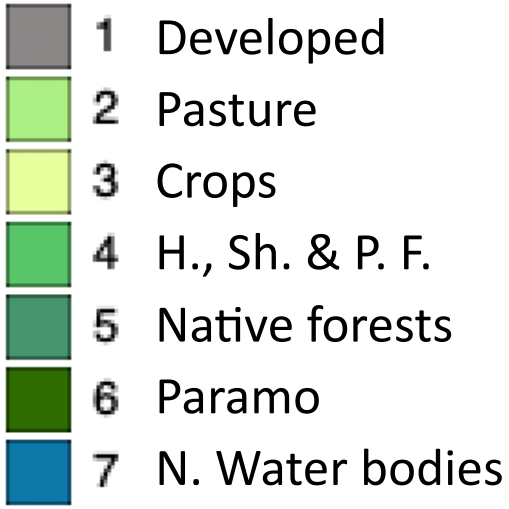

1990


2000


2008

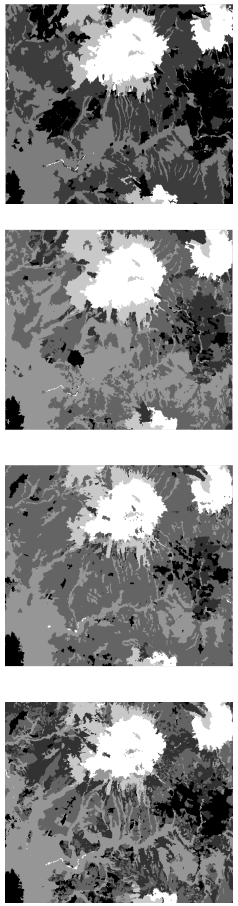

2014

Reclass 13 (level 2) classes to 7 simp. typ



Shapefiles
From LANDSAT
Resolution:
30 x 30 m

Rasterize



Landscape structure

Land cover: sq. km & %

Landscape dynamics

Transition Matrix

Transition Probability Markov chain

Score the capacity of LULC typ. to provide ES

LULC typ.

1 Developed
2 Pasture
3 Crops
4 H., Sh. & P. F.
5 Native forests
6 Paramo
7 N. Water bodies

Scoring LULC

Available maps
Literature review
Knowledge of the system (EJ)

Types of ES

Regulating

Provisioning

Cultural

Burkhard (2009, 2012)

Scale for assessing potential supply

0.00 - 0.83	no relevant potential supply
>0.83 - 1.67	very low potential supply
>1.67 - 2.50	low potential supply
>2.50 - 3.34	medium potential supply
>3.34 - 4.17	high potential supply
>4.17 - 5.00	very high potential supply

Madrigal-Martinez & Miralles (2019)

CORINE land cover type:	Ecological Integrity Σ	Abiotic heterogeneity	Biodiversity	Biotic waterflows	Metabolic efficiency	Exergy Capture (Radiation)	Reduction of Nutrient loss	Storage capacity (SOM)	Regulating services Σ	Local climate regulation	Global climate regulation	Flood protection	Groundwater recharge	Air Quality Regulation	Erosion Regulation	Nutrient regulation	Water purification	Pollination	Provisioning services Σ	Crops	Livestock	Fodder	Capture Fisheries	Acquaculture	Wild Foods	Timber	Wood Fuel	Energy	Biochemicals and Medicine	Freshwater	Cultural services Σ	Recreation& Aesthetic Values	Intrinsic Value of Biodiversity
Continuous urban fabric	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Discontinuous urban fabric	7	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	3	1	0	1	0	0	1	0	0	1	0	0	0	0	0
Industrial or commercial units	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Road and rail networks	4	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Port areas	2	1	1	0	0	0	0	0	3	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
Airports	7	1	1	1	1	1	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Mineral extraction sites	4	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
Dump sites	8	2	1	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Construction sites	3	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Green urban areas	18	3	3	2	1	4	3	2	11	2	1	0	2	1	2	1	1	1	2	0	0	0	0	0	1	0	1	0	0	0	3	3	0
Sport and leasure facilities	16	2	2	2	1	4	3	2	9	1	1	0	2	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	5	5	0
Non-irrigated arable land	22	3	2	3	4	5	1	4	5	2	1	1	1	0	0	0	0	0	21	5	5	5	0	0	0	0	0	2	1	0	1	1	0
Permanently irrigated land	21	3	2	5	2	5	1	3	5	3	1	1	0	0	0	0	0	0	18	5	5	2	0	0	0	0	0	1	1	0	1	1	0
Ricefields	20	3	2	5	1	5	1	3	4	2	0	0	2	0	0	0	0	0	7	5	0	2	0	0	0	0	0	0	0	0	1	1	0
Vineyards	14	3	2	3	1	3	0	2	3	1	1	0	1	0	0	0	0	0	5	4	0	0	0	0	0	0	1	1	0	0	5	5	0

Burkhard (2012)

Author scoring

Next steps:
Expert judgement
Local stakeholder perception

Score the capacity of LULC typ. to provide ES

Types of ES

Regulating

- L_clim_ reg
- G_clim_ reg
- Water purification
- Soil erosion regulation
- Water flow regulation

Provisioning

- Crops
- Livestock
- Fodder
- Wild food
- Wood fuel
- Timber
- Fresh water

Cultural

- Intrinsic value of biodiversity
- Recreation & aestethic values

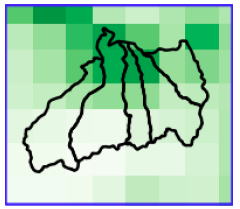
Madrigal-Martinez & Miralles (2019)

Burkhard (2009, 2012)

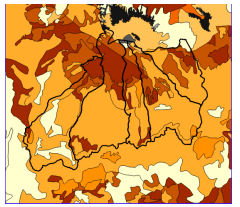
Burkhard (2012)

Regulating Ecosystem services

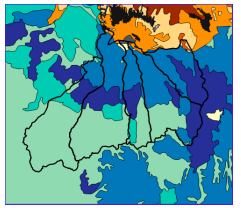
Organic C



Soil erosion susc.

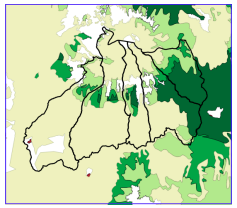


Soil fertility



Provisioning Ecosystem services

Potential for potato production



Cultural Ecosystem services

Natural tourism attractions

Author scoring

Next steps:
Expert judgement
Local stakeholder perception

Test the hypothetical scoring of the capacity of LULC typ. to provide ES of existing data

Quantification of ES based on official statistics for different years

Land cover class [GJ/ha]	Year	Crops	Fodder	Livestock	Capture Fisheries & Aquaculture	Wild Foods	Food provision (weighted aggregation)
		Classification					
Non-irrigated arable land	1990	43,7	183	0	0	0	38
	2000	59,9	200,6	0	0	0	49,2
Fruit trees and berry plantations	1990	25,5	0	0	0	0	25,5
	2000	70	0	0	0	0	70
Pastures	1990	0	0	9,4	0	0	9,4
	2000	0	0	14	0	0	14
Complex cultivation pattern	1990	22	45,7	0	0	0	21,1
	2000	37,7	50,1	0	0	0	30
Arable land and natural vegetation	1990	32,8	137	0	0	0	28,8
	2000	44,9	150	0	0	0	36,8
Water bodies	1990	0	0	0	1,3	0	1,3
	2000	0	0	0	0,5	0	0,5
Forests	1990	0	0	0	0	0,01	0,01
	2000	0	0	0	0	0,02	0,02

very high relevant capacity | high relevant capacity | medium relevant capacity | relevant capacity | low relevant capacity | no relevant capacity

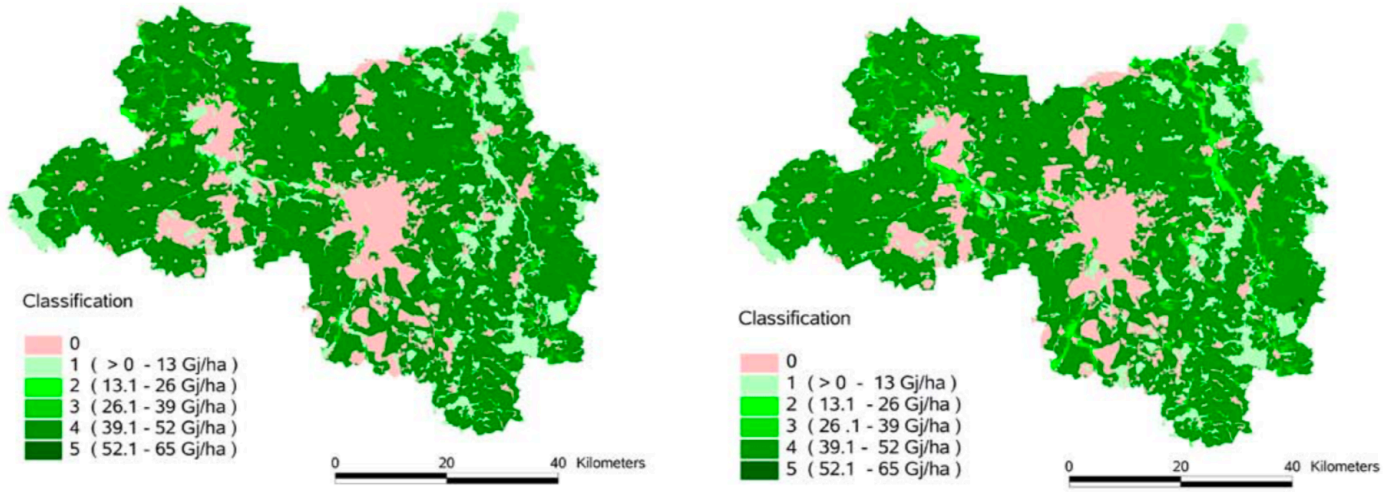


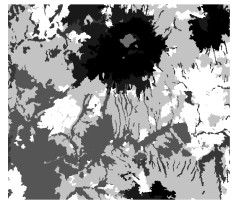
Figure 3: Spatial distribution of the ecosystem service "crop provision" in the year 1990 (left) and 2000 (right) for the region of Leipzig, Halle, and surrounding districts.

Preliminary results

1

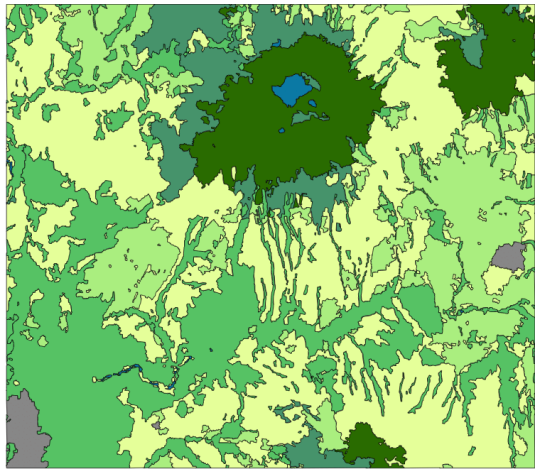
Estimation of land use patterns and dynamics through time

1

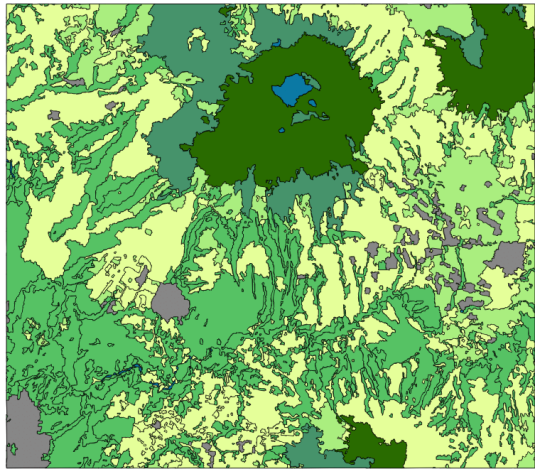


Main land uses in the territory are Agricultural areas (C + P) followed by Secondary vegetation (Herbs + Shrubs)

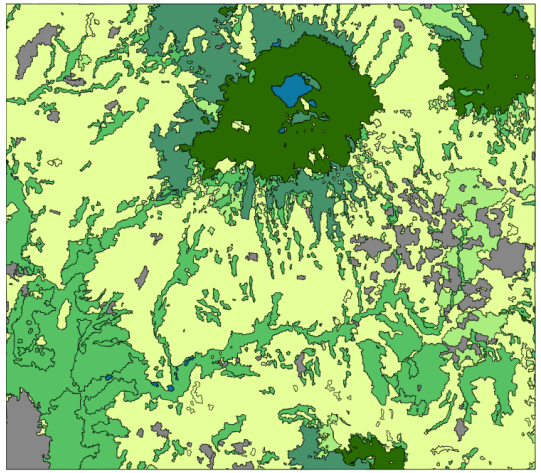
1990



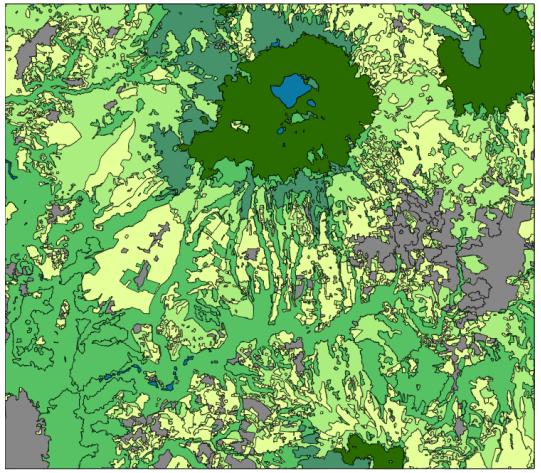
2000



2008

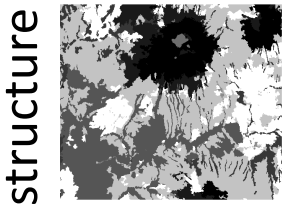


2014

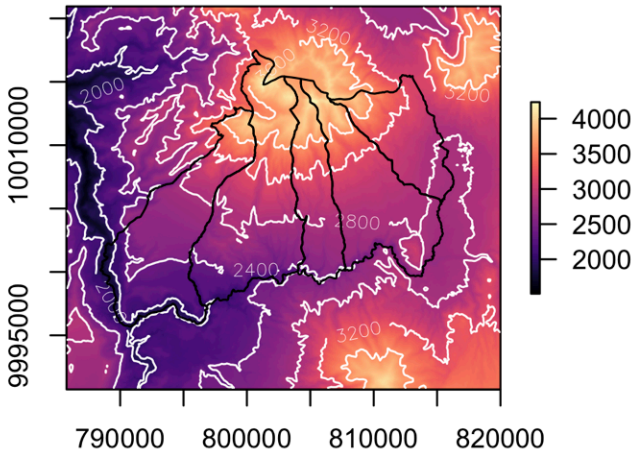


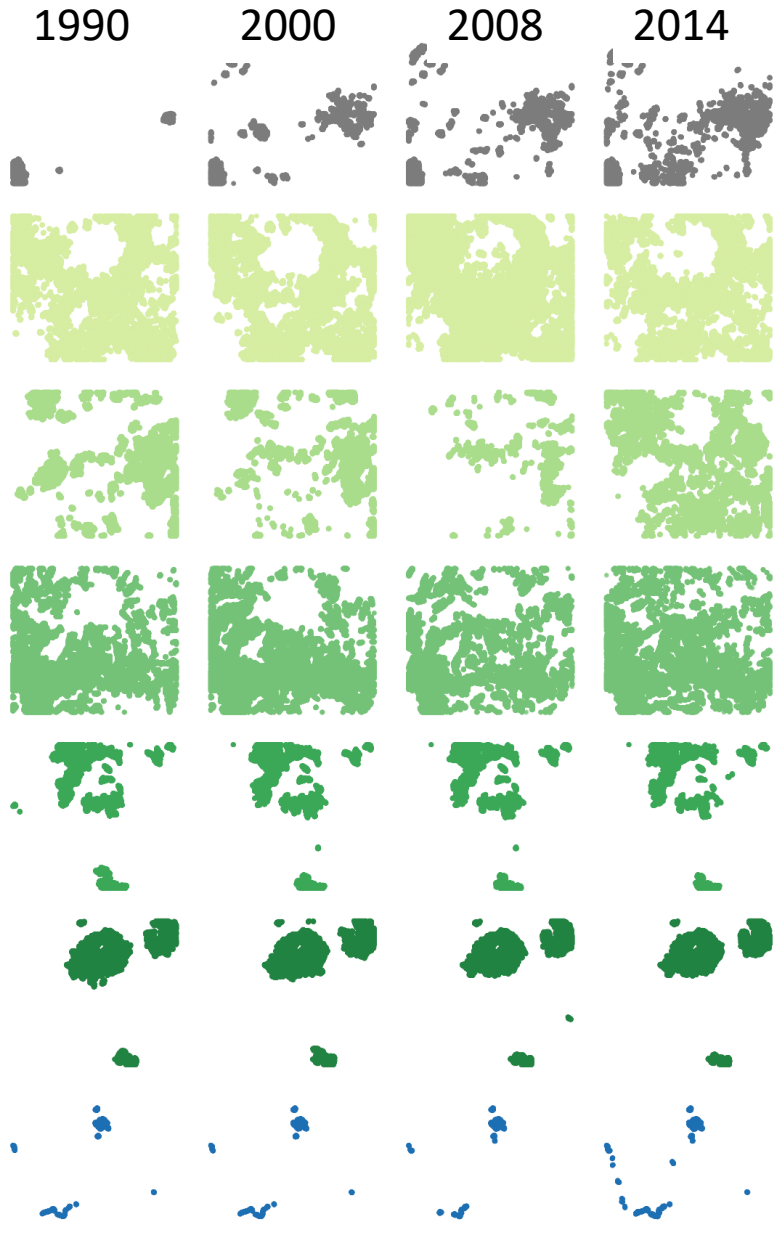
1 Developed
2 Pasture
3 Crops
4 Herbs, Shrubs & P. F.
5 Native forests
6 Paramo
7 N. Water bodies

1990		2000		2008		2014	
Area km^2	%	Area km^2	%	Area km^2	%	Area m^2	%
13.3272	1.30	36.3411	3.54	54.7587	5.33	90.4554	8.81
171.729	16.72	112.8204	10.99	43.7562	4.26	219.0708	21.33
377.6382	36.77	340.1856	33.12	534.9384	52.09	261.4797	25.46
270.7848	26.37	334.4724	32.57	217.5489	21.18	289.7694	28.21
75.5028	7.35	82.3158	8.01	70.1784	6.83	57.5928	5.61
113.8104	11.08	116.6319	11.36	101.7144	9.90	103.653	10.09
4.2336	0.41	4.2588	0.41	4.131	0.40	5.0049	0.49

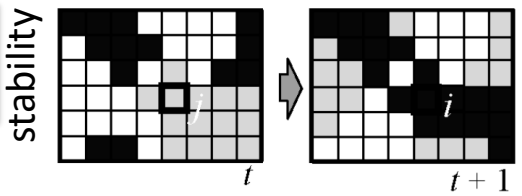


Dynamic landscape through time: Decreasing Crops, Natural ecosystems, increasing pastures and developed areas





	% ▲ 2014-1990
Developed	5.79
Crop	-0.31
Pasture	0.28
Herbs, Shrubs & Planted Forests	0.07
Native forests	-0.24
Paramo	-0.09
Natural Water bodies	0.18



Land-change dynamics through time demonstrate different trajectories

Land use transition matrix

Lange-change dynamic	Type of change	1990 to 2000		2000 to 2008		2008 to 2014		1990 to 2014	
		km	%	km	%	km	%	km	%
Agricultural expansion	Shr to C	156.15	19.17	474.86	43.48	57.59	7.88	104.66	7.73
	NF to C	31.52	3.87	100.12	9.17	7.78	1.06	31.78	2.35
	Pr to C	19.64	2.41	75.65	6.93	0.00	0.00	19.05	1.41
	Shr to P	0.00	0.00	7.20	0.66	42.64	5.83	159.28	11.77
	NF to P	15.68	1.92	28.21	2.58	73.65	10.07	110.02	8.13
	Pr to P	24.36	2.99	12.14	1.11	0.00	0.00	43.98	3.25
Agricultural de-intensificacion	C to Shr	287.88	35.34	77.89	7.13	162.04	22.17	183.87	13.59
	C to Pr	17.01	2.09	2.52	0.23	1.83	0.25	7.58	0.56
	P to Shr	76.67	9.41	67.81	6.21	80.76	11.05	89.04	6.58
	P to Pr	6.50	0.80	3.19	0.29	0.00	0.00	1.76	0.13
	C to NF	14.83	1.82	2.75	0.25	2.29	0.31	6.35	0.47
	P to NF	7.49	0.92	10.02	0.92	1.01	0.14	5.85	0.43
Deforestation	NF to Pr	1.57	0.19	0.00	0.00	12.67	1.73	13.23	0.98
	NF to Shr	27.02	3.32	60.18	5.51	118.58	16.22	164.30	12.14
	Pr to Shr	4.82	0.59	57.19	5.24	1.32	0.18	67.57	4.99
Urbanization	P to D	57.43	7.05	55.56	5.09	95.80	13.10	205.97	15.22
	C to D	26.75	3.28	37.89	3.47	60.79	8.32	88.10	6.51
	Shr to D	14.18	1.74	12.49	1.14	3.70	0.51	38.96	2.88
	NF to D	0.00	0.00	1.50	0.14	0.07	0.01	0.45	0.03
	Pr to D	0.00	0.00	0.20	0.02	0.18	0.02	0.37	0.03
Natural process	Shr to NF	21.16	2.60	3.32	0.30	3.38	0.46	8.29	0.61
	Shr to Pr	3.03	0.37	1.33	0.12	4.97	0.68	1.96	0.15
	Pr to NF	1.01	0.12	0.00	0.00	0.00	0.00	1.01	0.07
Total change		814.704	100	1092.01	100	731.062	100	1353.45	100.00

Madrigal-Martinez & Miralles (2019)

2

Score the capacity of LULC typ. to provide ES

Score the capacity of LULC typ. to provide ES

LULC typ.

1 Developed
2 Pasture
3 Crops
4 H., Sh. & P. F.
5 Native forests
6 Paramo
7 N. Water bodies

Scoring LULC

Available maps
Literature review
Knowledge of the system (EJ)

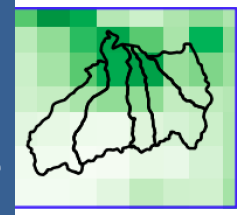
Types of ES

Regulating
Provisioning
Cultural

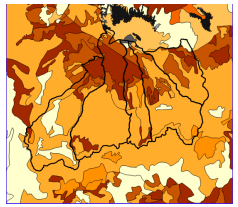
Burkhard (2009, 2012)

Regulating Ecosystem services

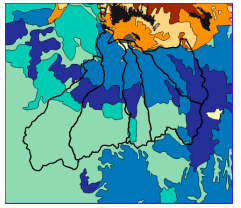
Organic C



Soil erosion susc.

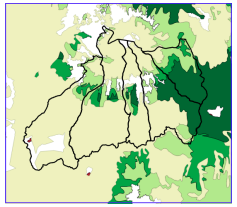


Soil fertility



Provisioning Ecosystem services

Potential for potato production



Scale for assessing potential supply

0.00 - 0.83	no relevant potential supply
>0.83 - 1.67	very low potential supply
>1.67 - 2.50	low potential supply
>2.50 - 3.34	medium potential supply
>3.34 - 4.17	high potential supply
>4.17 - 5.00	very high potential supply

Author scoring

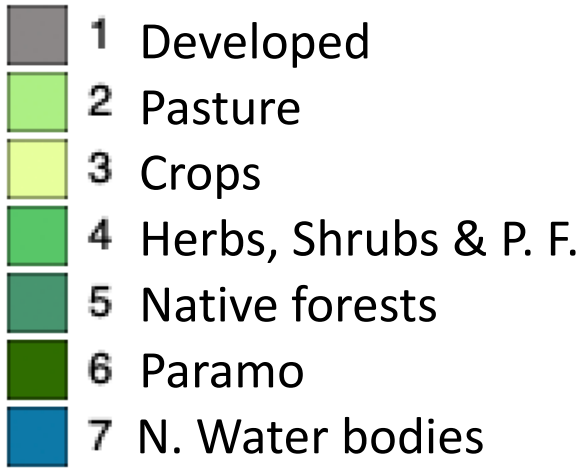
Next steps:
Expert judgement
Local stakeholder perception

Cultural Ecosystem services

Natural tourism attractions

Next steps:
Expert judgement
Local stakeholder perception

Score the capacity of LULC typ. to provide ES

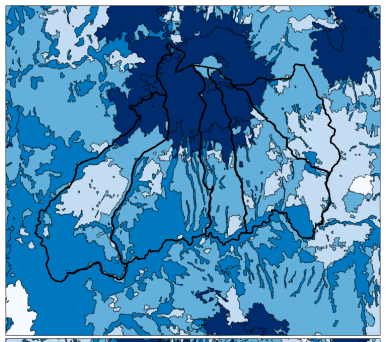
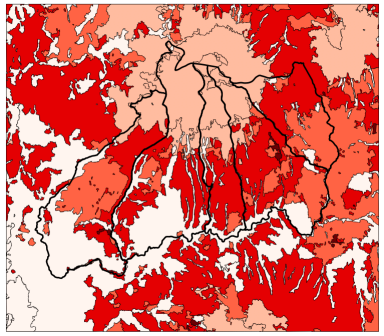
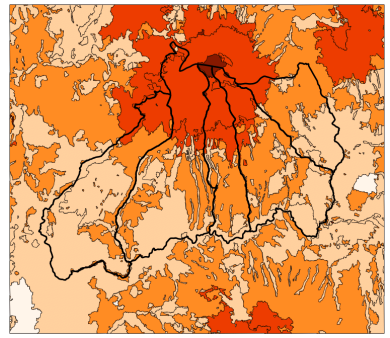
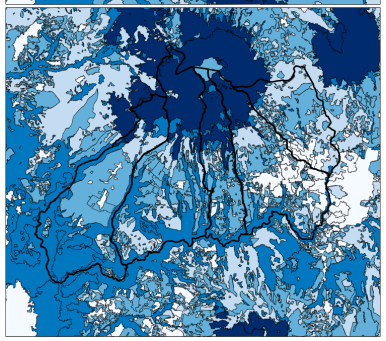
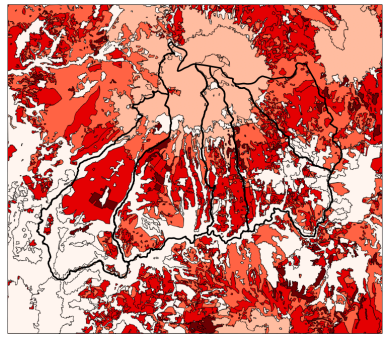
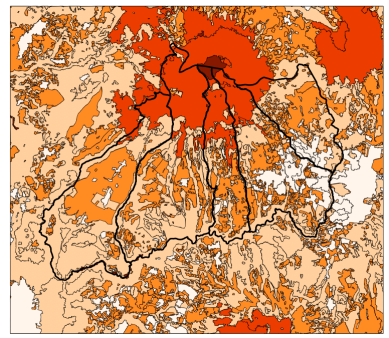


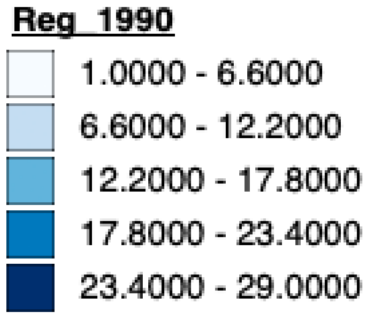
LULC Type	L_clim_ reg	G_clim_ reg	Water purificati	Soil erosion	Soil quality	Water flow
1	0.0	0.0	0.0	0.0	0.0	0.0
2	2.0	0.0	1.0	2.0	3.0	1.0
3	1.7	1.7	0.0	1.7	1.0	0.5
4	2.6	2.6	1.3	3.4	2.3	1.3
5	5.0	4.0	4.0	5.0	5.0	4.0
6	5.0	5.0	5.0	5.0	5.0	5.0
7	3.8	2.2	3.6	0.6	3.0	4.4

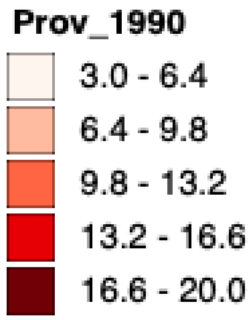
LULC Type	Crops	Livestock	Fodder	Wild foods	Wood fuel	Timber	Fresh water
1	1	1.0	1.0	0.0	0.0	0.0	0.0
2	2	2.8	3.0	2.0	0.0	0.0	1.0
3	5	2.3	2.5	1.0	1.0	0.0	1.0
4	0	0.4	0.4	1.6	2.6	3.0	1.3
5	0	0.0	0.0	4.0	5.0	4.0	4.0
6	0	0.0	0.0	4.0	3.0	1.0	5.0
7	0	0.0	0.0	0.4	0.6	0.6	2.0

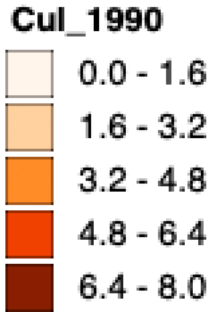
LULC Type	Intrinsic value of biodiversity	Recreation & aestethic values
1	0.1	0.7
2	1.0	2.0
3	1.0	2.7
4	1.9	2.0
5	5.0	5.0
6	5.0	5.0
7	3.0	4.4

Score and map the capacity of LULC typ. to provide ES

	Reg.	Prov	Cul.
1990			
2014			







- Regulation capacity →ELA
- Provisioning capacity →ELA
- Cultural capacity →ELA

Summarizing

- This case study demonstrates that highlands landscapes in the northern region of the Ecuadorian Andes present dynamic land patterns through time with different trajectories along the years.
- Specifically agricultural expansion, agricultural de-intensification, urbanization and deforestation

- Land use dynamics appear to show a geographic pattern

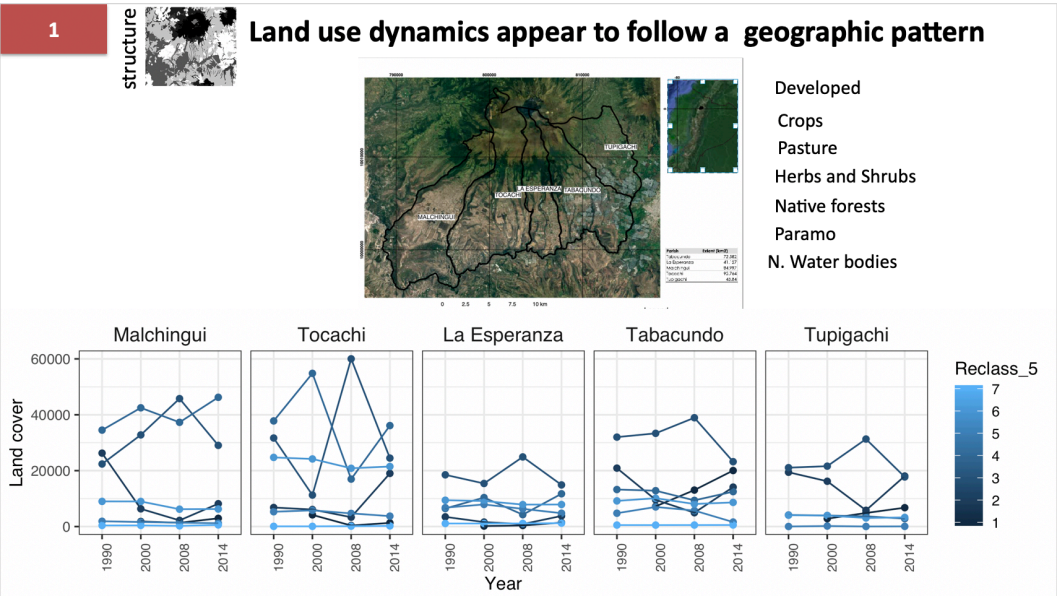
- Supply of ecosystem services associated to different Land use typologies would change along with the land-change dynamics observed at geographic and temporal scales

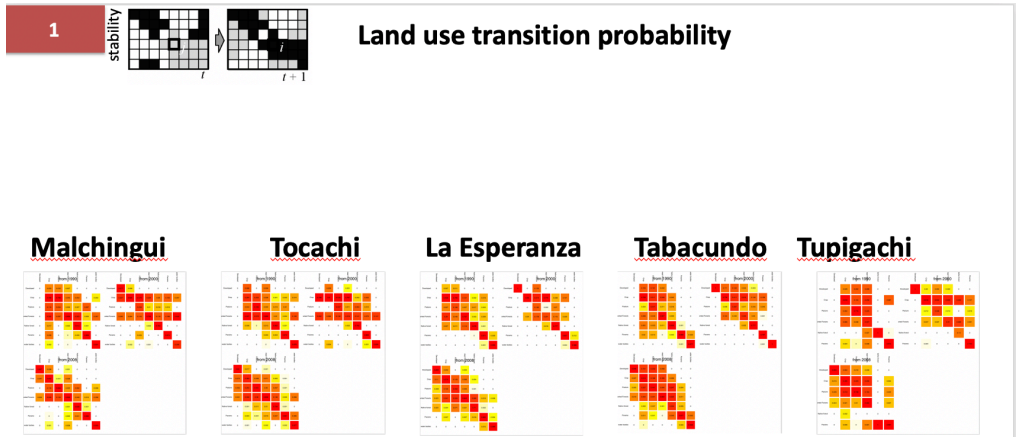
Next steps

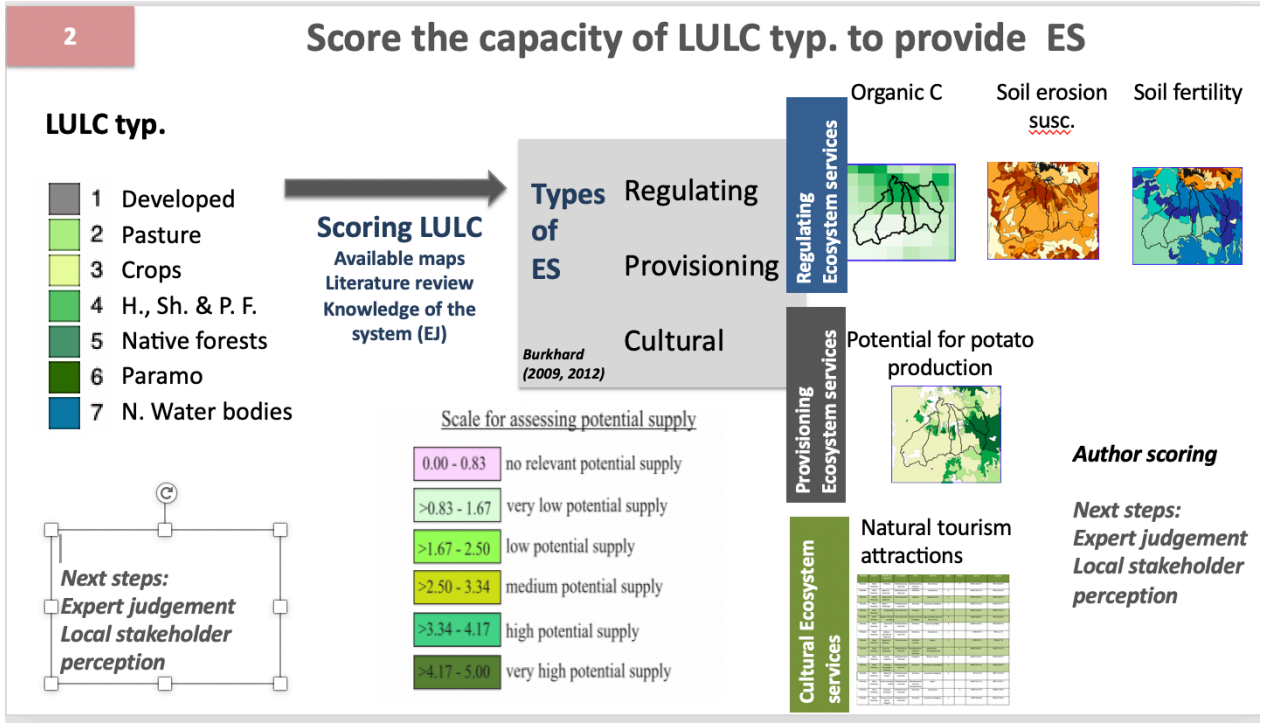
Analyze Landscape patterns and dynamics
Altitudinal gradient
Administrative geographic administration

Analyze Landscape configuration
Fragmentation
Connectivity

Include expert knowledge where there are gaps of information







Thanks

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