

Vínculos entre la biodiversidad y los servicios ecosistémicos en un gradiente de intensidad de uso del suelo en paisajes andinos del norte del Ecuador

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Advisor: Marc Dufrene (PhD)
Franz Smith (PhD)



Objetivo

Contribuir al entendimiento de los impactos del cambio de uso del suelo sobre la biodiversidad, los servicios ecosistémicos y la transferencia de beneficios hacia sistemas montañosos en los Andes norte de Ecuador

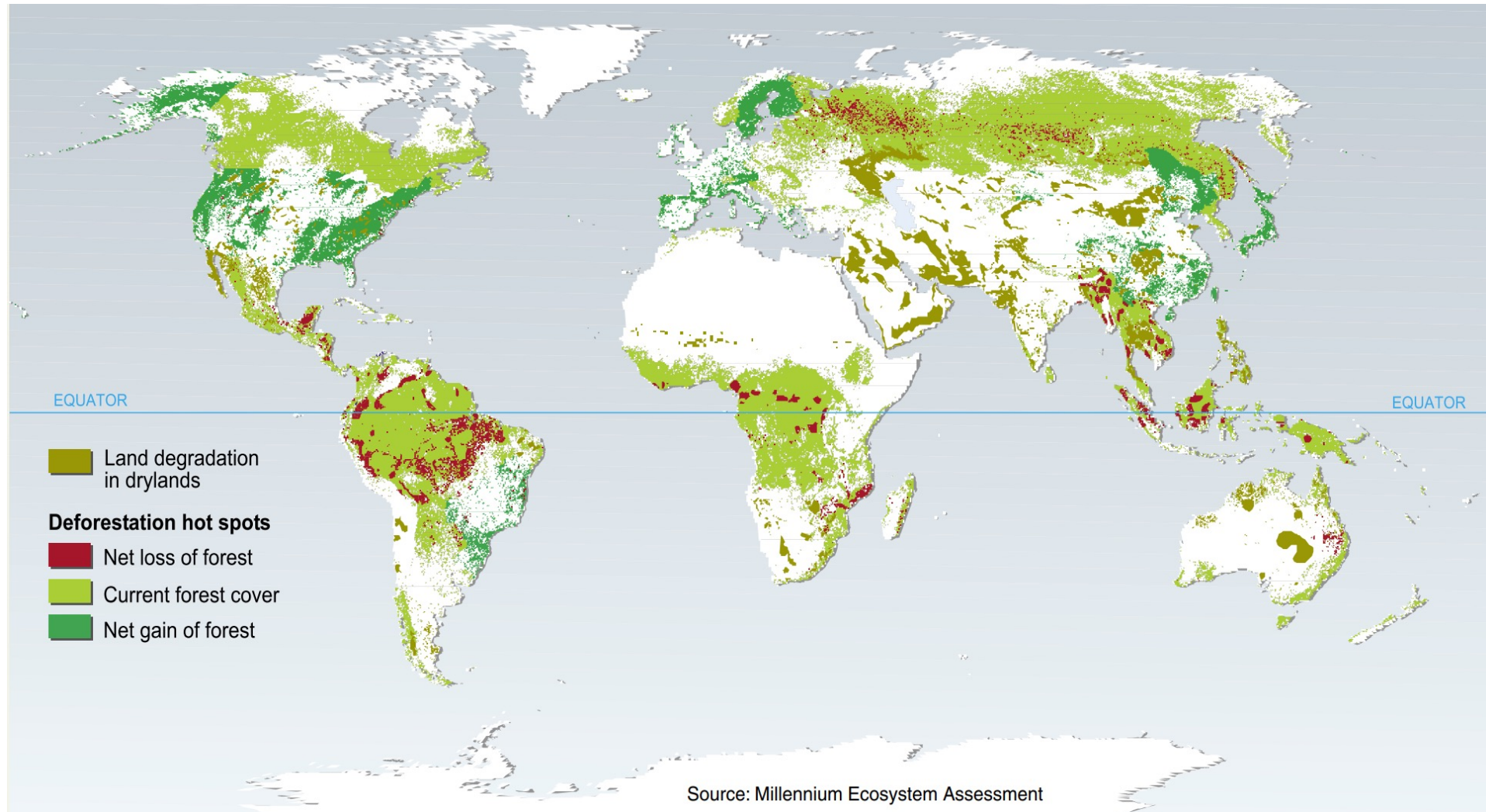
Esquema de la charla

- Contexto
- Justificación
- Marco conceptual
- Preguntas de investigación
- Aproximación de la investigación
- Resultados preliminares



Contexto

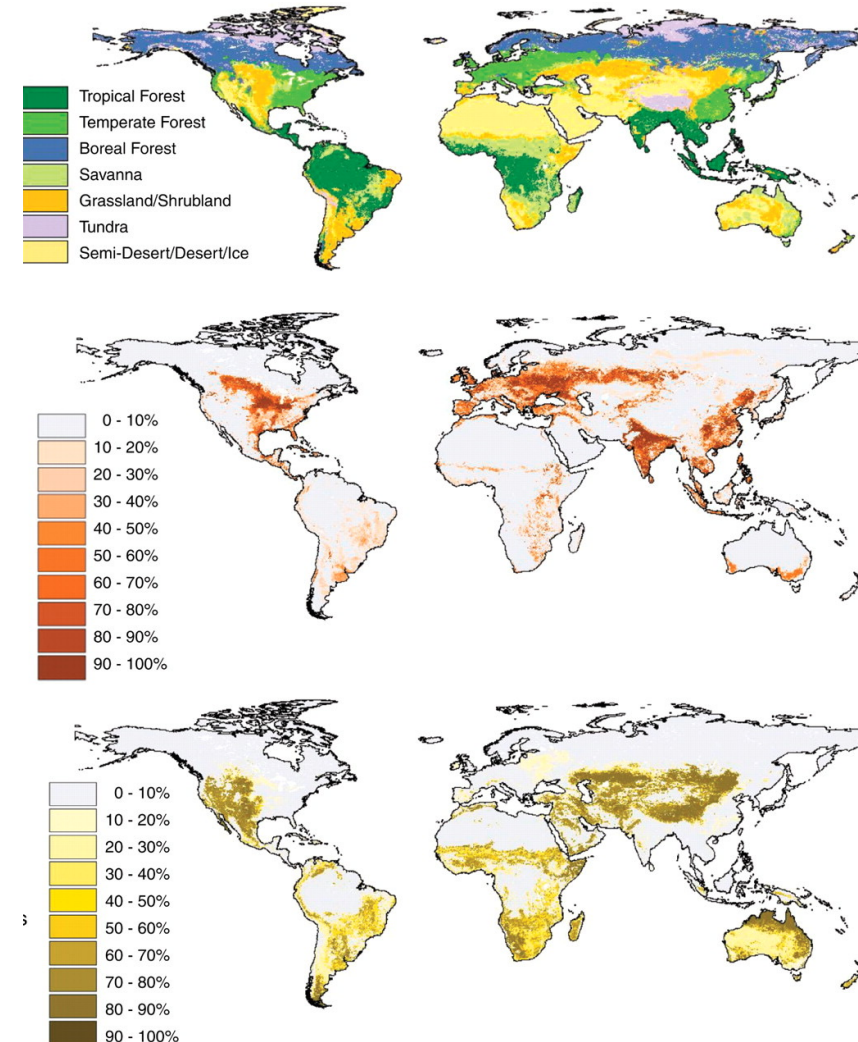
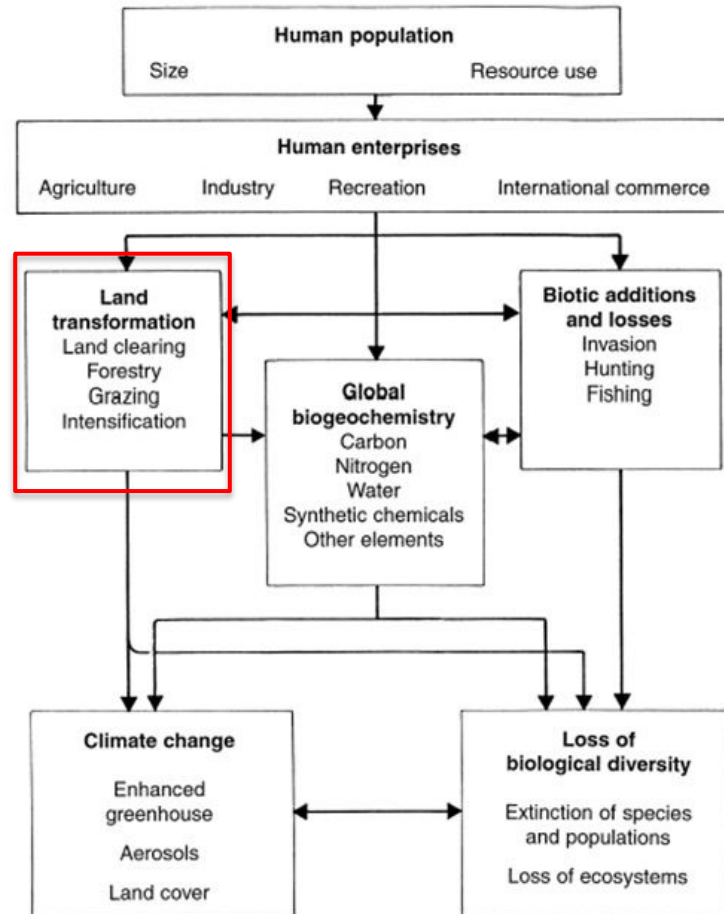
Todos los ecosistemas de la tierra han sido transformados significativamente a través de las actividades humanas



El cambio de uso del suelo es la variable más importante que afecta a los sistemas ecológicos

Vitousek et al. 1997, Sala 2000,

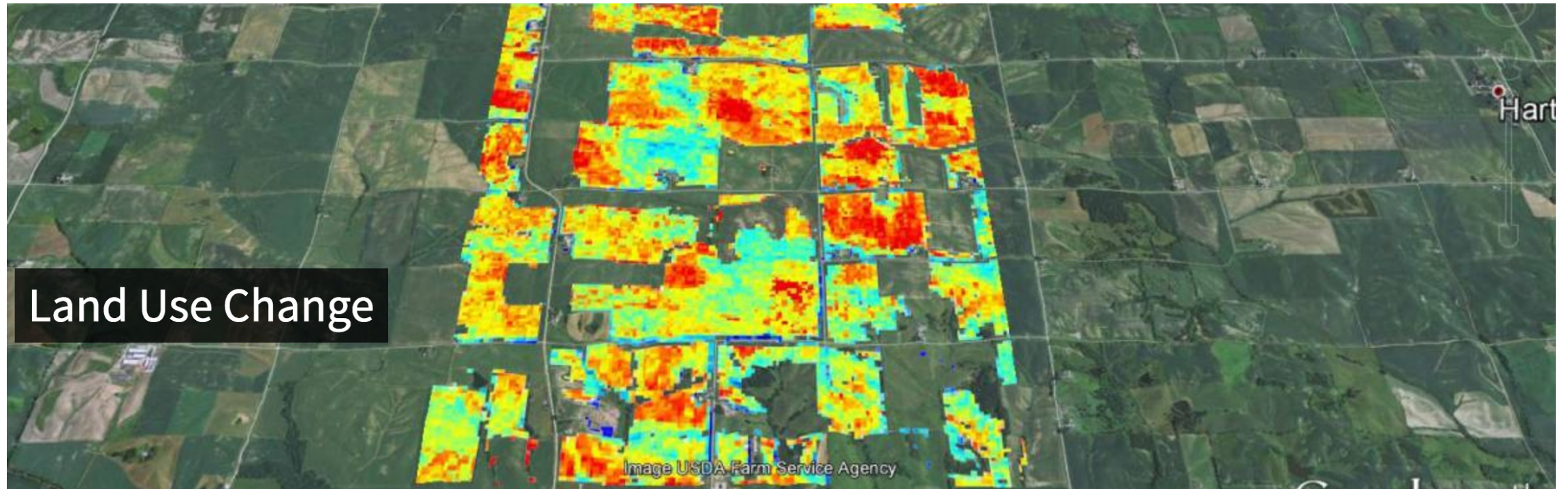
Fig. 1. A conceptual model illustrating humanity's direct and indirect effects on the Earth system [modified from (56)].



(Vitousek et al. 1997)

Foley et al 2005

El cambio de la cobertura y uso del suelo impacta en diversas características, procesos, propiedades de los sistemas ambientales



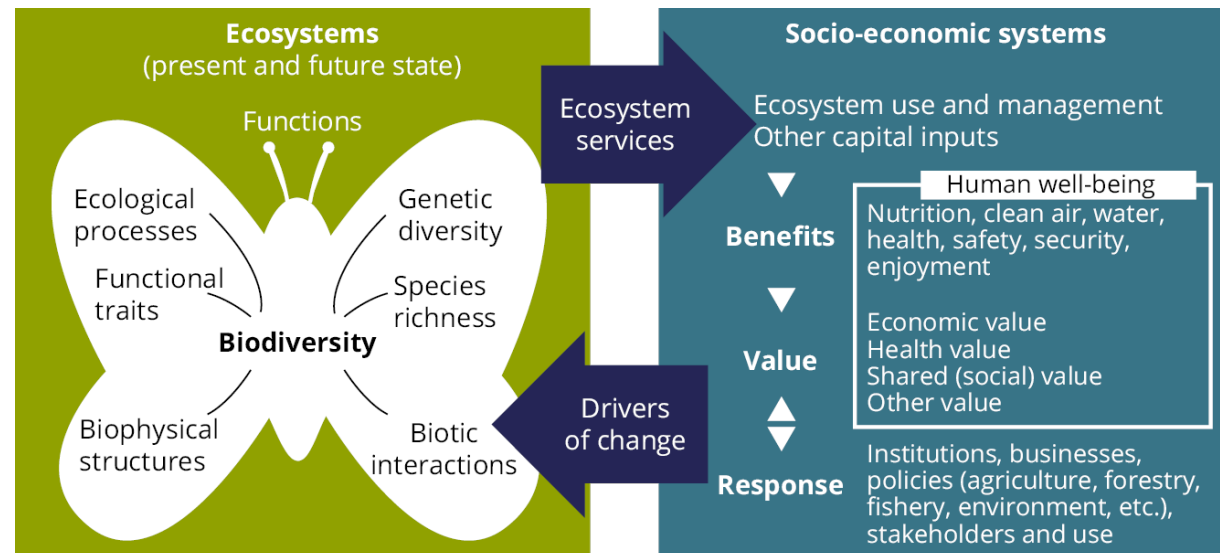
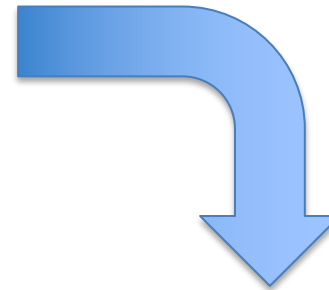
Cambio en los ciclos hidrológicos y del C
Efectos sobre el clima local, regional y global
Degradación de los ecosistemas

Degradación del suelo del agua
Sobreexplotación de especies nativas
Pérdida de biodiversidad

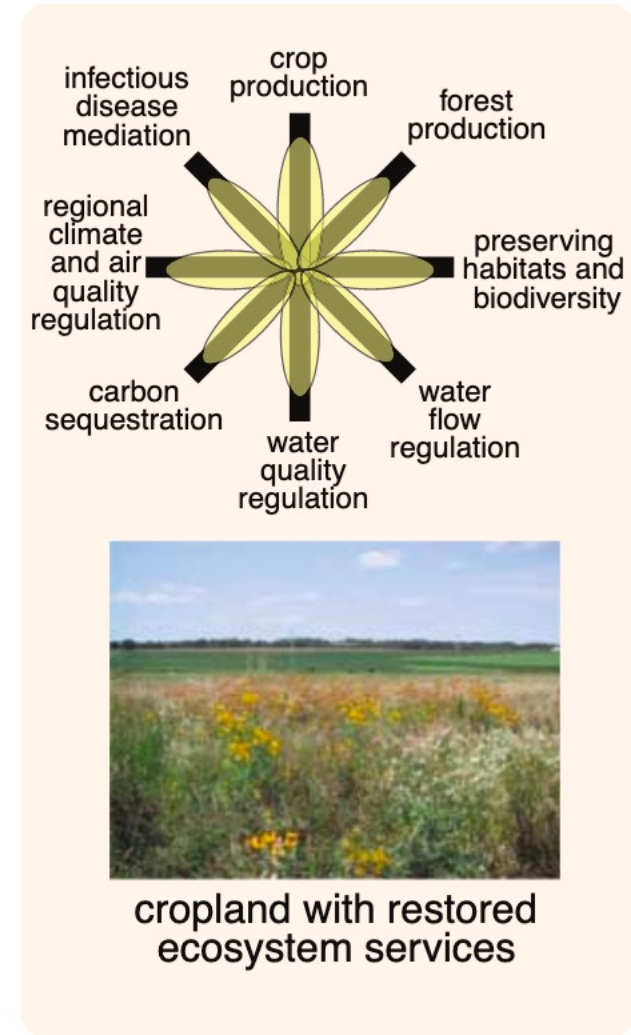
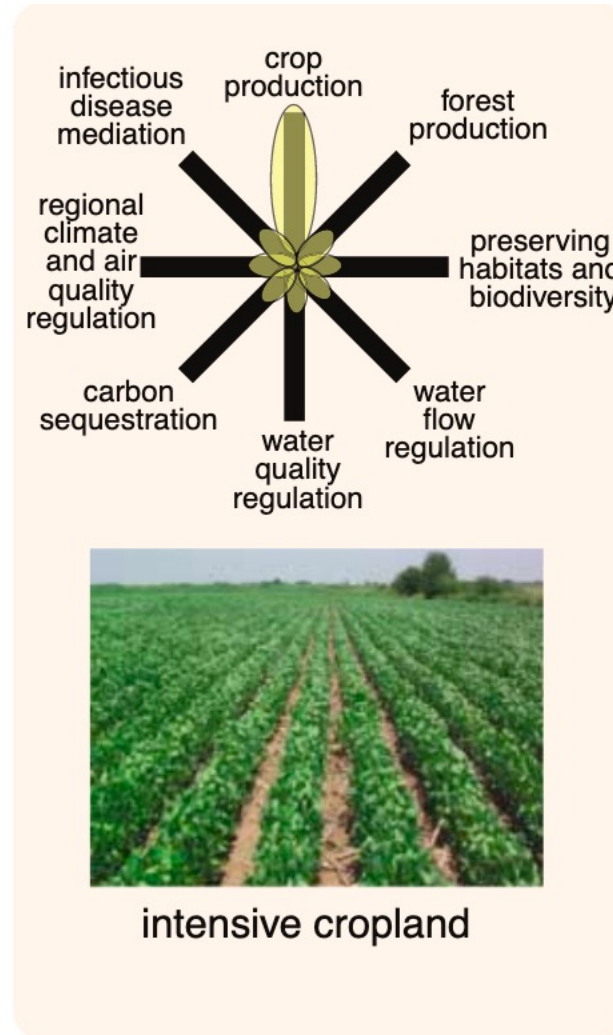
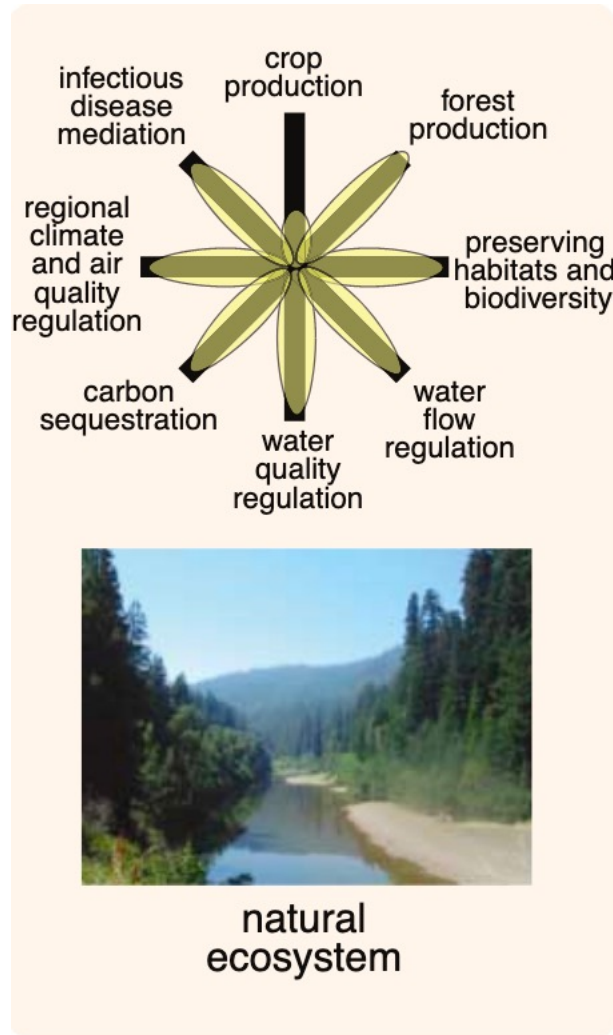
El cambio de la cobertura y uso del suelo afecta a la provision de multiples servicios ecosistémicos



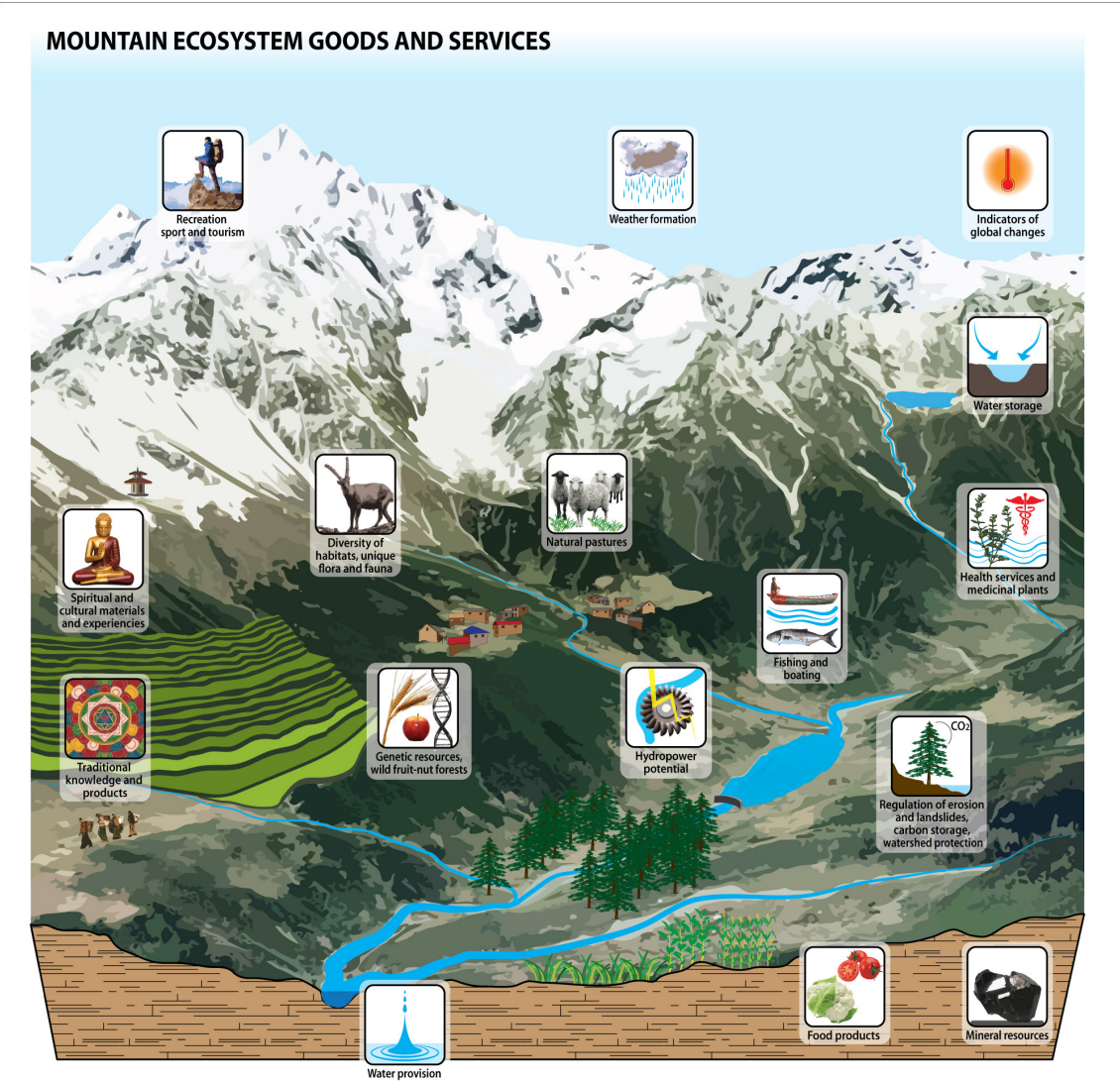
Kuratola 2015



Desafío: balance entre las necesidades humanas inmediatas y la capacidad de la biósfera de proveer los bienes y servicios a largo plazo



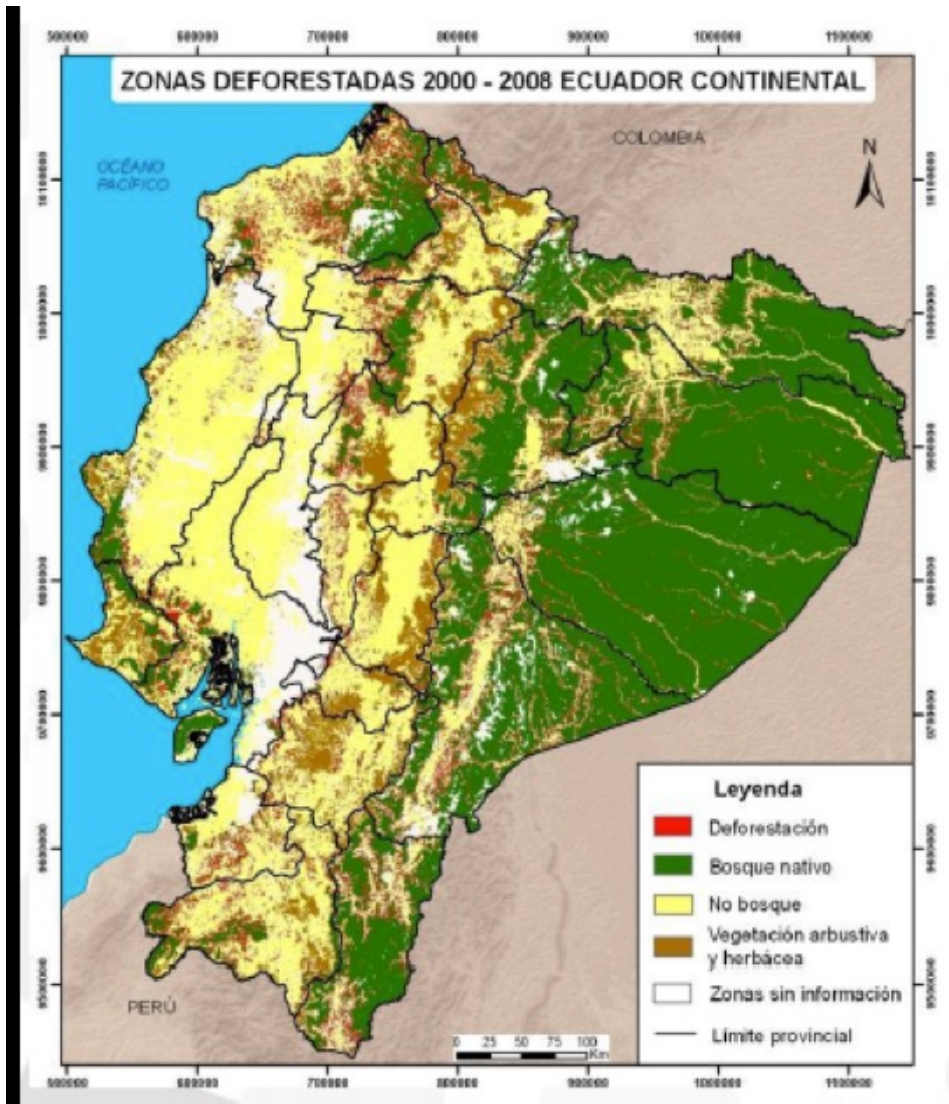
Ecosistemas de montaña proven múltiples servicios ecosistémicos que están amenazados por actividades humanas





Justificación

Los ecosistemas montanos en Ecuador han sido afectados por la pérdida y la fragmentación de vegetación natural



- Deforestación, intensificación y de-intensificación agrícola y urbanización son dinámicas complejas, documentadas en los Andes
- Los ecosistemas montanos de Ecuador están amenazados, son bosques remanentes en una matriz de área agrícola

(Halliday & Glaser, 2011)

Los ecosistemas montañosos en Ecuador han sido afectados por la pérdida y la fragmentación de vegetación natural



- Evaluaciones cuantitativas de los efectos del cambio de uso del suelo sobre los servicios ecosistémicos es uno de los enfoques de investigación más relevantes en la ciencia del Desarrollo sostenible
- El impacto del cambio de uso del suelo sobre la biodiversidad y el valor de los ecosistemas de montaña han sido poco evaluados en Ecuador

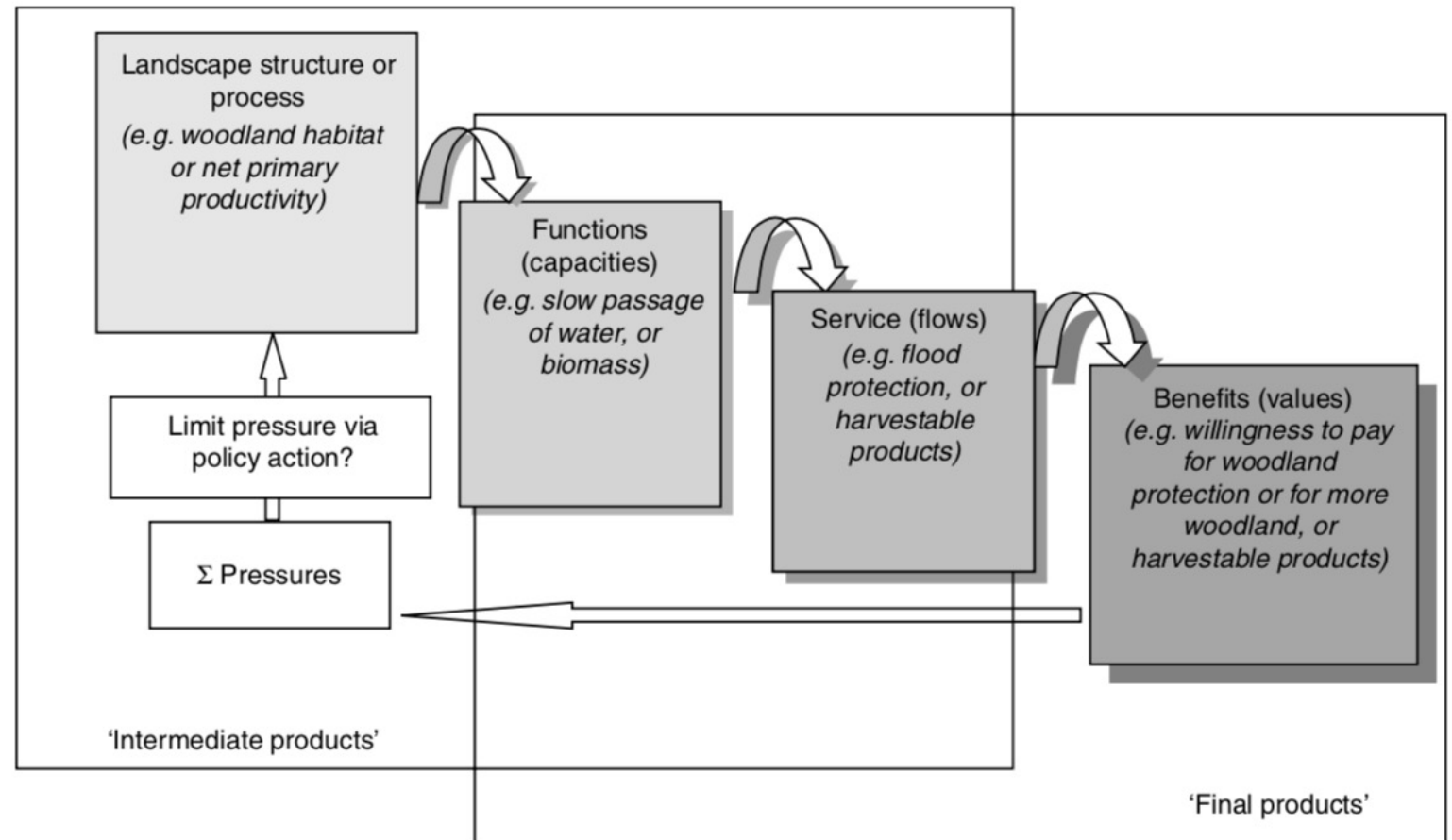


Marco conceptual

Modelo de cascada: Modelo conceptual entre la biodiversidad, las funciones ecológicas y los servicios ecosistémicos

Conectando escalas

Probando diferentes aproximaciones



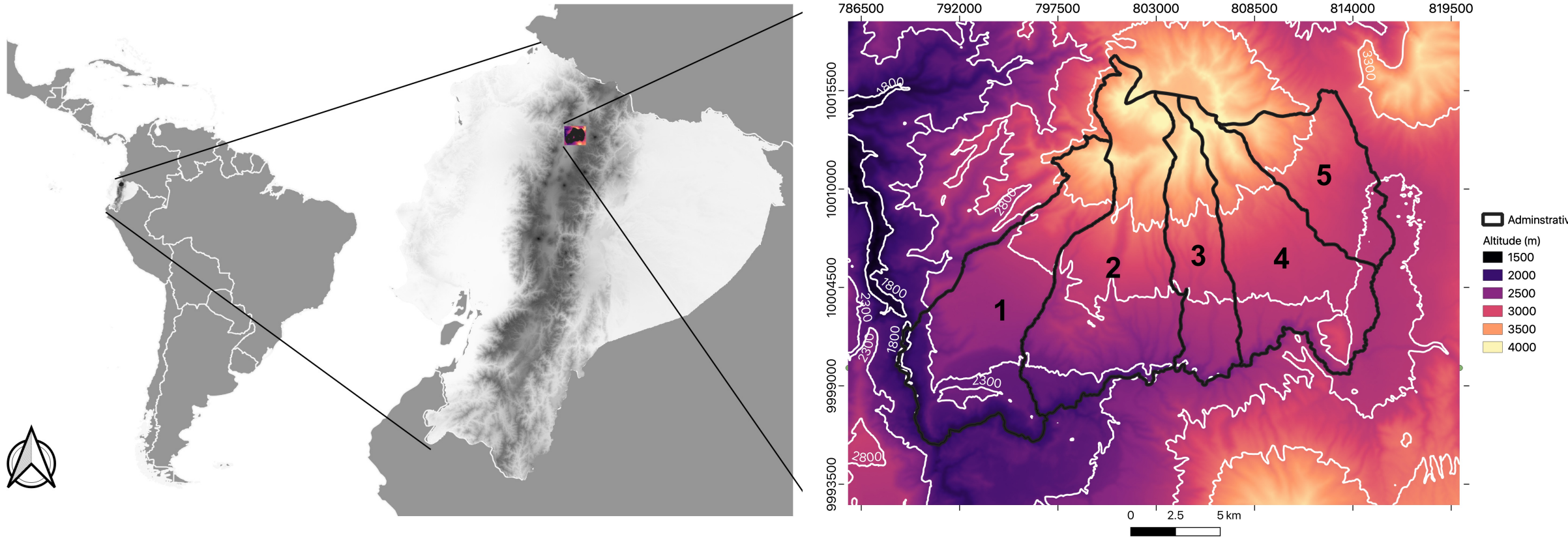
Pregunta de investigación

**Conectando
escalas**

**Probando
diferentes
aproximaciones**

?Cómo el cambio de uso del suelo afecta a la biodiversidad y a la capacidad de los ecosistemas de proveer servicios en un paisaje andino del norte del Ecuador?

Caso de estudio Cantón Pedro Moncayo – Sistema modelo

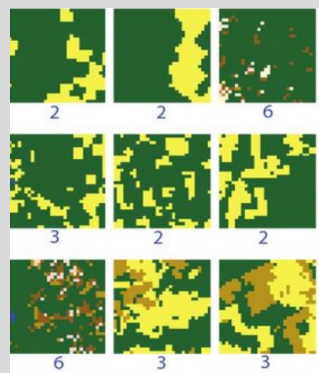
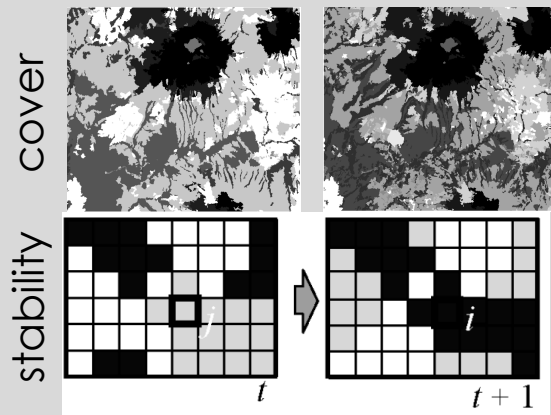


Tiene un interesante gradiente altitudinal ~ intensidad de act. humana

Aproximación de la investigación

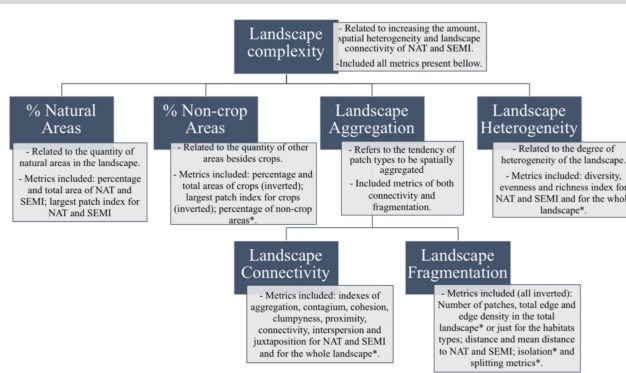
LULC ~ Patrones del paisaje y provisión de SE

Patrones LULC a través del tiempo

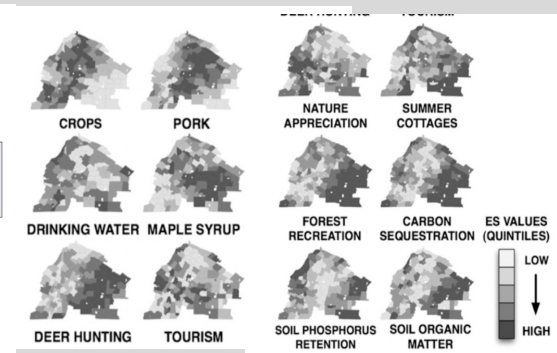


Nowosad & Stepinski 2019

Complejidad del paisaje vs. SE



Teixeira Duarte et al 2018



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

Of. Datos Modelos Expert

Cómo el cambio de uso del suelo afecta a la biodiversidad y a la capacidad de los ecosistemas para proveer servicios en un paisaje andino de N.Ecuador?

LULC ~ Biodiversidad, funciones ecológicas y SE



Grupos de biodiversidad

- Artrópodos
- Cobertura vegetal
- Biomasa de raíces
- Polinizadores
- Microb biomass

Proyectos de estudiantes

Función ecológica

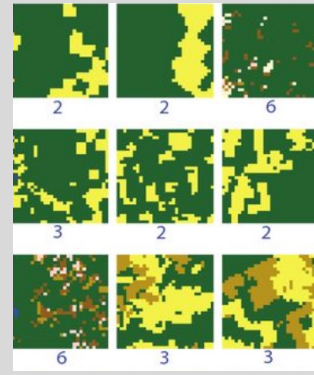
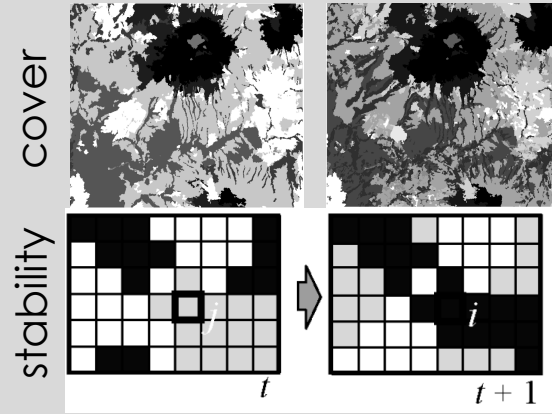
- Mineralization
- Formación de suelo
- Act. Biológica de microorg.

SE as. suelo

- Fertilidad del suelo
- Prevención de la erosión
- Capacidad de mantener agua
- Regulación microclima
- Secuestro de carbono

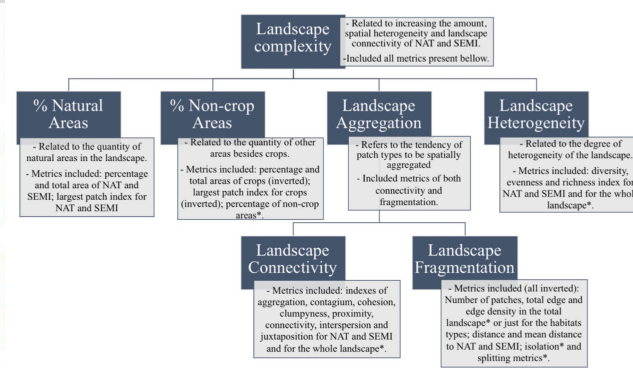
LULC ~ Patrones del paisaje y provisión de SE

Patrones LULC a través del tiempo

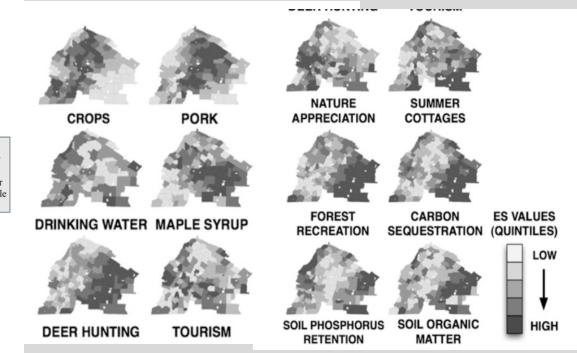


Nowosad & Stepinski 2019

Complejidad del paisaje vs. SE



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Of. Datos Modelos Expert

Cómo el cambio de uso del suelo afecta a la biodiversidad y a la capacidad de los ecosistemas para proveer servicios en un paisaje andino de N.Ecuador?

LULC ~ Biodiversidad, funciones ecológicas y SE



Grupos de biodiversidad

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Proyectos de estudiantes

Función ecológica

- Mineralization
- Formación de suelo
- Act. Biológica de microorg.

SE as. suelo

- Fertilidad del suelo
- Prevención de la erosión
- Capacidad de mantener agua
- Regulación microclimática
- Secuestro de C

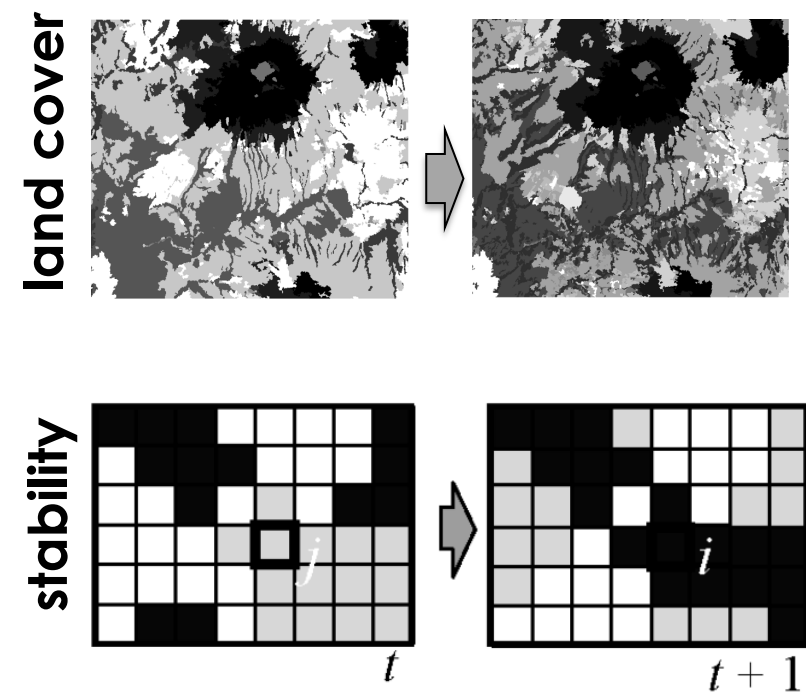
LULC ~ Patrones del paisaje y provisión de SE

1. Cómo LULC ha cambiado en el tiempo?
2. Existen diferencias en la estabilidad y dinámica del paisaje a lo largo de gradientes geográficos y biofísicos a través del tiempo?

LULC ~ Patrones del paisaje y provisión de SE

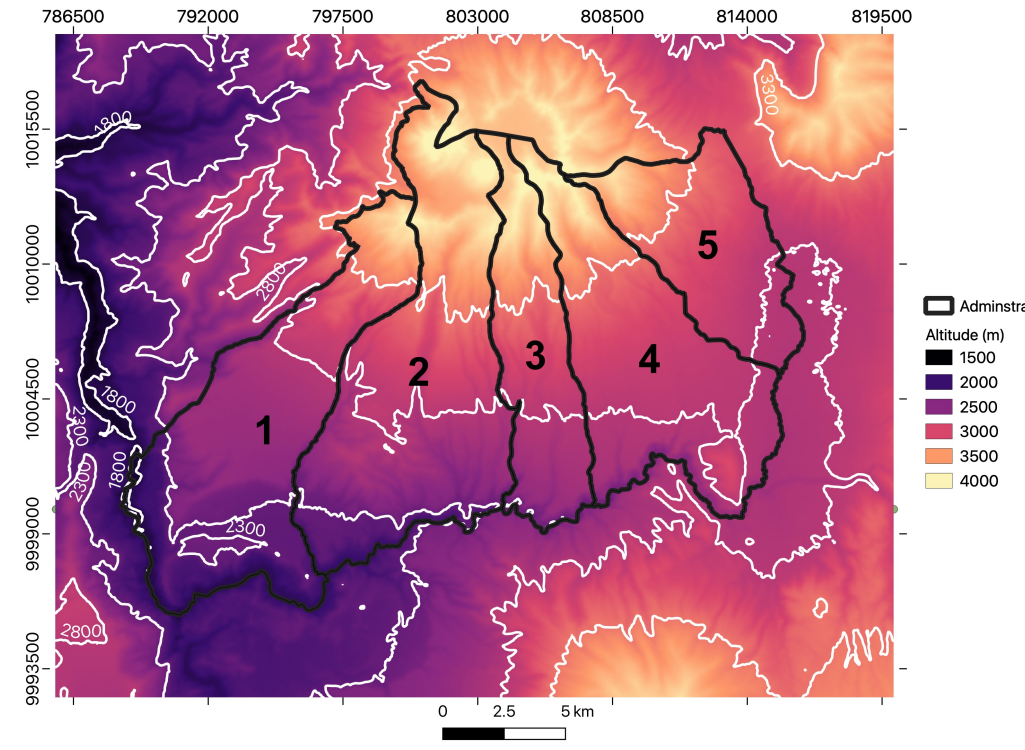
Complejidad del paisaje vs. SE

Cómo el cambio de uso del suelo afecta a la biodiversidad y a la capacidad de los ecosistemas para proveer servicios en un paisaje andino de N.Ecuador?



1990
2000
2008
2014

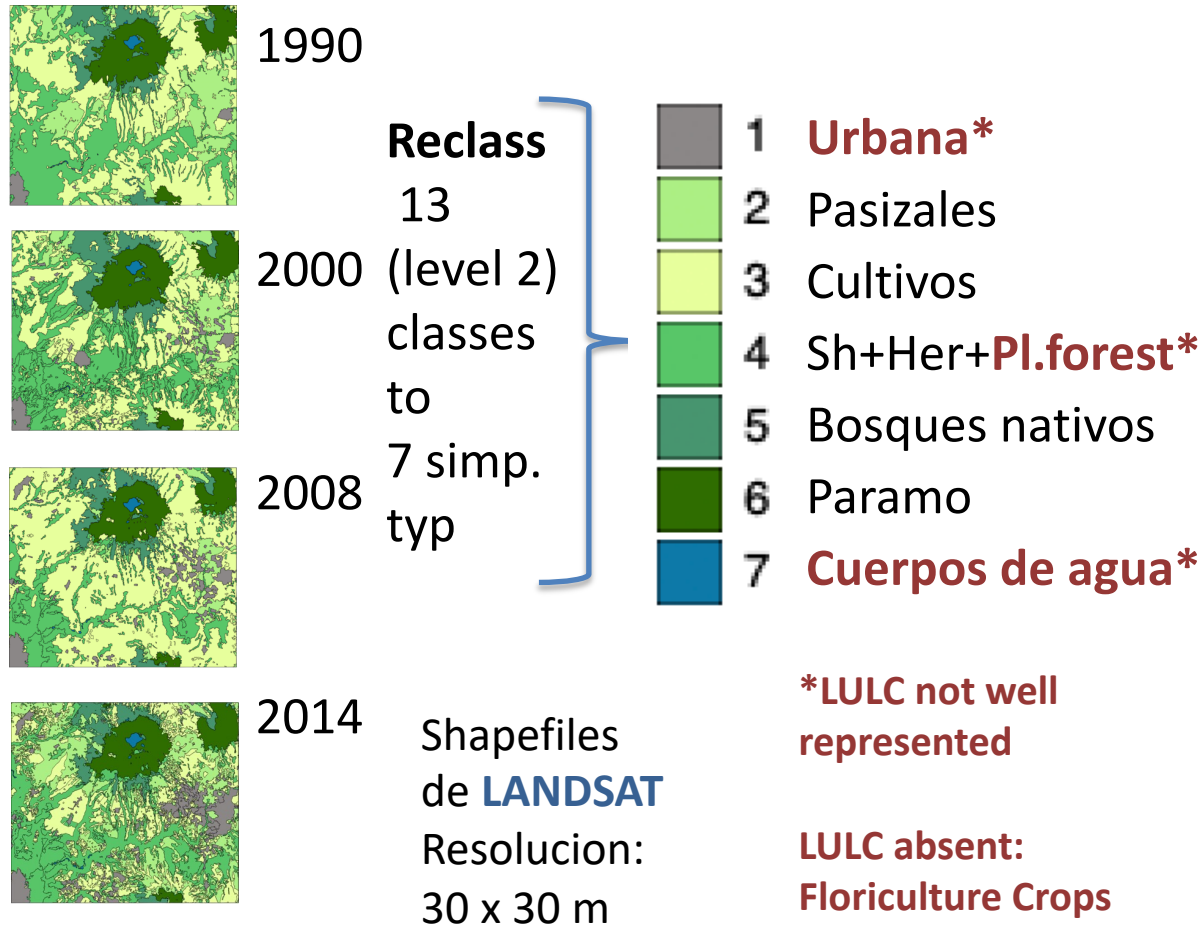
Analisis:
Paisaje general
Bandas altitudinal
Zonas administrati



Análisis de patrones de dinámica del paisaje - tiempo

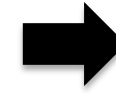
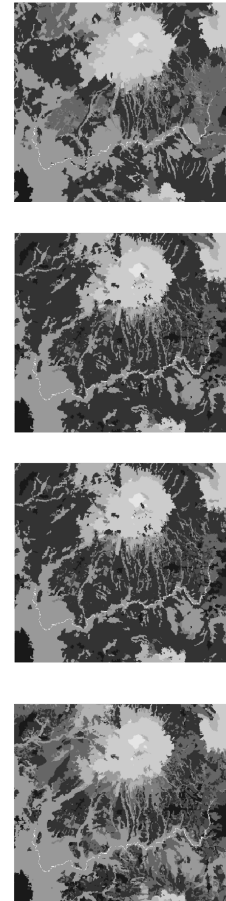
Datos oficiales LULC:

Ministerio del Ambiente de Ecuador



Conversión Raster

Improve LULC accuracy
Digitization
Overlay analysis



Análisis Patrones del Paisaje

Tiempo

Cobertura *Cobertura: km² & %*

LUC dinámica *Matriz de transición*

Matriz de probabilidad de Markov

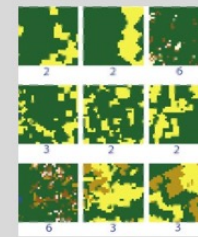
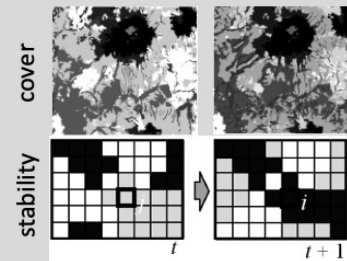


Resultados preliminares

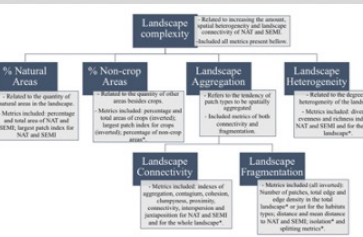
1

LULC ~ Patrones del paisaje y provisión de SE

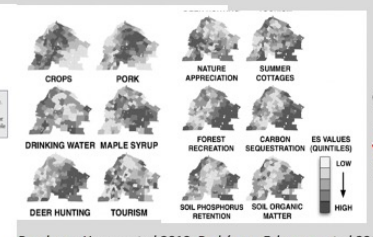
Patrones LULC a través del tiempo



Nowosad & Stepinski 2019



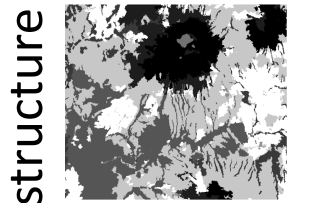
Teixeira Duarte et al 2018



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

Off. Data
Modelos
Expert

Cómo el cambio de uso del suelo afecta a la biodiversidad y a la capacidad de los ecosistemas para proveer services en un paisaje andino de N.Ecuador?



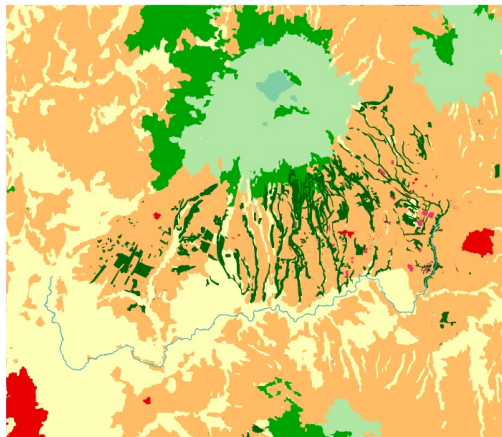
composition

Main LULC classes in the territory are:

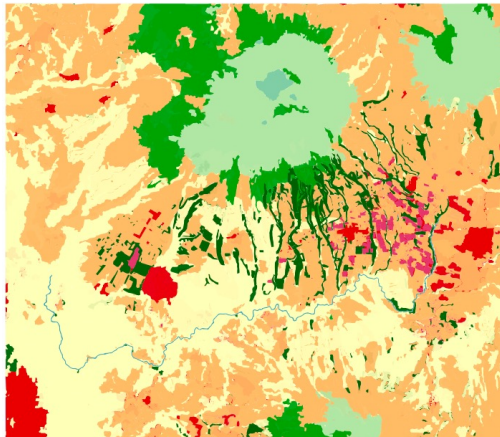
Agricultural areas

Herbs & Shrubs

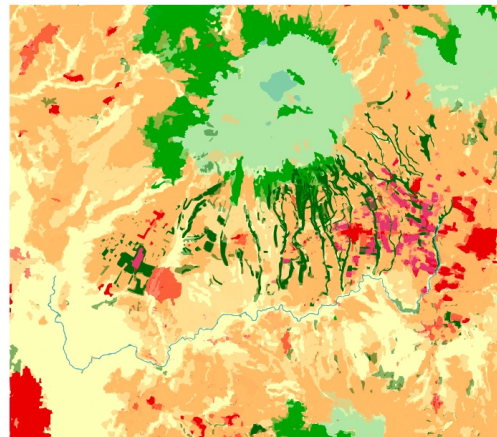
1990



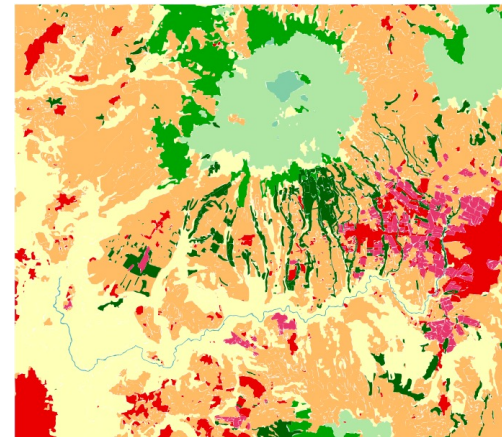
2000



2008

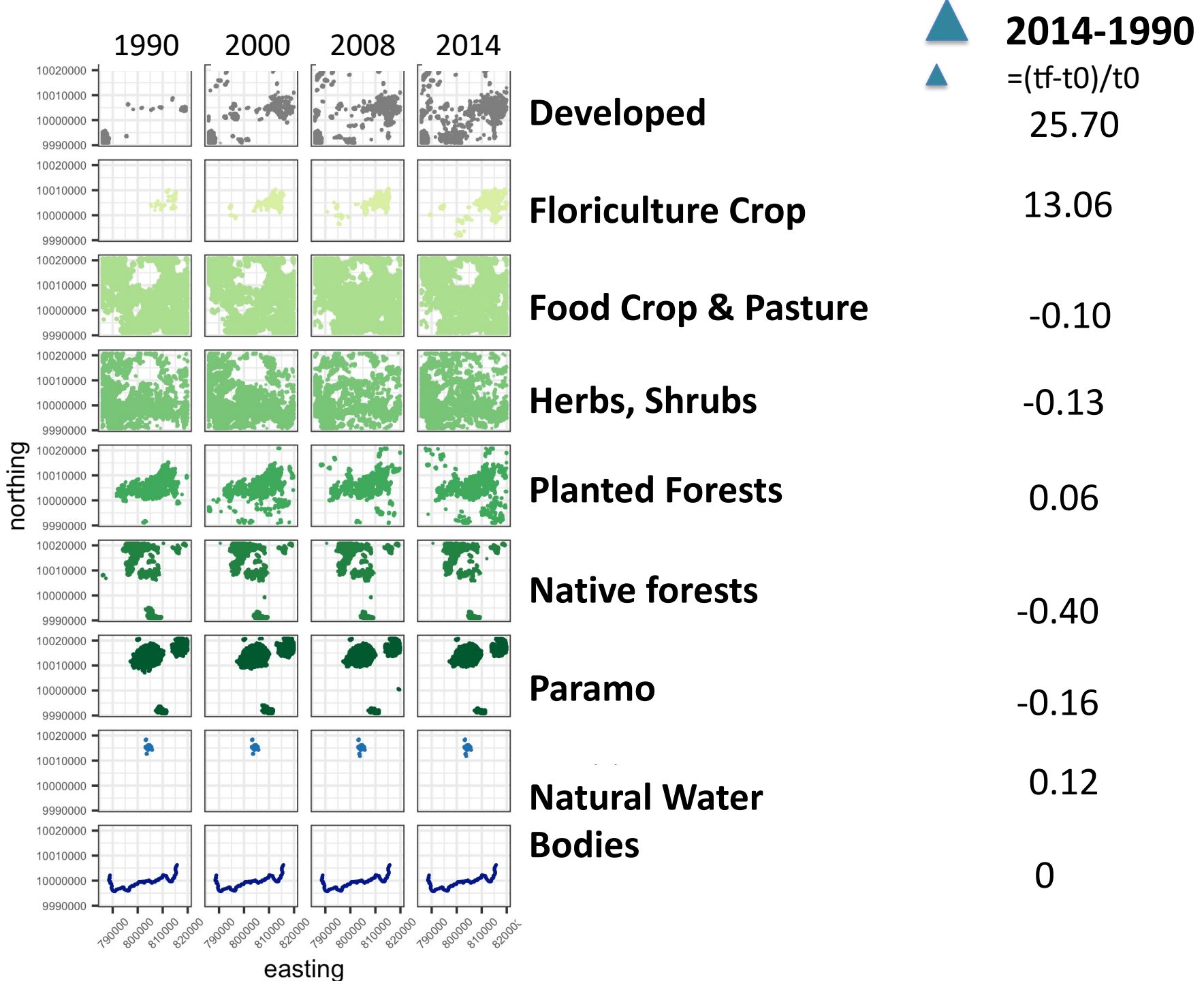
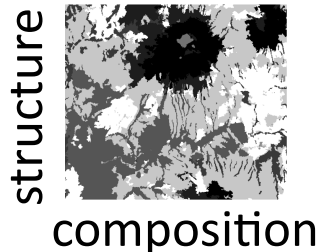


2014



Developed
Floriculture crop
Food Crops and Pasture
Planted forests
Herbs & Shrubs.
Native forests
Paramo
Lake
River
TOTAL

	1990		2000		2008		2014	
	Area km ²	%	Area km ²	%	Area km ²	%	Area km ²	%
Developed	0.58	0.17	9.15	2.71	9.61	2.84	15.54	4.60
Floriculture crop	1.19	0.35	9.36	2.77	14.06	4.16	16.75	4.95
Food Crops and Pasture	152.92	45.20	117.69	34.79	169.29	50.04	137.03	40.51
Planted forests	44.16	13.05	38.66	11.43	37.35	11.04	38.24	11.30
Herbs & Shrubs.	73.33	21.68	95.24	28.15	53.40	15.78	77.75	22.98
Native forests	12.96	3.83	15.18	4.49	11.29	3.34	7.77	2.30
Paramo	50.62	14.96	50.49	14.93	40.73	12.04	42.51	12.57
Lake	1.48	0.44	1.47	0.44	1.52	0.45	1.66	0.49
River	1.04	0.31	1.04	0.31	1.04	0.31	1.04	0.31
TOTAL	338.29	100.00	338.29	100.00	338.29	100.00	338.29	100

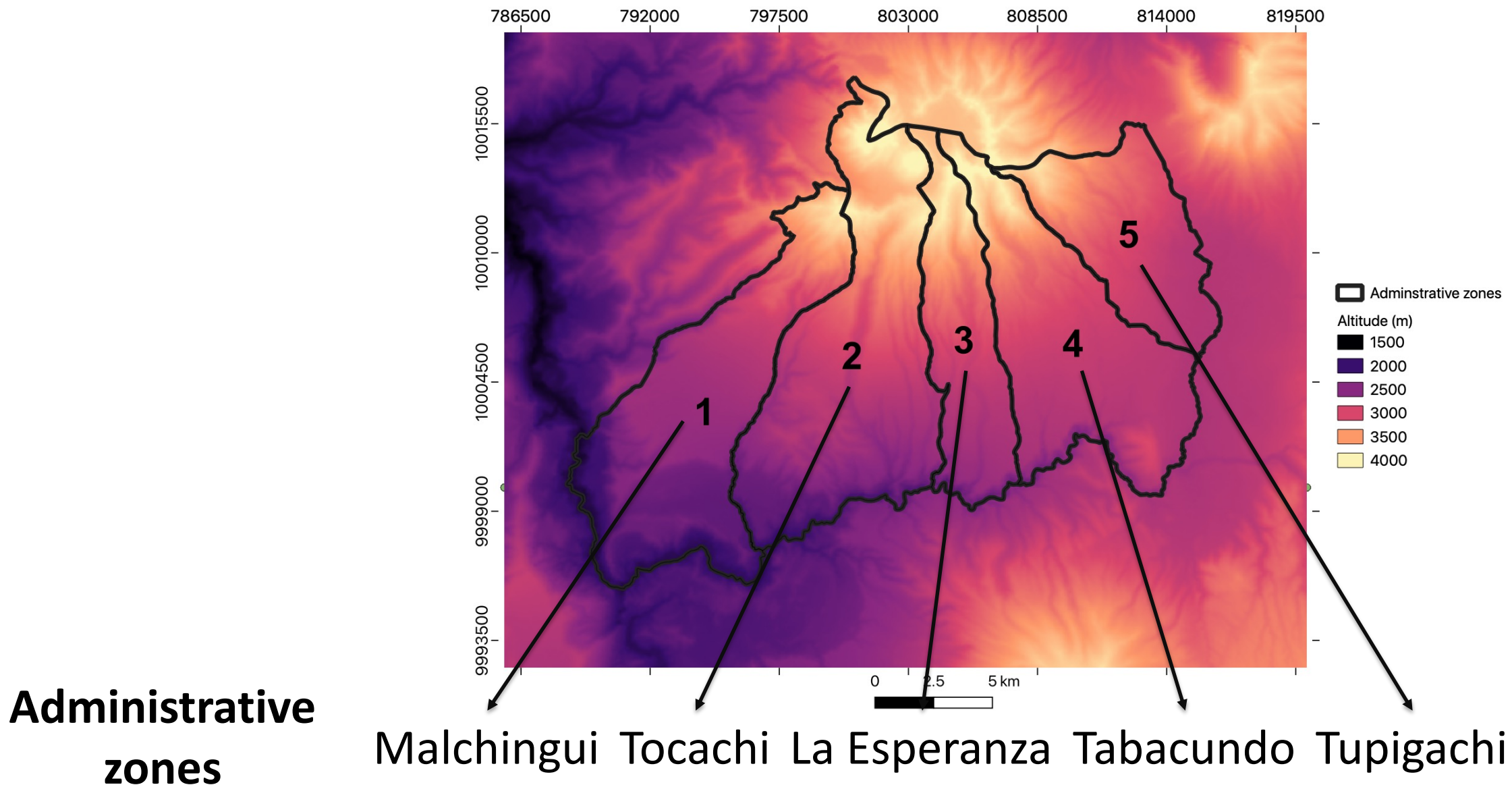
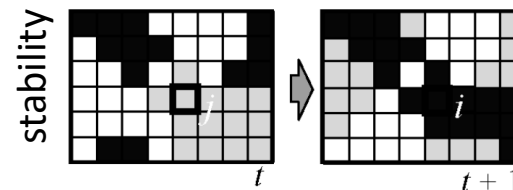


Developed and Floriculture Crops are steadily increasing through time

Native forests and Paramo are decreasing

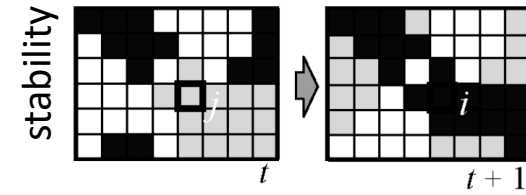
LULC pattern analysis – time

Administrative zones



LULC pattern analysis – time

Administrative zones



Natural
ecosystems

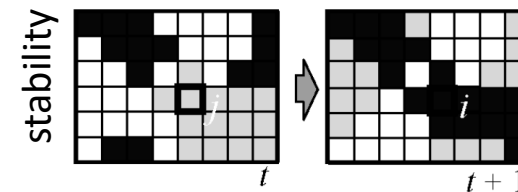


Artificial
ecosystems

Native forests
Paramo
Shrubs and Herbs

Developed
Planted Forests
Food Crops and Pastures
Floriculture Crops

LULC pattern analysis – time Administrative zones



Natural
ecosystems



Artificial
ecosystems

Transition
From **Natural** to X Typology

- Native forest to Native forest
- Native forest to Food crop and Pasture
- Native forest to Floriculture crop
- Native forest to Planted forest
- Native forest to Paramo
- Native forest to Shrubs and Herbs
- Native forest to Developed

eg.
From
Native forest
to
X. Typology

Transition
From X Typology to **Artificial**

- Developed to Developed
- Floriculture crop to Developed
- Food crop and Pasture to Developed
- Planted forest to Developed
- Shrubs and Herbs to Developed
- Native forest to Developed
- Paramo to Developed

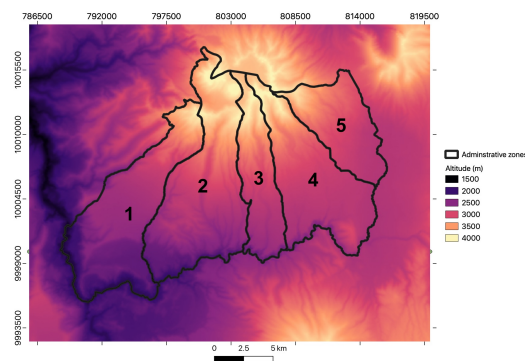
eg.
From
X. Typology
to
Developed

Natural ecosystems

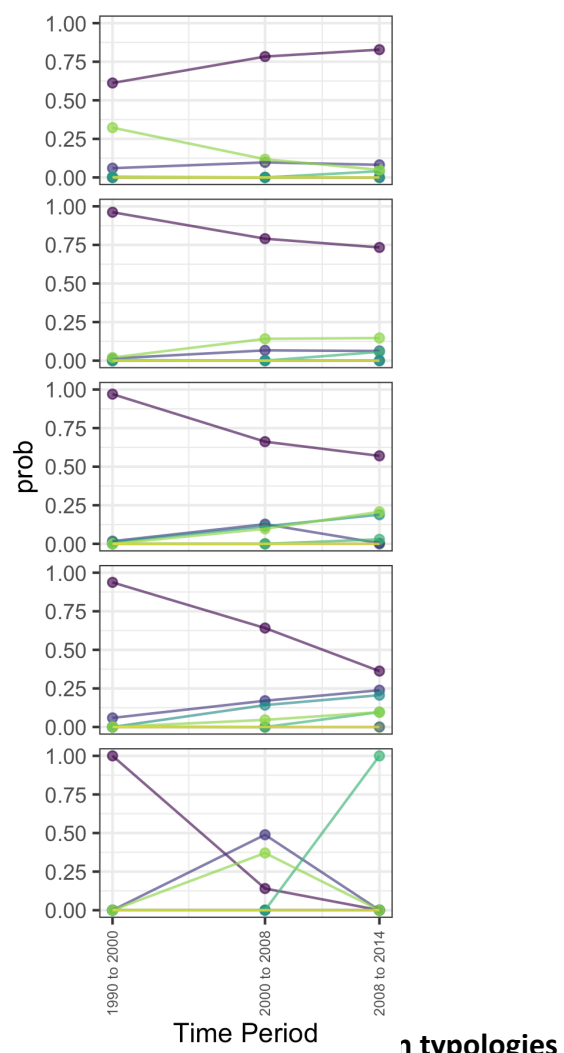


Artificial ecosystems

Dynamics through time of native ecosystems across admin. zones

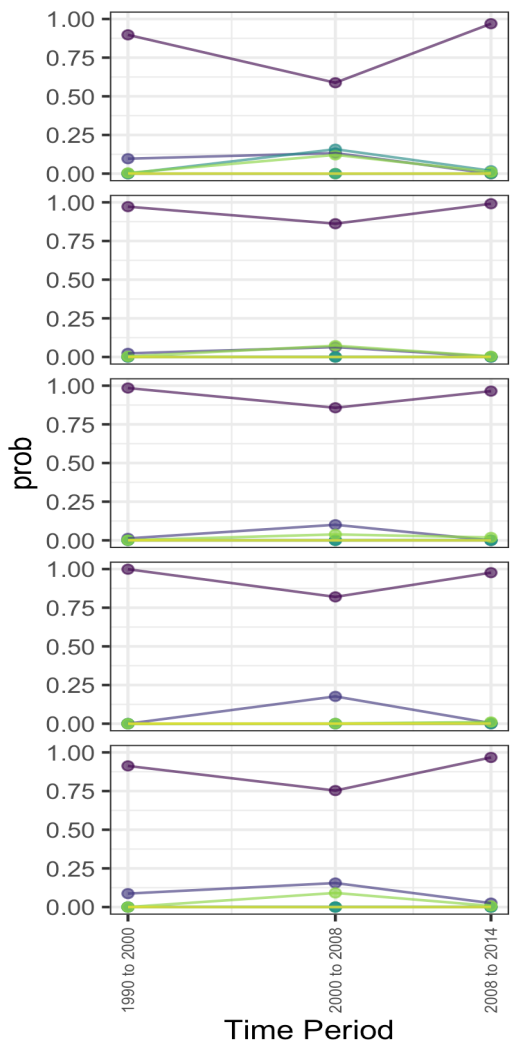


Native forests (-)



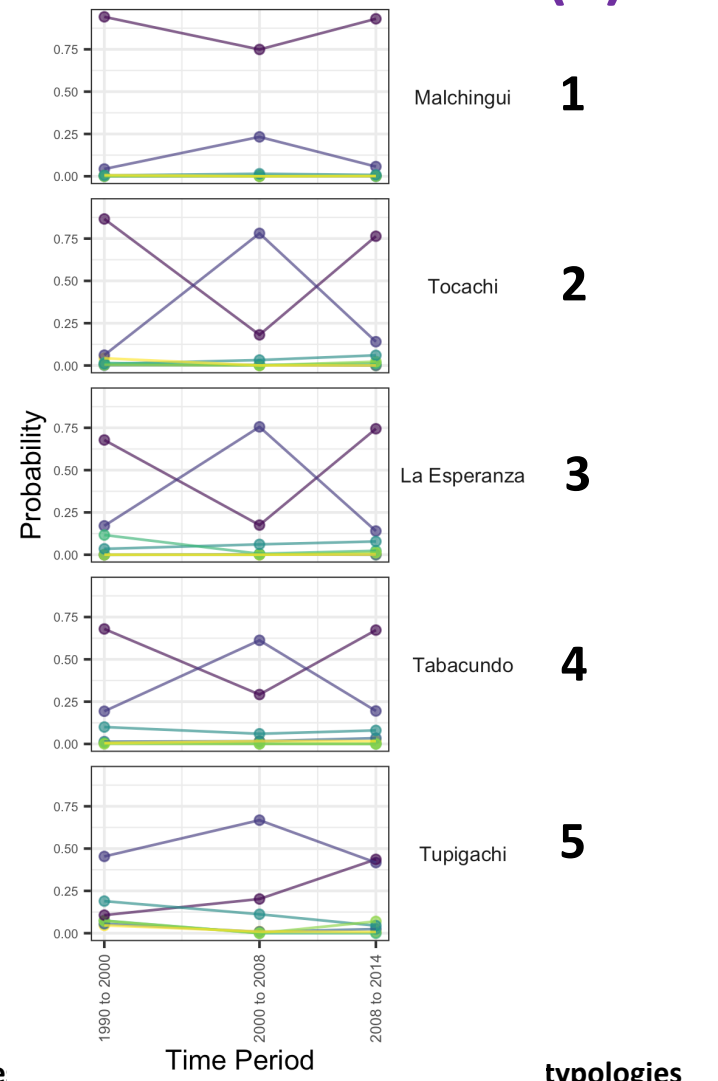
- 1 typologies**
- Native forest to Native forest
 - Native forest to Food crop and Pasture
 - Native forest to Floriculture crop
 - Native forest to Planted forest
 - Native forest to Paramo
 - Native forest to Shrubs and Herbs
 - Native forest to Developed

Paramo (S)



- Transition typologie**
- Paramo to Paramo
 - Paramo to Food crop and Pasture
 - Paramo to Floriculture crop
 - Paramo to Planted forest
 - Paramo to Native forest
 - Paramo to Shrubs and Herbs
 - Paramo to Developed

Shrubs and Herbs (C)



- typologies**
- Shrubs and Herbs to Shrubs and Herbs
 - Shrubs and Herbs to Food crop and Pasture
 - Shrubs and Herbs to Floriculture crop
 - Shrubs and Herbs to Planted forest
 - Shrubs and Herbs to Native forest
 - Shrubs and Herbs to Paramo
 - Shrubs and Herbs to Developed

(-) Decreased
(S) Stable
(C) Dynamic

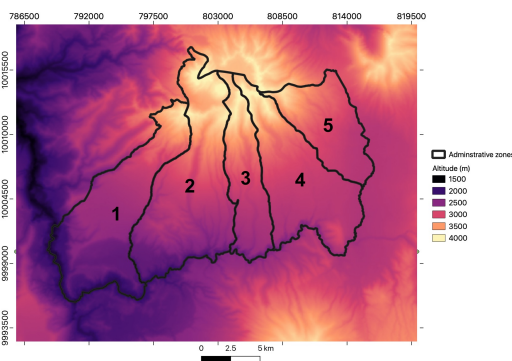
Natural ecosystems



Artificial ecosystems

Developed

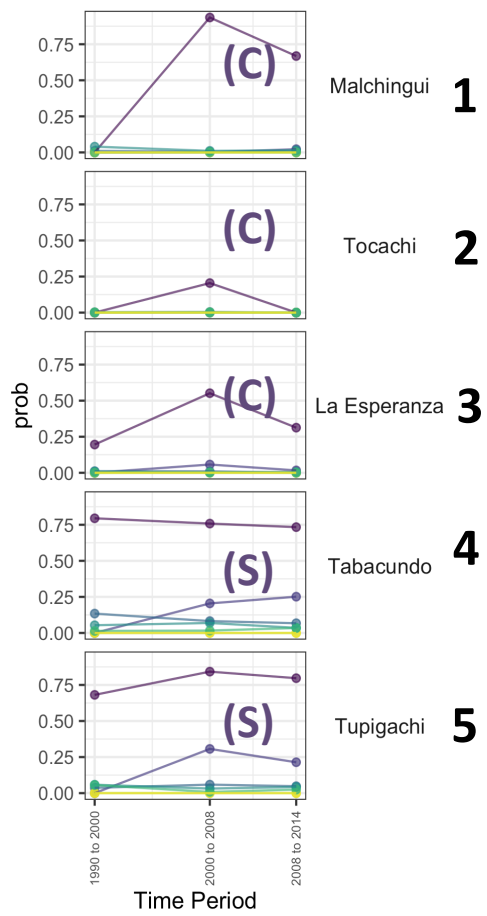
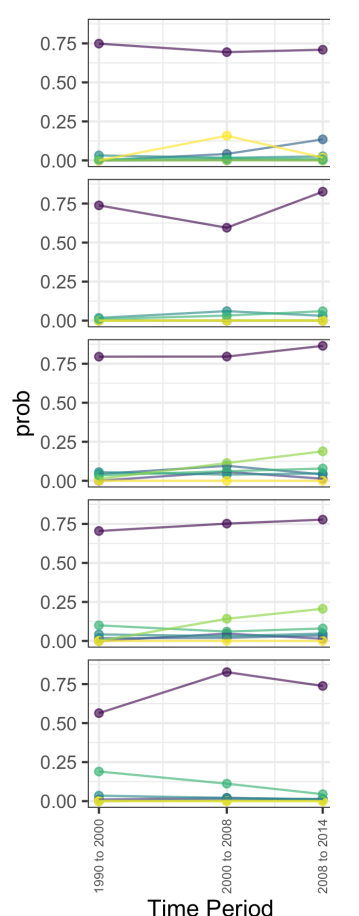
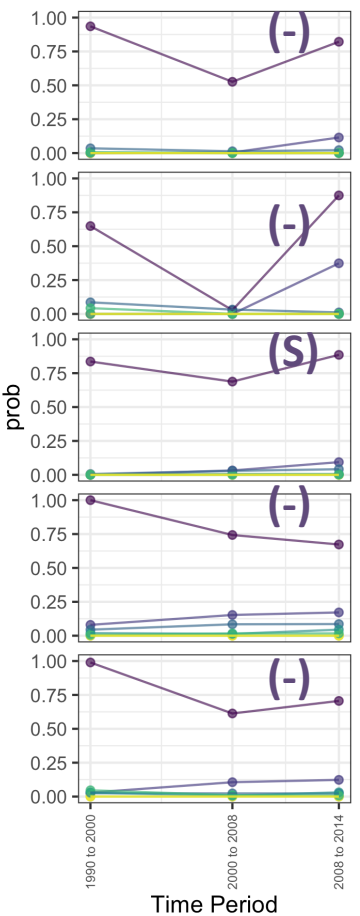
Dynamics through time of artificial ecosystems across admin. zones



Planted Forests (S)

Food Crops & Pastures (C)

Floriculture Crops



Transition typologies

Transition typologies

Transition typologies

Transition typologies

- Developed to Developed
- Floriculture crop to Developed
- Food crop and Pasture to Developed
- Planted forest to Developed
- Shrubs and Herbs to Developed
- Native forest to Developed
- Paramo to Developed

- Planted forest to Planted forest
- Developed to Planted forest
- Floriculture crop to Planted forest
- Food crop and Pasture to Planted forest
- Shrubs and Herbs to Planted forest
- Native forest to Planted forest
- Paramo to Planted forest

- Food crop and Pasture to Food crop and Pasture
- Developed to Food crop and Pasture
- Floriculture crop to Food crop and Pasture
- Planted forest to Food crop and Pasture
- Shrubs and Herbs to Food crop and Pasture
- Native forest to Food crop and Pasture
- Paramo to Food crop and Pasture

- Floriculture crop to Floriculture crop
- Developed to Floriculture crop
- Food crop and Pasture to Floriculture crop
- Planted forest to Floriculture crop
- Shrubs and Herbs to Floriculture crop
- Native forest to Floriculture crop
- Paramo to Floriculture crop

(-) Decreased
(S) Stable
(C) Dynamic

LULC pattern analysis – time

Administrative zones
Altitudinal bands

Altitudinal bands (m)

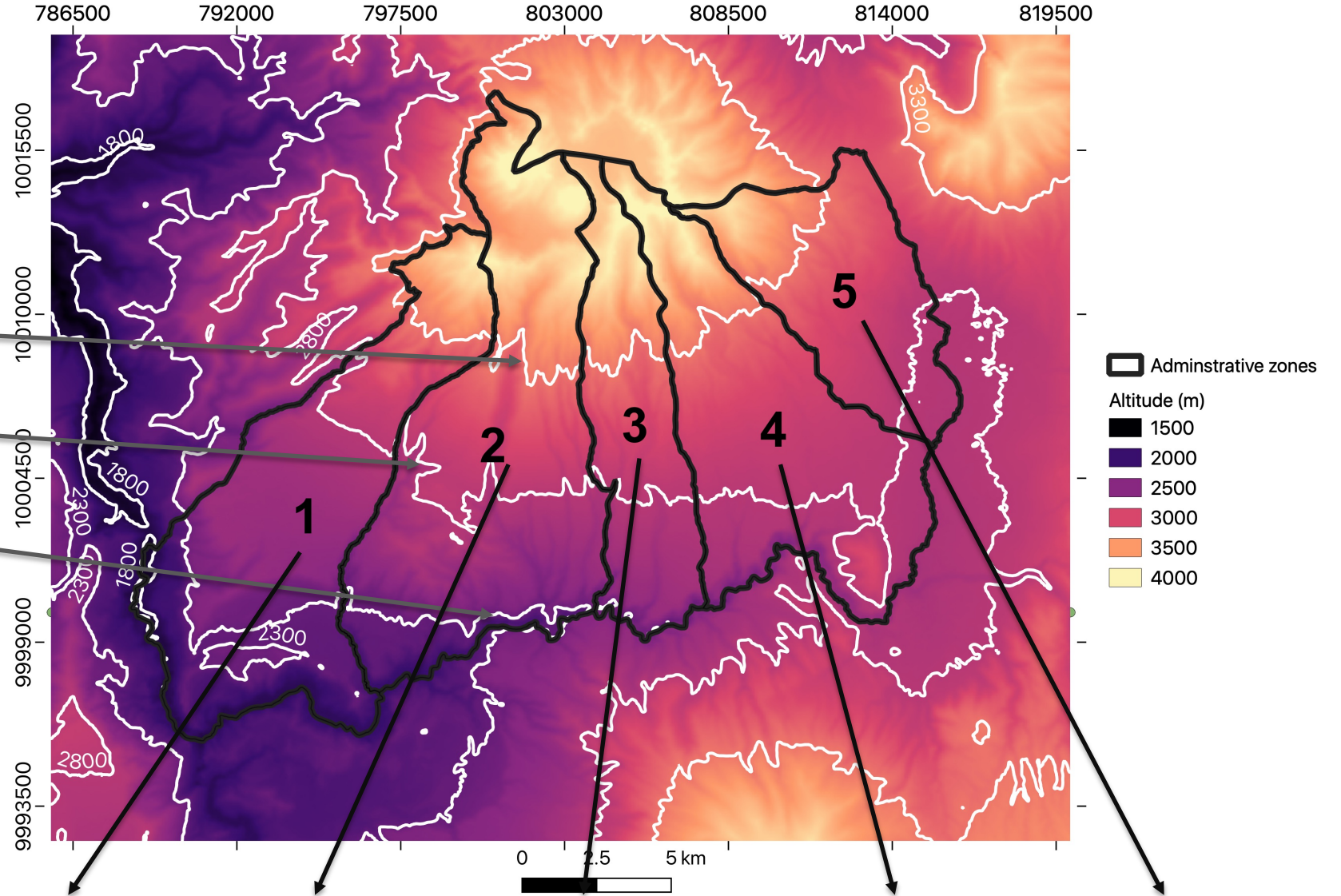
3300

2800

2300

Administrative zones

Malchingui Tocachi La Esperanza Tabacundo Tupigachi

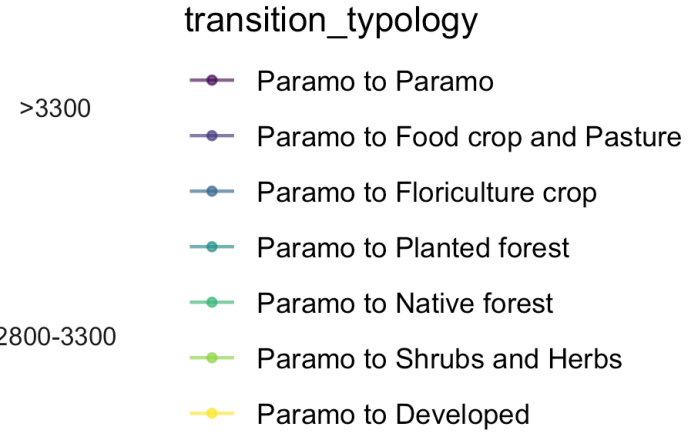
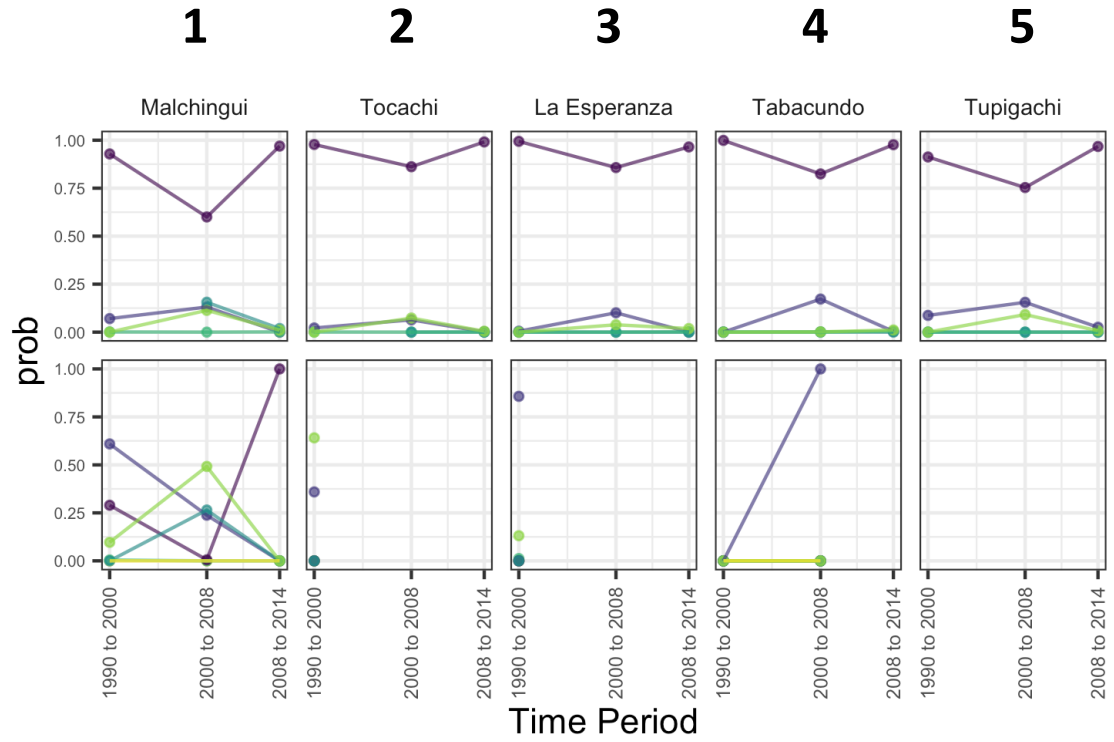
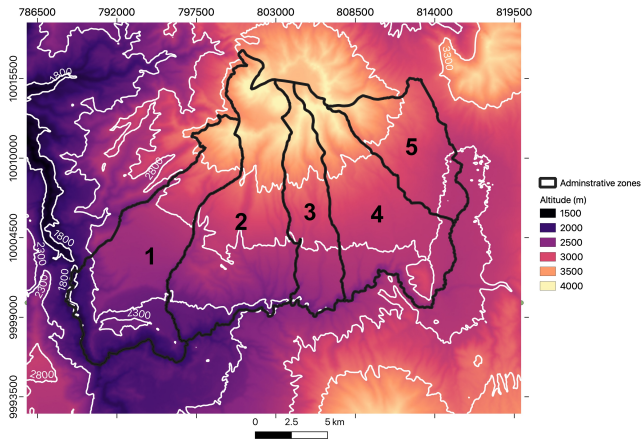


Natural ecosystems



Artificial ecosystems

Stability of Paramo through time



(-) Decreased
 (S) Stable
 (C) Dynamic
 (+) Increased
 (0) Absent

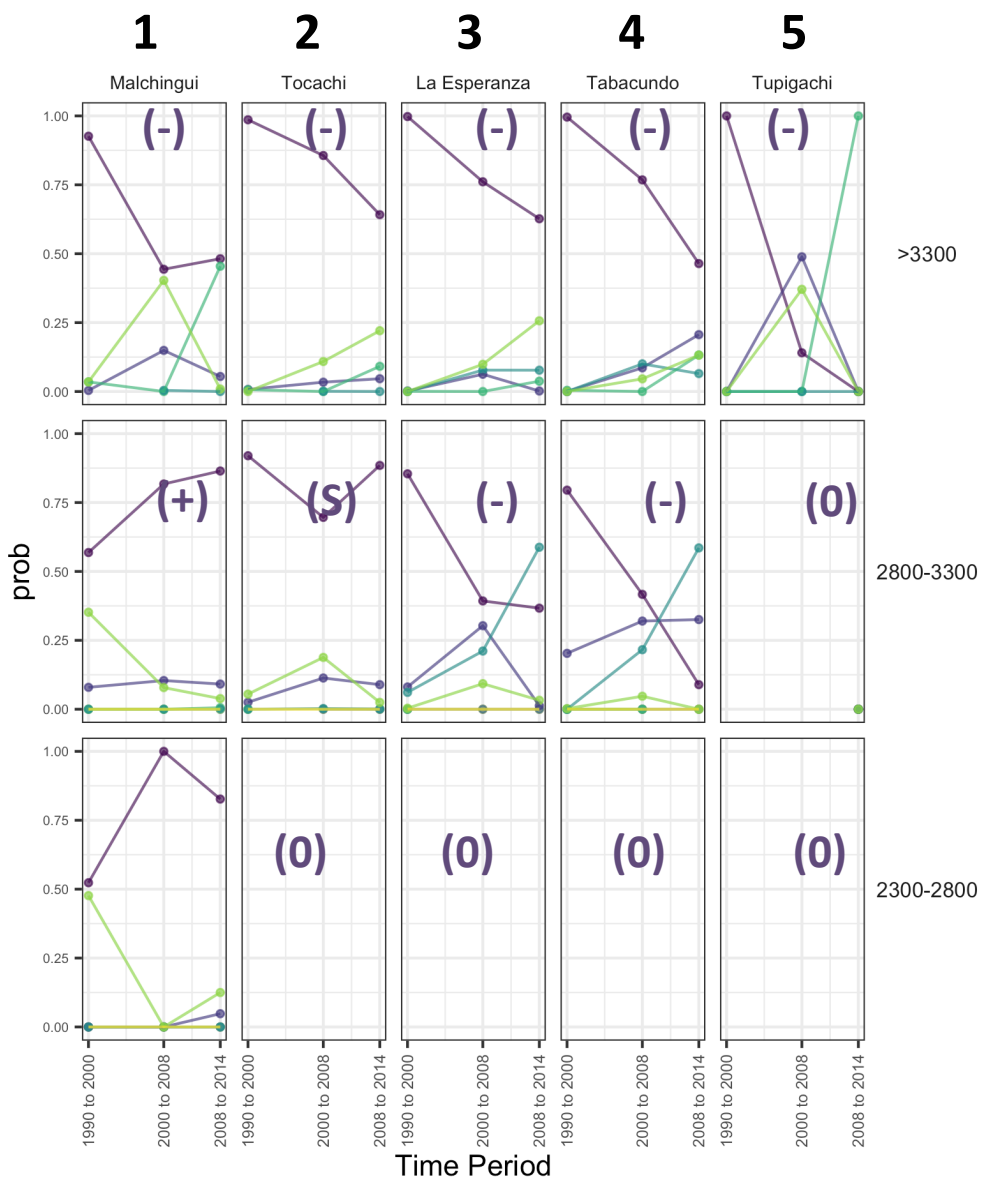
Highly stable across Adm. zones

Natural ecosystems



Artificial ecosystems

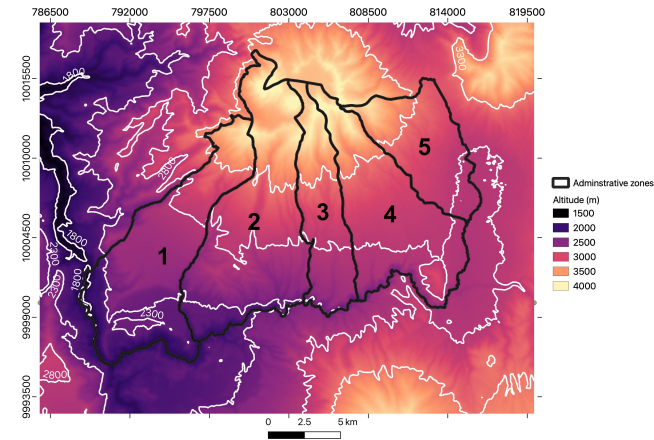
Stability of Native forests through time



transition_typology

- Native forest to Native forest
- Native forest to Food crop and Pasture
- Native forest to Floriculture crop
- Native forest to Planted forest
- Native forest to Paramo
- Native forest to Shrubs and Herbs
- Native forest to Developed

- (-) Decreased
- (S) Stable
- (C) Dynamic
- (+) Increased
- (0) Absent



Mostly decreasing
Slope increasing through time

Converting to planted forests
(La Esperanza + Tabacundo) →
2800 - 3300

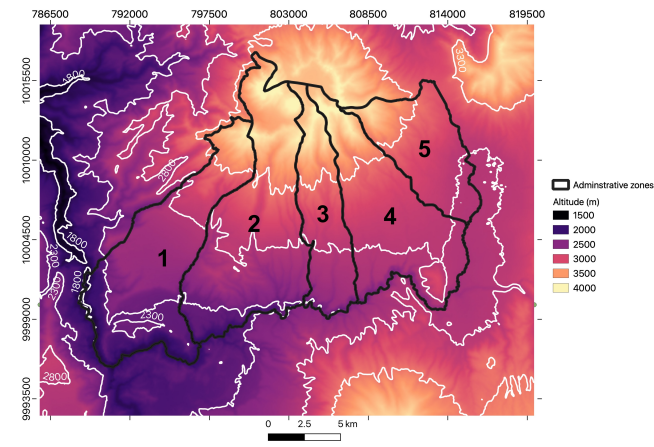
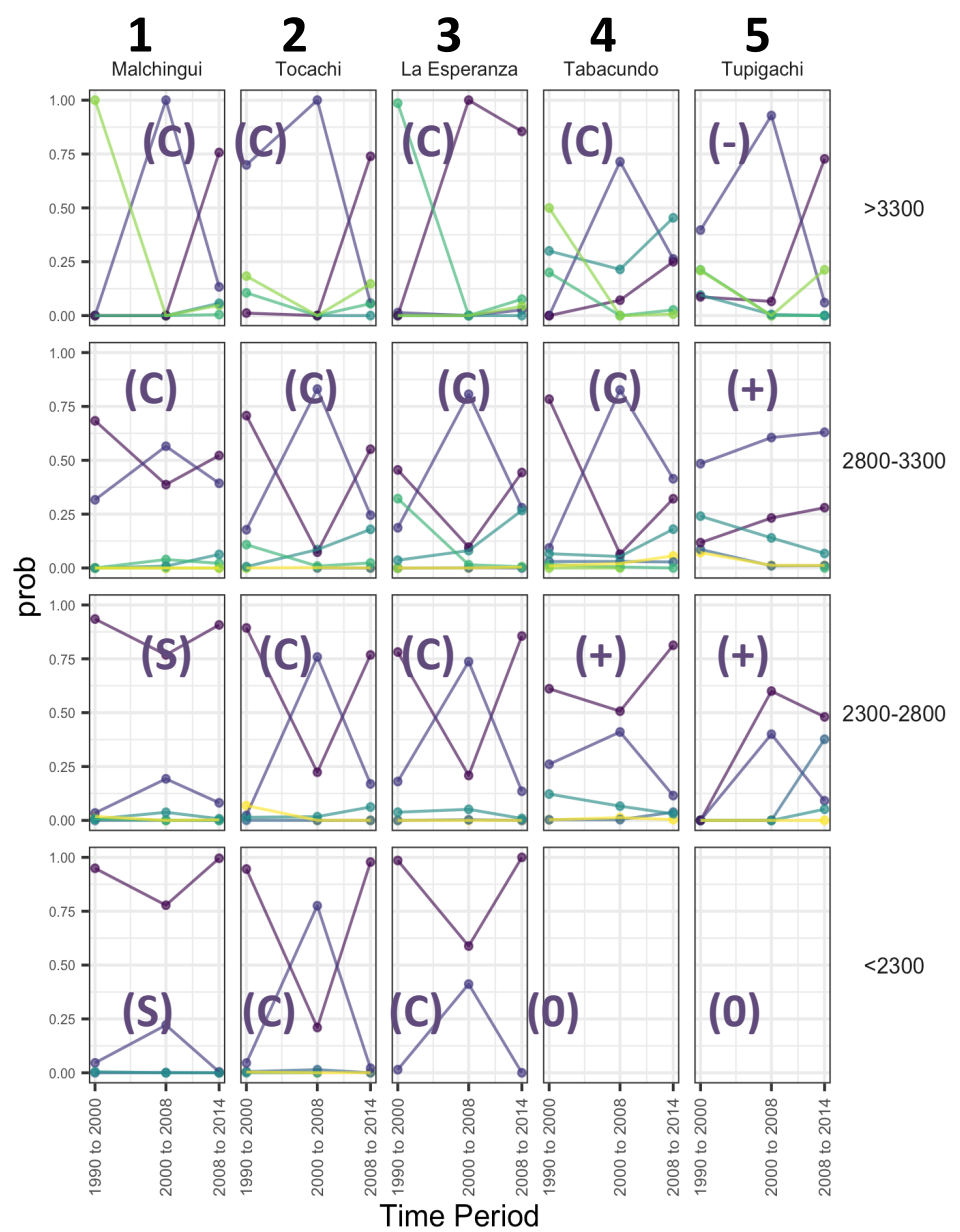
Converting to paramo + shrubs &
herbs → >3300

Natural ecosystems



Artificial ecosystems

Stability of Shrubs and herbs through time



- transition_typology
- Shrubs and Herbs to Shrubs and Herbs
 - Shrubs and Herbs to Food crop and Pasture
 - Shrubs and Herbs to Floriculture crop
 - Shrubs and Herbs to Planted forest
 - Shrubs and Herbs to Native forest
 - Shrubs and Herbs to Paramo
 - Shrubs and Herbs to Developed

- (-) Decreased
- (S) Stable
- (C) Dynamic
- (+) Increased
- (0) Absent

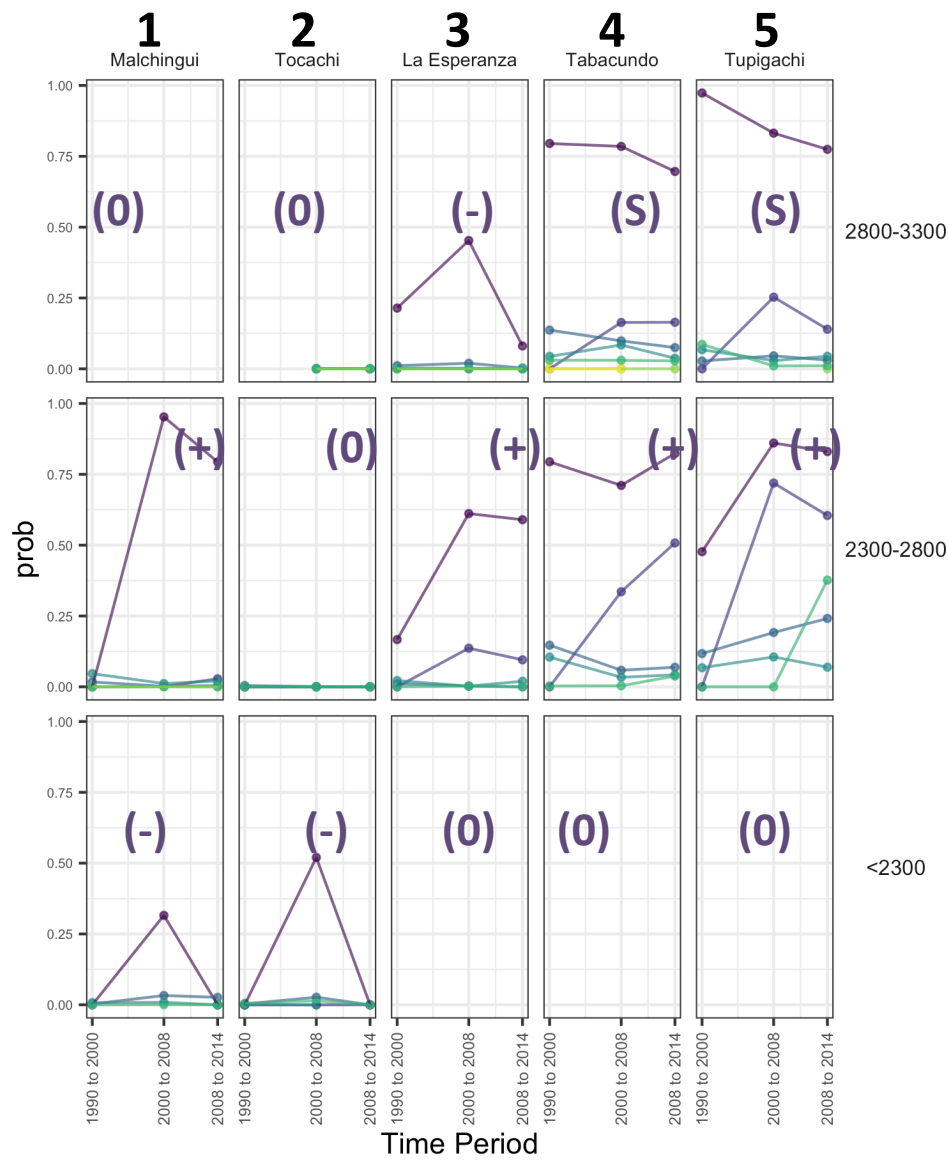
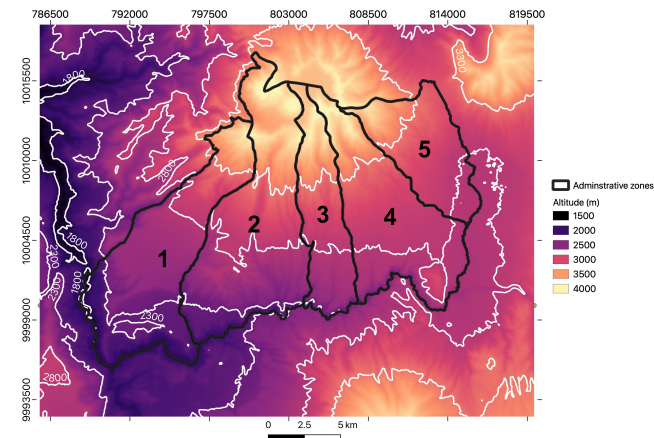
Highly variable across altitudinal bands & administrative zones
 Dynamically shifting towards Food crop And Pasture
 Tabacundo and Tupigachi more stable

Natural ecosystems



Artificial ecosystems

Conversion to Floriculture Crop



transition_typology

- Floriculture crop to Floriculture crop
- Developed to Floriculture crop
- Food crop and Pasture to Floriculture crop
- Planted forest to Floriculture crop
- Shrubs and Herbs to Floriculture crop
- Native forest to Floriculture crop
- Paramo to Floriculture crop

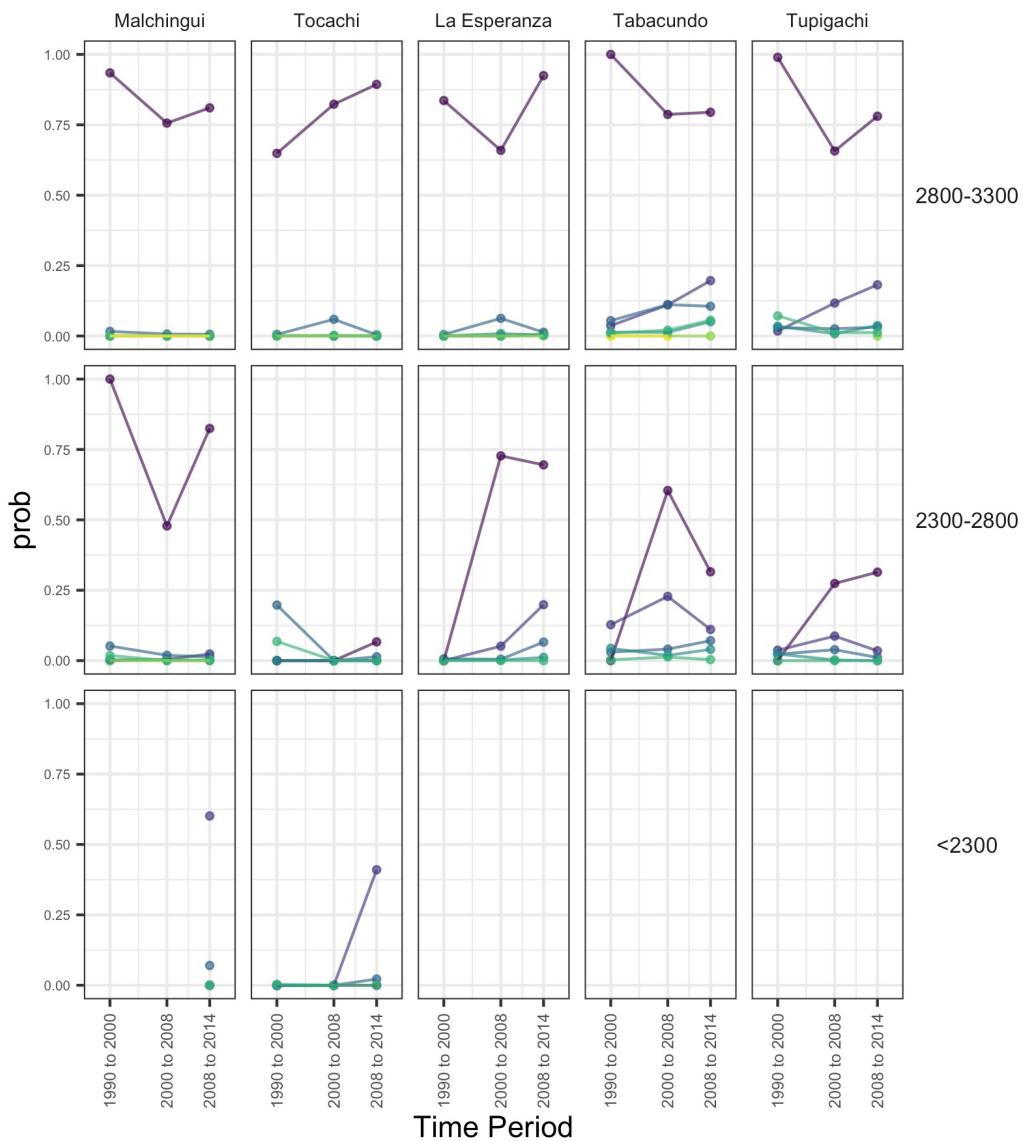
Increasing and stable in the adm. zones located to the East → >2300 m

Natural ecosystems



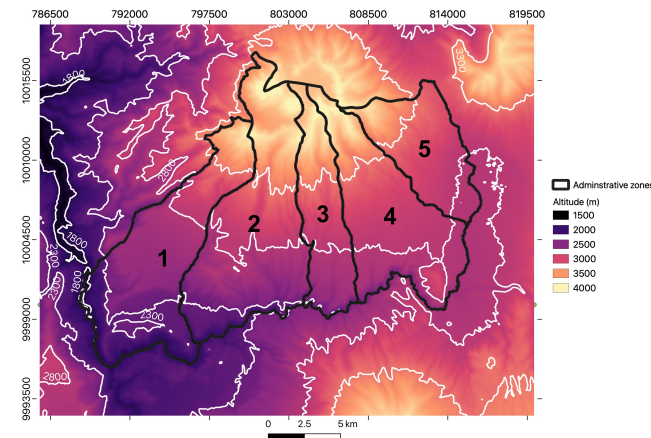
Artificial ecosystems

Conversion to Developed



transition_typology

- Developed to Developed
- Floriculture crop to Developed
- Food crop and Pasture to Developed
- Planted forest to Developed
- Shrubs and Herbs to Developed
- Native forest to Developed
- Paramo to Developed



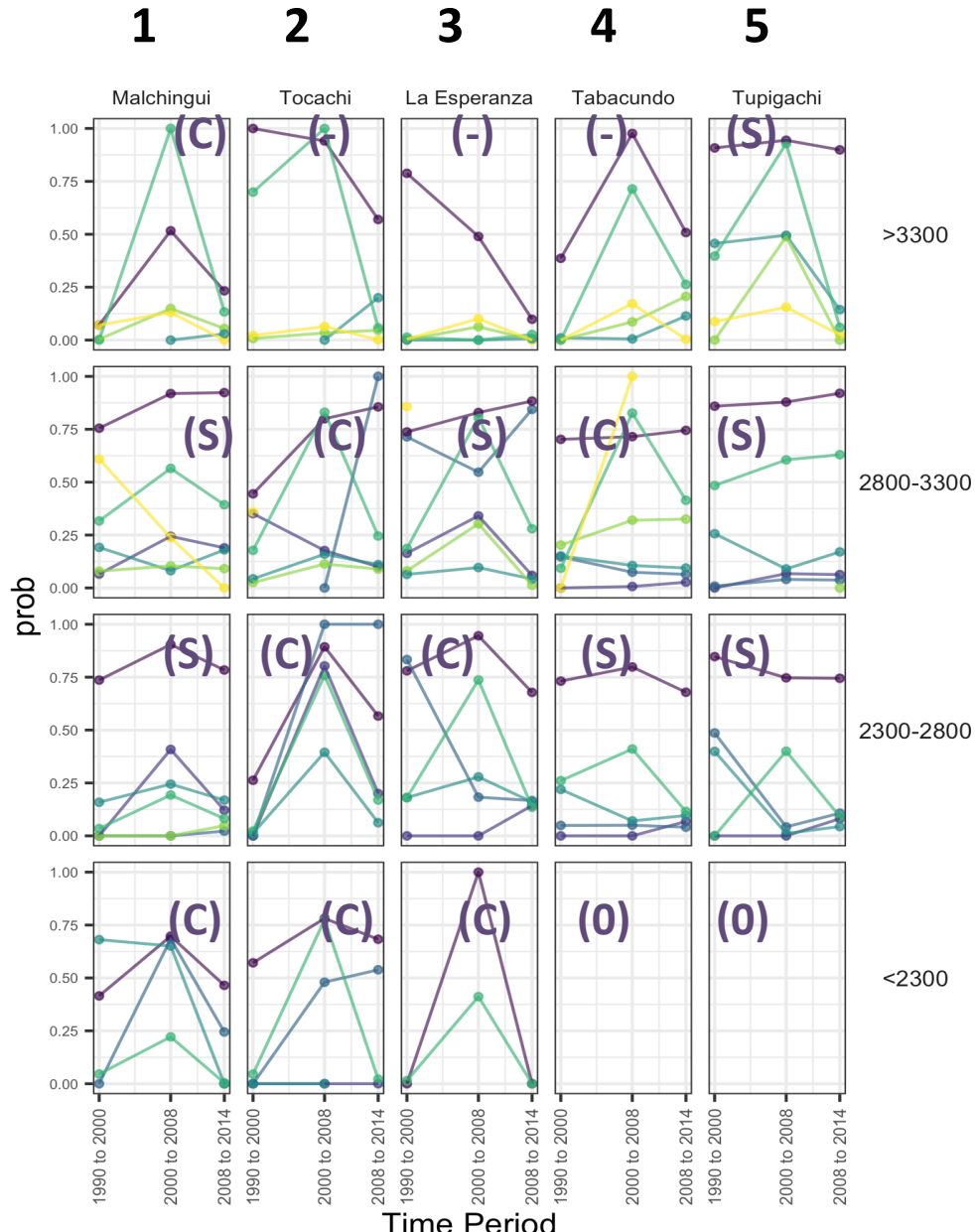
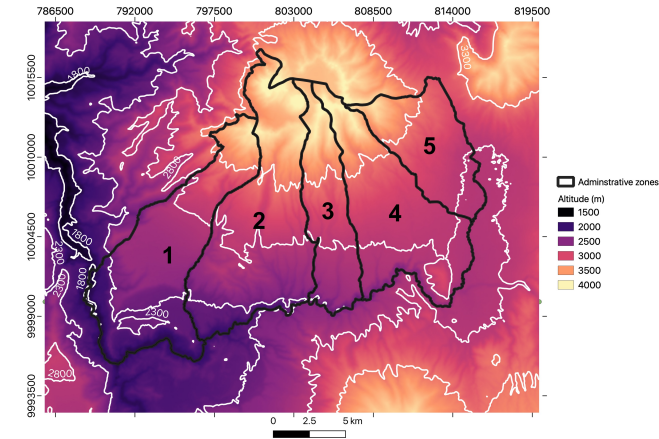
Increasing and stable in the adm. zones located to the East → >2300 m

Natural ecosystems



Artificial ecosystems

Conversion to Food crop and Pasture



transition_typology

- Food crop and Pasture to Food crop and Pasture
- Developed to Food crop and Pasture
- Floriculture crop to Food crop and Pasture
- Planted forest to Food crop and Pasture
- Shrubs and Herbs to Food crop and Pasture
- Native forest to Food crop and Pasture
- Paramo to Food crop and Pasture

Stable in the adm. zones located to the East + West → >2300 m

Decreasing in the center of the territory above 3300

Highly dynamic in the rest of the territory

Resumen de los resultados preliminares

- Los paisajes en los Andes norte de Ecuador continúan cambiando
- La dinámica del paisaje muestra patrones geográficos y altitudinales:
 - Zonas administrativas localizadas en la zona E. del territorio son las más transformadas hacia sistemas artificiales (antropogenizados):
Urbano + Cultivos florícolas + Pastizales y cultivos agrícolas
 - La banda altitudinal 2300-2800 es la que más se ha transformado
- Los bosques nativos están decreciendo, su estabilidad ha disminuido drásticamente (~40%) durante el segundo periodo de análisis (2000-2008) y está disminuyendo continuamente en el último periodo (2008-2014).

3. Cuáles son los factores (drivers of change) que determinan los patrones de cambio encontrados?

Table 1. Summary of the characteristics and origin of the datasets for the variables considered in the LUCC analysis.

Type	Name	Units	Description	Source
Demographic	Total population (Pob)	Number of inhabitants	Absolute change of rural population between 1985 and 2005	National Administrative Department of Statistics (DANE) (1985 y 2005)
	Forced population migration (Desp)	Number of people	Natural logarithm of number of people forced to leave their lands by illegal armed groups or displaced population	Consultoria para los Derechos humanos y el desplazamiento-Codhes (2005)
Socioeconomic	Economic activity (Ecac)	Million Colombian pesos	Taxes, revenues per municipality, equivalent to tax income in million Colombian pesos in 2005	National Planning Department (Departamento Nacional de Planeación-DNP, 2005) and the Unified Information System for (Sistema Único de Información de Servicios Públicos-SUI 2005)
	Unsatisfied basic needs (Nbi)	%	Population with unsatisfied basic needs in 2005; unsatisfied basic needs is a commonly used composite indicator combining census level household measures such as access to adequate housing conditions, water, electricity and sanitation (Feres and Mancero, 2001)	National Administrative Department of Statistics (DANE) (2005)
Land use	Mineria (Mi)	ha	Area of mineral concessions	Calculated from map of mineral concessions. Unidad de Planeación Minero Energética (UPME) (2005)
	Protected area (PA)	ha	Area under special management either under category of national protected area or indigenous reserve	Agustin Codazzi National Institute of Geography (IGAC) (2005)

(Continued)

Journal of Land Use Science

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Table1. (Continued).

Type	Name	Units	Description	Source
	Private reserve (PR)	ha	Area private under special management for conservation	Resnatur (2000)
	Change 1985–2000 (CH8500)	ha	Likelihood of total change of area between 1985 and 2000 derived from the satellite image classification	Calculated from Maps of land cover and land use 1985 and 2000
Physical environment	Digital elevation model (DEM)	m asl	Altitude values	The Shuttle Radar Topography Misión (SRTM, 90 m resolution)
	Soil drainage (Soildrain)	Type of drainage	Likelihood of measures aiming at controlling a high water table and water logging in the land	IGAC and CORPOICA (2002)
	Soil fertility (EL_solifert)	Types of fertility	Likelihood of the quality of a soil that enables it to provide essential chemical elements	IGAC and CORPOICA (2002)
	Type of soil (EL_Soils)	Kind of soil	Likelihood of type of soil based on USDA classification	IGAC and CORPOICA (2002)
	Slope (Slope)	%	Likelihood to diverge from the vertical or horizontal	Data derived from DEM
	Depth of soil (Soildepth)	cm	Likelihood of depth of soil	IGAC and CORPOICA (2002)
Attractors	Precipitation (Prec)	mm	Annual precipitation	Calculated from CIAT database (2000)
	Distance to cities (Dist_cabec)	km	Distance to urban and suburban center existing in the region	Calculated based on human settlements map provided by IGAC (2005)
	Distance to focus of fire (Dist_fire)	km	Distance to hotspot fire between 2000 and 2002	Calculated based Map of urban center provided by IGAC (2005)
	Distance to nearest forest fragment (Dist_forest)	km	Distance to forest existing in 1985	Calculated based on Maps of land use and land cover, 1985
	Distance to nearest pasture (Dist_pasture)	km	Distance to pasture existing in 1985	Calculated based on Maps of land use and land cover, 1985
	Distance to road (Dist_roads)	km	Distance to road existing in the region	Calculated based on road networks map provided by IGAC (2005)

4. Cómo el LULC ha influenciado en la capacidad de los ecosistemas de proveer SE?

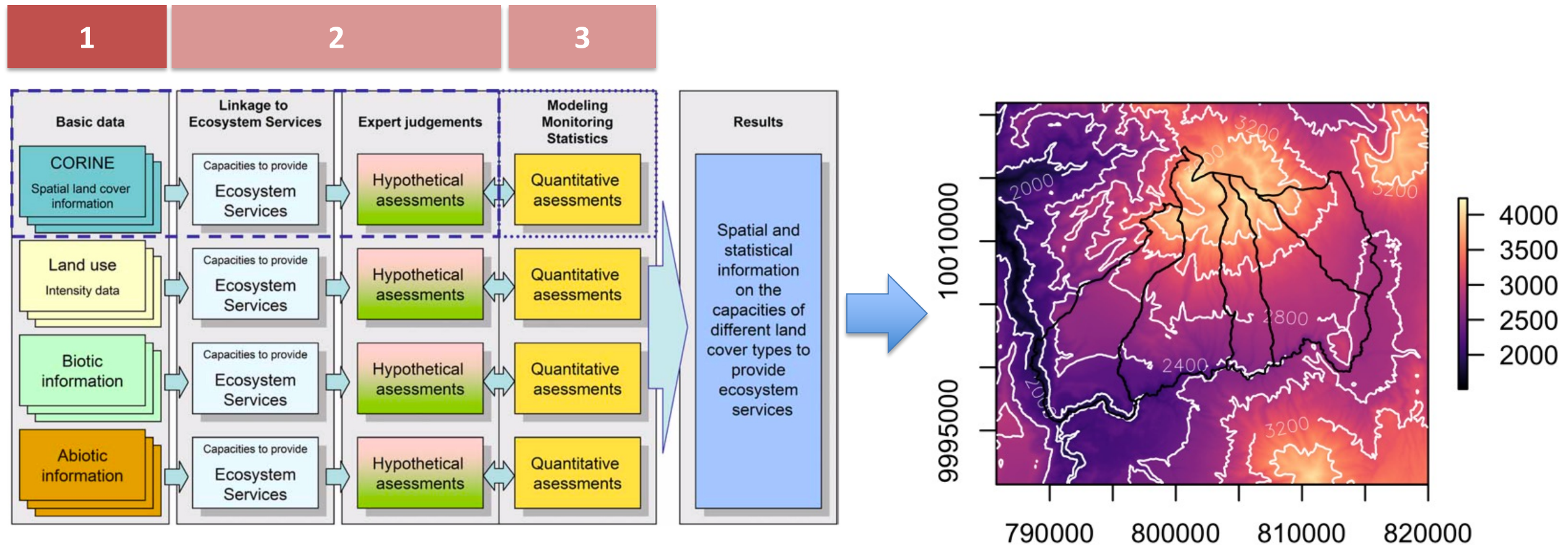


Figure 5: Conceptual framework to assess and quantify landscapes' capacities to provide ecosystem services.

The dashed and dotted lines indicate the components presented with examples in this paper.

Burkhard (2009, 2012)

Mapped
Hypothetical
Assessment

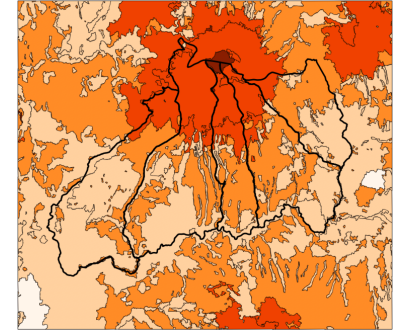
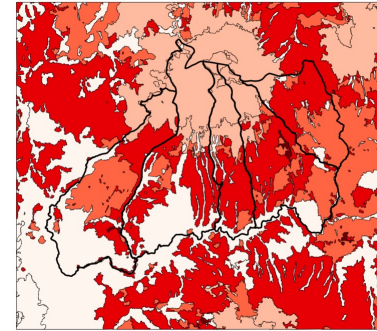
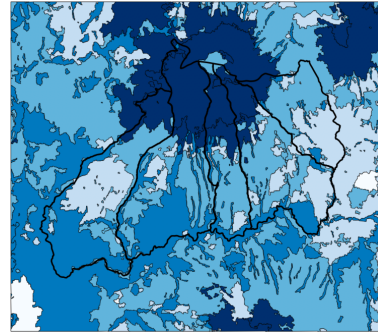
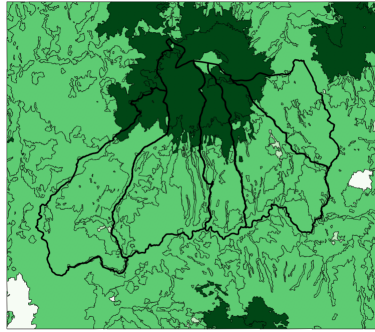
Ec-Int

Reg.

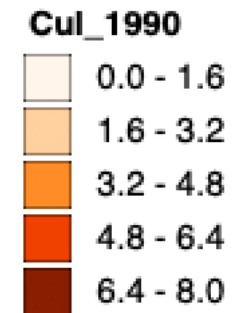
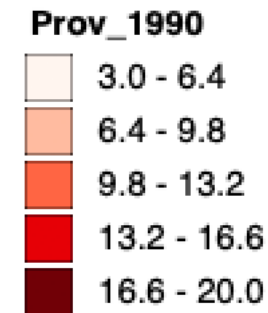
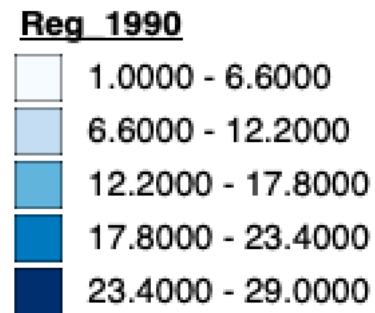
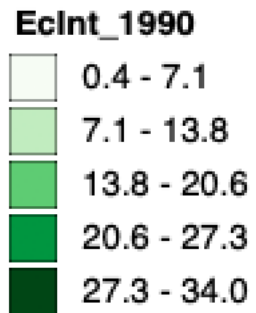
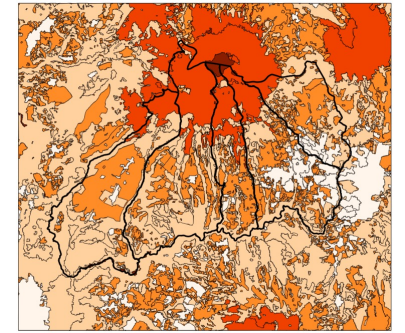
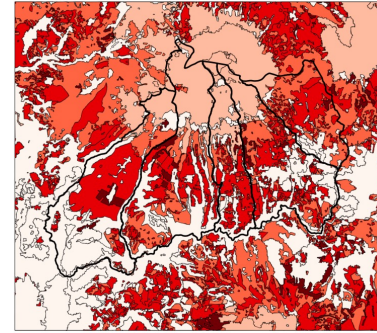
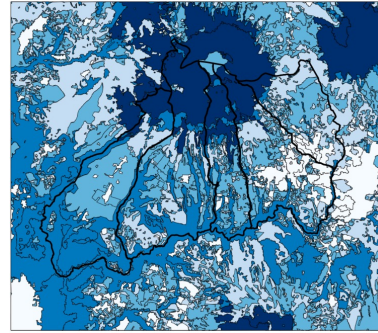
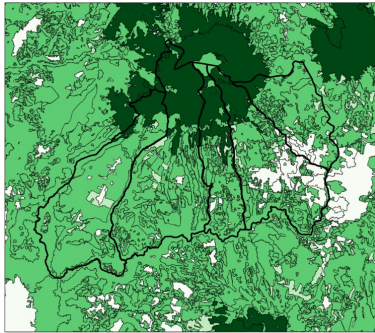
Prov

Cul.

1990



2014



Scale them
to compare?

Aproximación de la investigación

Cómo el cambio de uso del suelo afecta a la biodiversidad y a la capacidad de los ecosistemas para proveer servicios en un paisaje andino de N.Ecuador?

2

LULC ~ Biodiversidad, funciones ecológicas y SE

Grupos de biodiversidad

- Artrópodos
- Cobertura vegetal
- Biomasa de raíces
- Polinizadores
- Microb biomass

Proyectos de estudiantes

Función ecológica

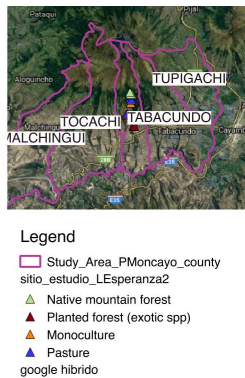
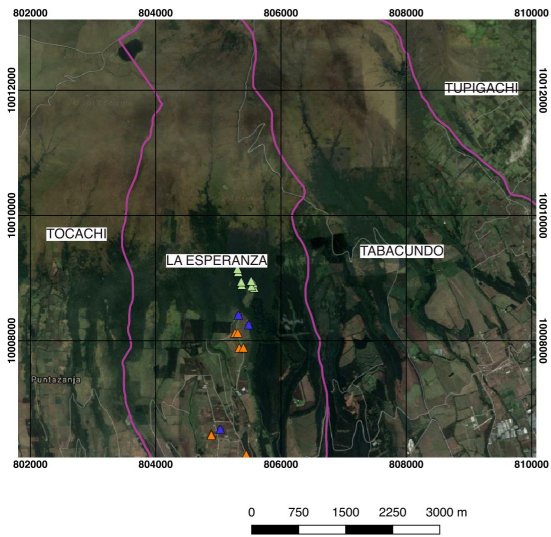
- Mineralization
- Formación de suelo
- Act. Biológica de microorg.

SE as. suelo

- Fertilidad del suelo
- Prevención de la erosión
- Capacidad de mantene agua
- Microclimate regulation



LULC ~ Biodiversidad, funciones ecológicas y SE



Tipologías LULC

Bosques Nativos

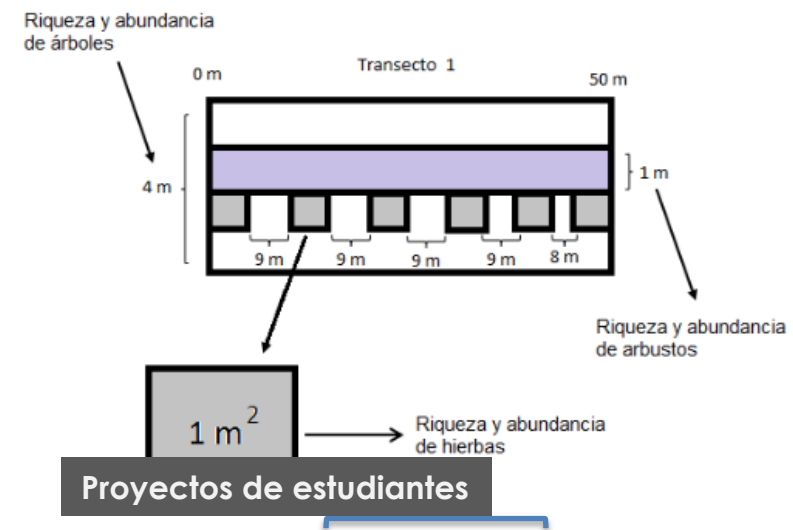
Bosques Plantados

Pastizales

Monocultivos



Proyectos de investigación de grado



Control

Taxonomía del suelo: Inseptisol

Altitude: 3000 – 3600 m

N = 10

Manejo administrativo

Una parroquia-> La Esperanza

Grupos de biodiversidad

- Artrópodos
- Cobertura vegetal
- Biomasa de raíces
- Polinizadores
- Microb biomass



Función ecológica

- Mineralization
- Formación de suelo
- Act. Biológica de microorg.



SE as. suelo

- Fertilidad del suelo
- Prevención de la erosión
- Capacidad de mantener agua
- Microclimate regulation

1 Datos de biodiversidad



2.1 Datos de funciones ecológicas



2.2 Datos de servicios ecosistémicos



3



4 5



Resultados

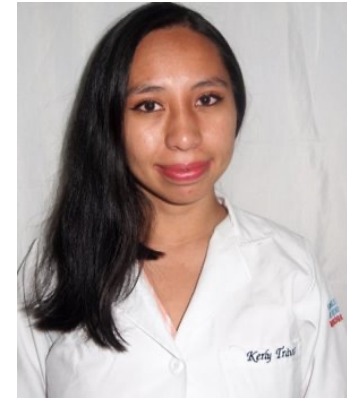
Proyectos pregrado



Wendy Guamán-Trávez



Alejandra Solórzano



Kerly Alejandra Trávez



Camilo Andrés Rosero-Gómez



Justine Villalba-Alemán