

Exploring the Relationship between International Migration Processes and Land Use/ Land Cover Change in Mexico from 2000 to 2010.

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Introduction – Project

- Drivers of LU/CC are:
 - Multiple
 - Complex
 - Important
- Mexico has large forested areas undergoing dynamic LU/CC changes.
- Research Question: What is the relationship between migration, population & economic processes and LU/CC in Mexico?

Introduction - Mexico

- Good Case Study:
 - Large, heterogeneous nation
 - Environmentally diverse
 - Has experienced large scale deforestation AND reforestation
 - Migration and remittances important social factors



1. Wikipedia contributors, "A List of countries by GNI (PPP) per capita" *Wikipedia, The Free Encyclopedia* https://en.wikipedia.org/wiki/List_of_countries_by_GNI_%28PPP%29_per_capita (accessed August 10, 2015).

Introduction – Mexican Agriculture

- Large migration of population, especially to North America, strong tradition of agricultural worker migration
- Mexican Agriculture
 - 22% of population is rural (2010)
 - Agricultural powerhouse in Latin America
 - Industrial agriculture & small scale agriculture



Associations between Migration and LU/CC

- Forest Transition Theory: rural outmigration leads to
 - Forest returns on abandoned small farms
 - Forest decline in areas with large industrial farms

Rudel, T. K., Schneider, L., & Uriarte, M. (2010). Forest transitions: An introduction. *Land use policy*, 27(2), 95-97.
- Remittances
 - Similar story, can lead to multiple outcomes
 - Allow for increased migration, back to above
 - Allow, non-farm investment = forest return
 - Allow for farm investment = forest loss.
- Outcome is very context and scale dependent.
- Can result in different LU/CC outcomes in seemingly similar situations.
 - Aide, T. M., M. L. Clark, H. R. Grau, D. López-Carr, M. A. Levy, D. Redo, M. Bonilla-Moheno, G. Riner, M. J. Andrade-Nunez, & M. Muniz (2012). Deforestation and Reforestation of Latin America and the Caribbean (2001-2010). *Biotropica*
 - Barbieri, A. and D.L. Carr (2005). Gender-specific Out-Migration, Deforestation and Urbanization in the Ecuadorian Amazon. *Global and Planetary Change* 47 (2-4): 99-110.
 - Pan, WK, D.L. Carr, A Barbieri, RE. Bilsborrow, C. Suchindran. (2007). Forest Clearing in the Ecuadorian Amazon: A Study of Patterns over Space and Time. *Population Research and Policy Review* 26(5-6): 635-659.

Methods

- LU/CC Data
 - Woody Vegetation Change
 - Biomes
- Predictor Variable Suites
 1. Environmental Variables
 2. Migration Variables
 3. Population Variables
 4. Economic Variables
- Regression Analyses

Methods – LU/CC Data

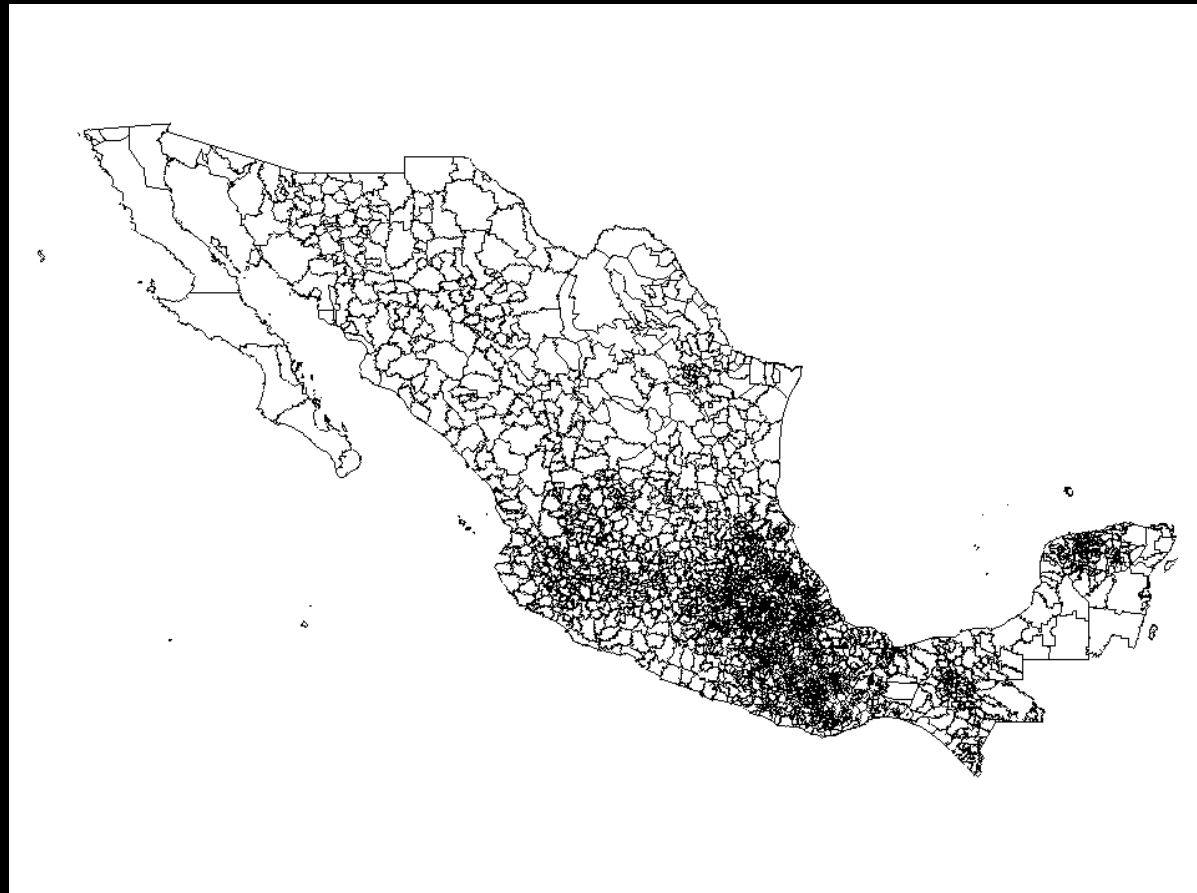
- LU/CC Data
 - Annual (2000-2010) land cover maps based on 250-m Moderate Resolution Imaging Spectroradiometer (MODIS) Satellite Data.
 - Classification of Pixels (VIEW-IT)⁵
 - Linear Regression to identify significant SLOPE of change between 2000 and 2010
- Outcome Variable
 - Significant ($p > 0.10$) slopes of change in Woody Vegetation between 2000 and 2010 by Municipio nested within biomes
- Aide, T. Mitchell, Matthew L. Clark, H. Ricardo Grau, David López-Carr, Marc A. Levy, Daniel Redo, Martha Bonilla-Moheno, George Riner, María J. Andrade-Núñez, and María Muñiz. (2013). "Deforestation and reforestation of Latin America and the Caribbean (2001–2010)." *Biotropica* 45, no. 2 (2013): 262-271.

Methods – LU/CC Data

Scale of analysis: Municipio Level – 2,438. Smallest unit of analysis possible given other data.



States (*Estados*) – 1st level
(n=31)

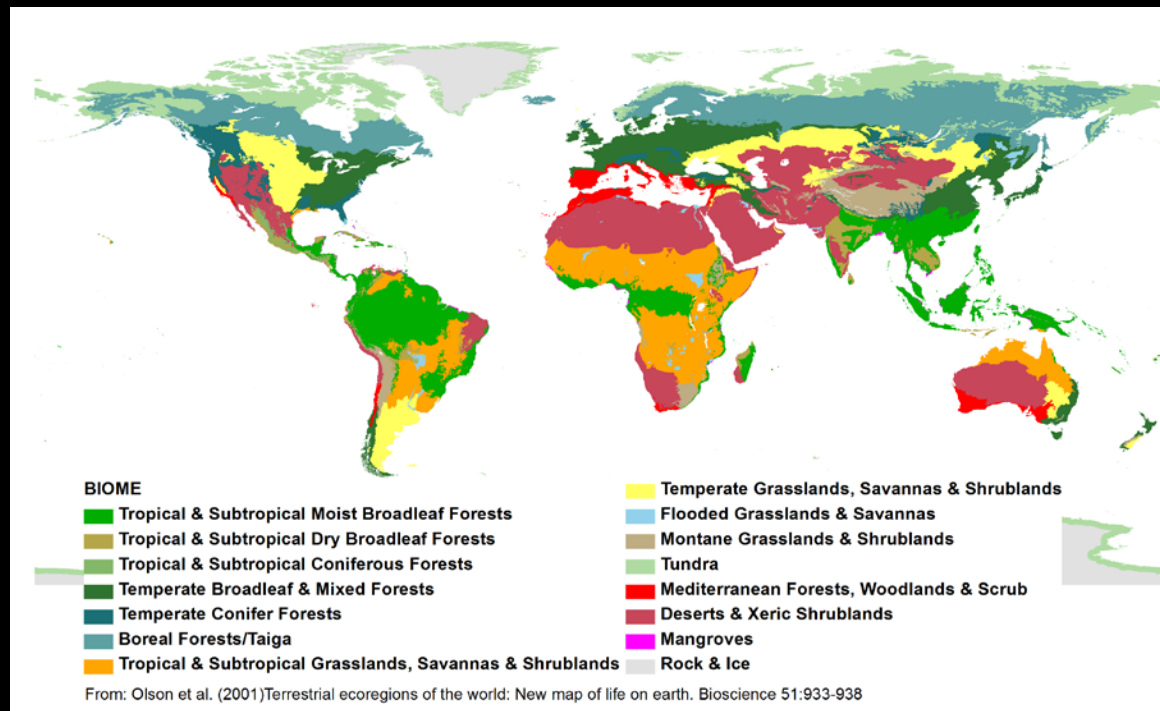


Municipalities (*Municipios*) – 2nd level (n=2,438)

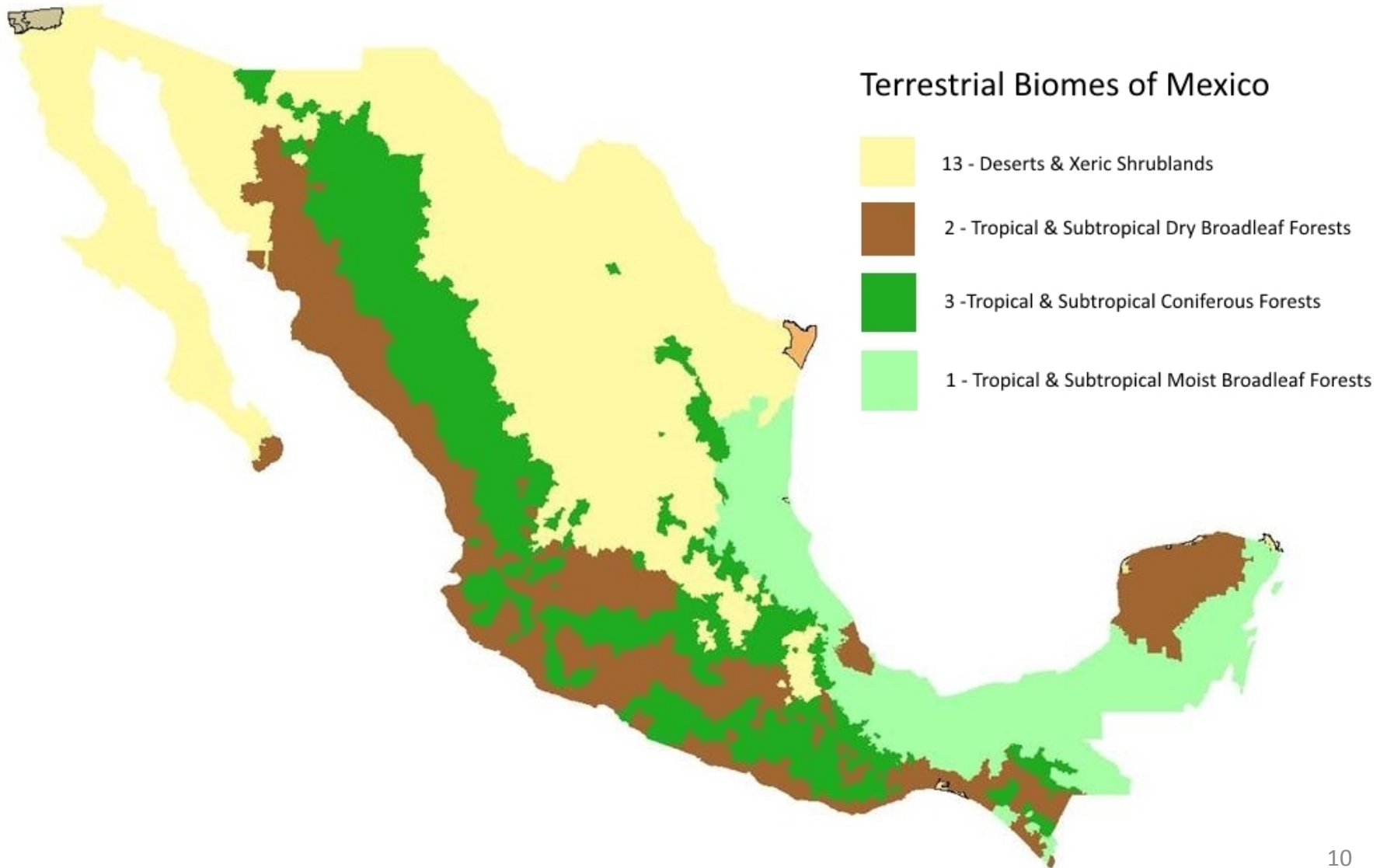
Biomes

- Current project inspired by similar work from colleagues examining LU/CC and land tenure systems
- Had identified that biome was an important predictor of vegetation change

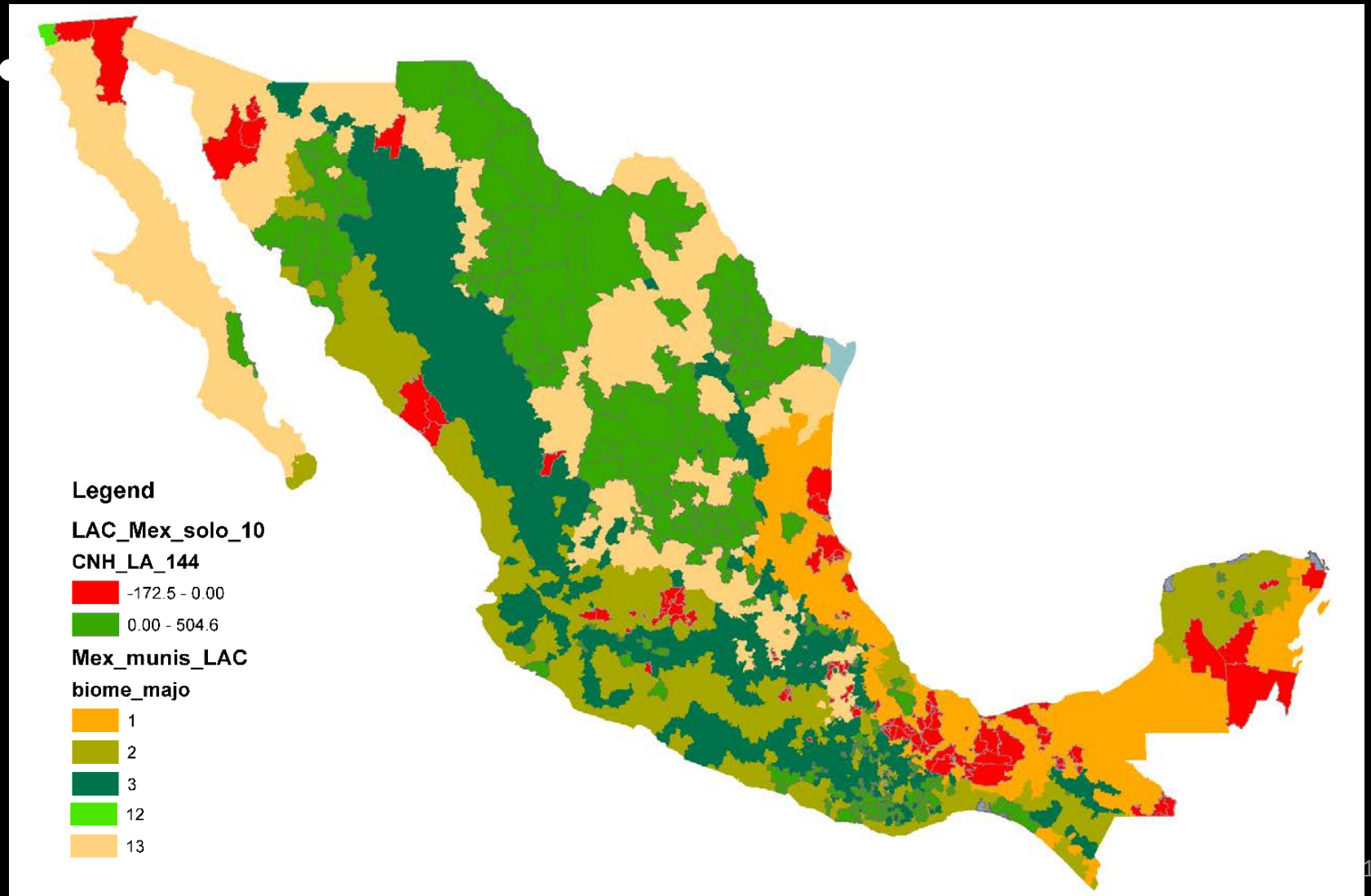
Bonilla-Moheno, Martha, Daniel J. Redo, T. Mitchell Aide, Matthew L. Clark, and H. Ricardo Grau. "Vegetation Change and Land Tenure in Mexico: A Country-Wide Analysis." *Land Use Policy* 30, no. 1 (January 2013): 355–64.



Mexican Biomes



Results - Significant Forest Cover Change 2000-2010



Results - Significant Forest Cover Change 2000-2010

Biome	Biome Count	Positive Change	Negative Change	% Positive	% Negative
1 - Tropical and subtropical moist broadleaf forests (TSMB)	432	8	57	2%	13%
2 - Tropical and subtropical dry broadleaf forests (TSB)	701	109	30	16%	4%
3 - Tropical and subtropical coniferous forests (CON)	829	165	10	20%	1%
13 - Desert and Xeric Shrubland (DES)	474	140	19	30%	4%
Total	2436	422	116	17%	5%
Biome	Land Area (SQ KM)	Positive Change (SQ KM)	Negative Change (SQ KM)	% Positive	% Negative
1 – Tropical and subtropical moist broadleaf forests (TSMB)	293,002	4,641	66,878	2%	23%
2 - Tropical and subtropical dry broadleaf forests (TSB)	382,262	57,690	20,000	15%	5%
3 - Tropical and subtropical coniferous forests (CON)	429,743	45,152	3,249	11%	1%
13 - Desert and Xeric Shrubland (DES)	862,085	393,781	29,164	46%	3%
Total	1,967,092	501,264	119,291	25%	6%



Predictor Variables

Variable Suites:

1. Environmental Variables
2. Migration Variables
3. Population Variables
4. Economic Variables

Predictor Variables - Environmental

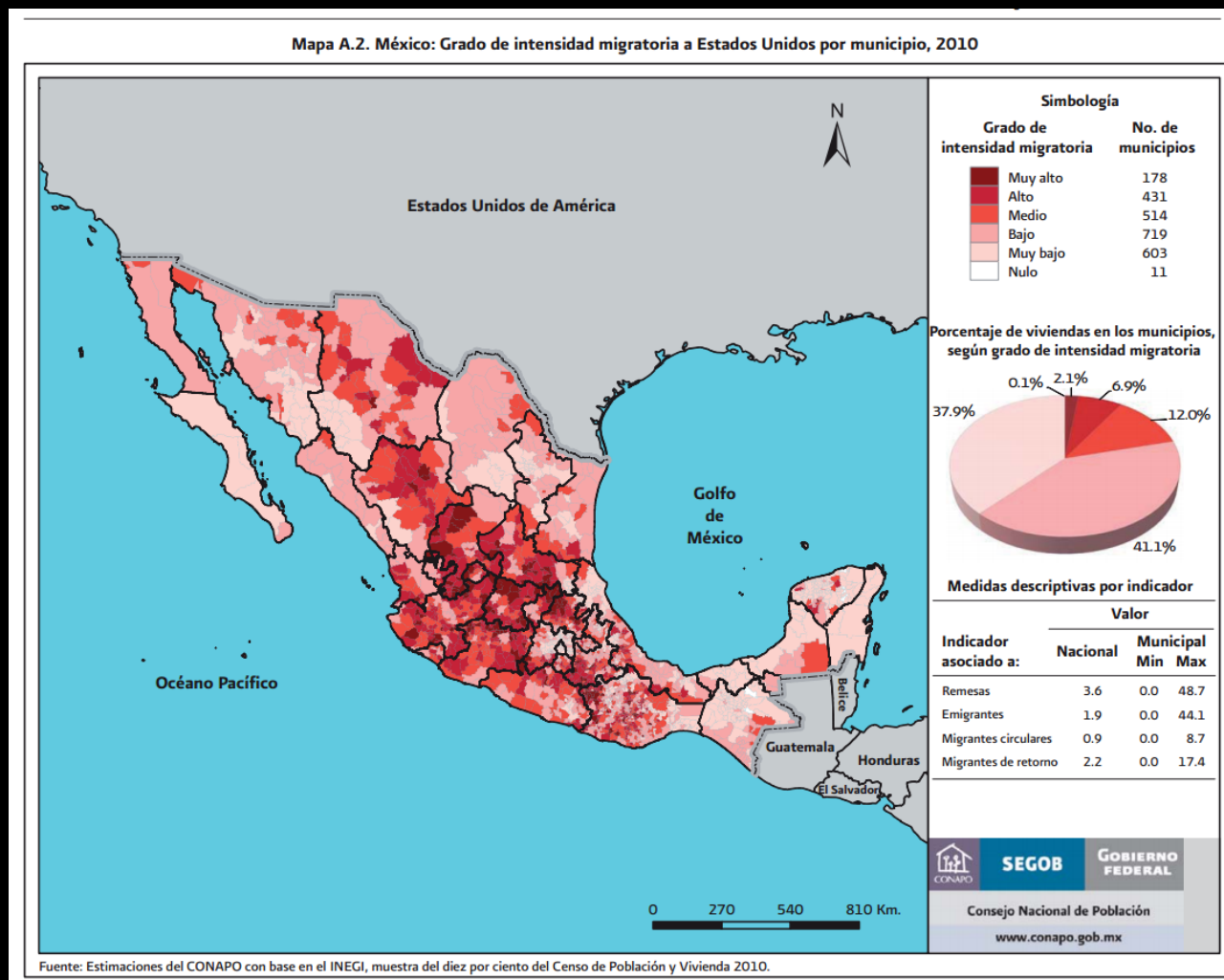
Variable name	Time Scale	Variable Description
Area_km2	2010	Area (km ²)
DEM_Mean	2010	Mean elevation
DEM_Std	2010	SD of elevation
Precip_Mean_Annual	2000-2010	Annual mean precipitation (mm)
Precip_Std_Annual	2000-2010	Annual SD of precipitation (mm)
Precip_Std_Mean_monthly	2000-2010	Monthly SD of precipitation (mm)
Temp_Mean_Annual	2000-2010	Annual mean temperature (C)
Temp_Std_Annual	2000-2010	Annual SD of precipitation (mm)
Temp_Std_Mean_Monthly	2000-2010	Monthly SD of precipitation (mm)

Predictor Variables - Migration

Variable name	Time Scale	Variable Description
pemig	2000, 2010	Proportional change in emigration from 2000 to 2010
pcirc	2000, 2010	Proportional change in circular migration from 2000 to 2010
pretr	2000, 2010	Proportional change in return migration from 2000 to 2010
pa25	2000, 2010	Change in 25-29 age class (proxy for internal migration)

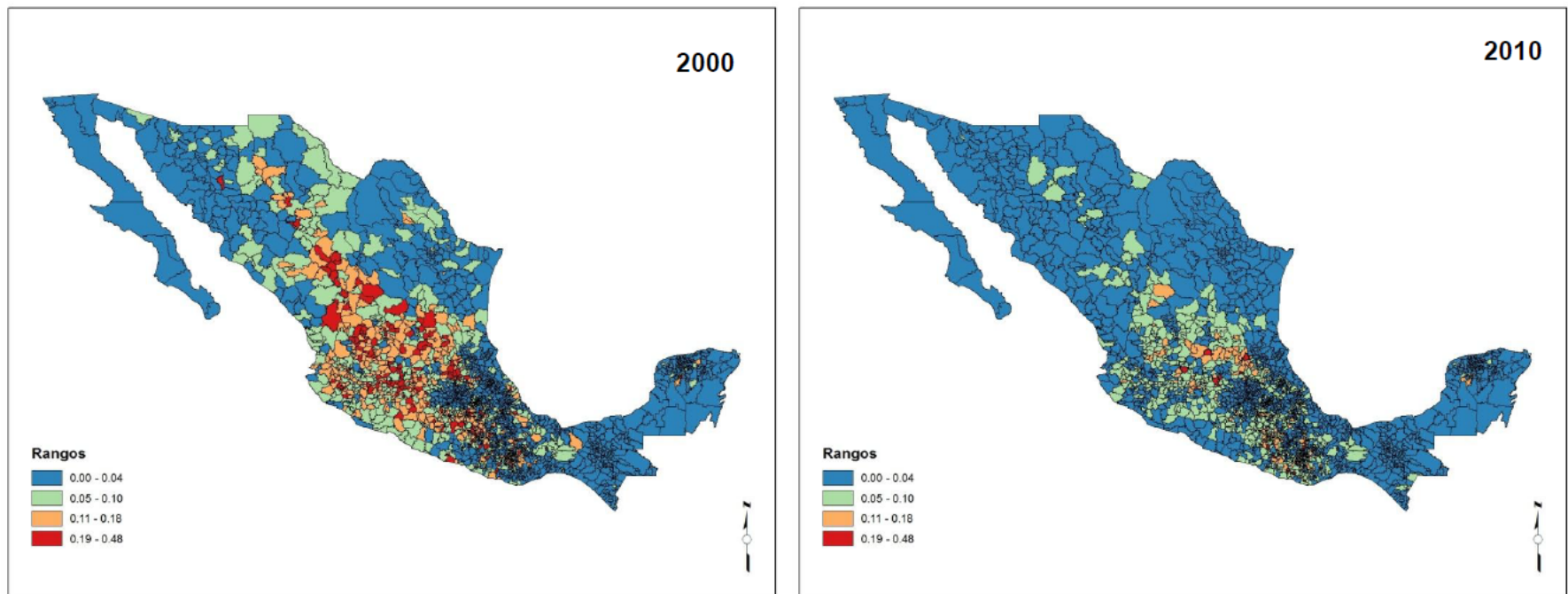
Predictor Variables - Migration

Migration Intensity Index, 2010.



Proportion of households in municipality in 2000 & 2010 with at least one U.S. migrant in the 5 years prior

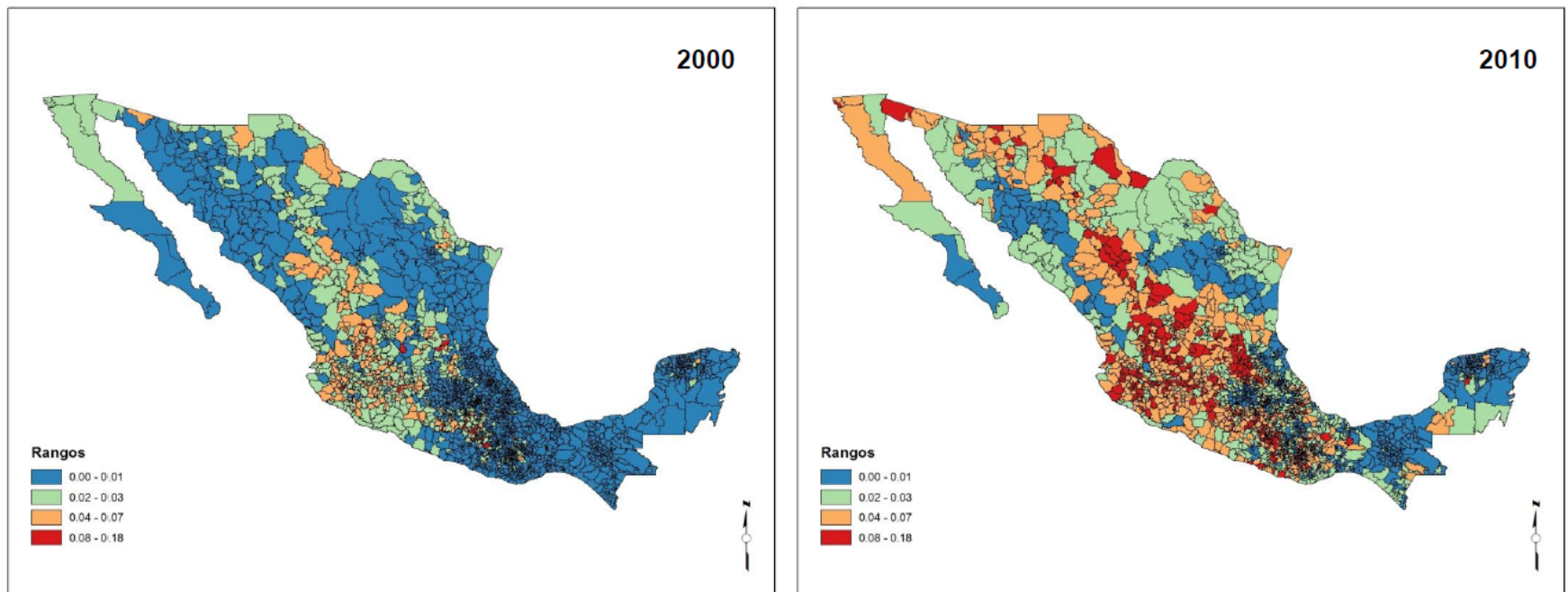
Mapa 1. Proporción de hogares con al menos un emigrante a Estados Unidos entre 2005 y 2010 por municipio. México, 2000 y 2010



Fuente: Estimaciones propias basadas en los microdatos de las muestras censales de 2000 y 2010, INEGI.

Proportion of households in municipality in 2000 & 2010 with at least one member returning from the United States in the 5 years prior

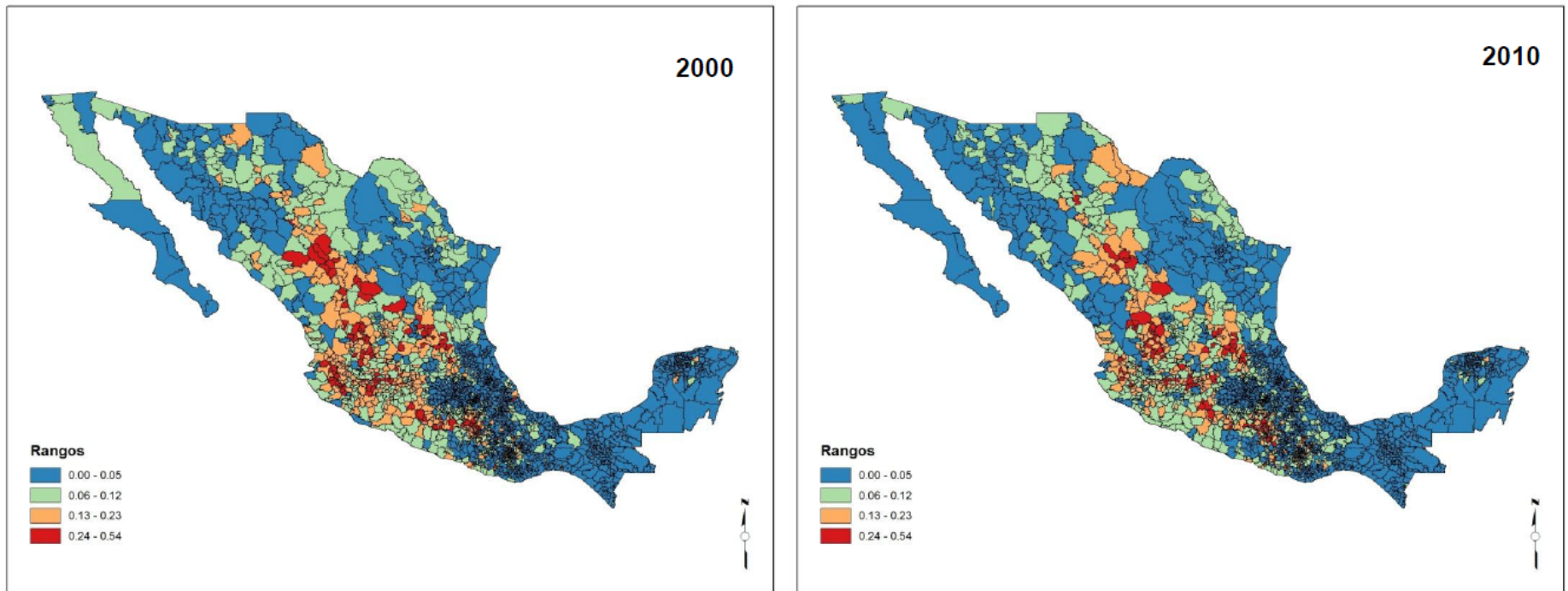
Mapa 3. Proporción de hogares con al menos un migrante de retorno por municipio. México, 2000 y 2010



Fuente: Estimaciones propias basadas en los microdatos de las muestras censales de 2000 y 2010, INEGI.

Proportion of households in municipality in 2000 & 2010 that reported receiving remittances from abroad

Mapa 2. Proporción de hogares que recibían remesas por municipio. México, 2000 y 2010



Fuente: Estimaciones propias basadas en los microdatos de las muestras censales de 2000 y 2010, INEGI.

Predictor Variables - Economic

Variable name	Time Scale	Variable Description
marg00	2000	A index of economic marginalization
pmarg	2000-2010	Proportional change in marginalization index (marg00) from 2000-2010
primsect00	2000	Percent of working people in primary sector activities
punemp	2000-2010	Proportional change in unemployment 2000-2010
totalheads	2007	Count of heads of beef cattle
Ed00	2000	Percentage of complete secondary level education
pEd	2000-2010	Proportional change in education level (Ed00) from 2000-2010

Predictor Variables - Population

Variable name	Time Scale	Variable Description
Cpop_00	2000	Population in 2000
pccpop	2000-2010	Mean annualized growth rate in population
pa4	2000, 2010	Ratio of population under 5 in 2010 by ratio of population under 5 in 2000 (Age structure proxy for fertility)
pa25	2000, 2010	Ratio of population aged 25-29 in 2010 by 25-29 year-olds in 2000 (Age structure proxy for migration)



Methods – Model Selection

- Begin with Environmental variables.
- Step through the variable suites in a multi-model selection method
- Using information theoretical approaches to ascertaining model fit
- Used to create a 'best' suite of variables from which to derive a best fit model.
- Evaluate models by ΔAIC (threshold of > 2) to ascertain model improvement.

Results - Models

Model Name	Model Description	Adjusted R ²	AICC	Variables
Environmental Suite Models				
MexE1	Significant slopes	0.47	5233	+Area_km2 +DEM_Mean - Precip_Mean_Annual -DEM_Std - Precip_Std_Annual +Precip_Std_Mean_monthly+Temp_Std_Annual
MexE1neg	Significant negative slopes	0.74	834	-Area_km2 -DEM_Mean -Temp_Mean_Annual +DEM_Std
MexE1pos	Significant positive slopes	0.68	3937	+Area_km2 -Precip_Mean_Annual -DEM_Std
MexE1despos	Significant positive slopes in DES biome	0.64	1449	+Area_km2 -DEM_Std +Precip_Std_Annual - Precip_Std_Mean_monthly -Temp_Std_Mean_Monthly
MexE1Conpos	Significant positive slopes in CON biome	0.78	874	+Area_km2, -DEM_mean, +Temp_Std_Mean_Monthly
MexE1tsmbneg	Significant negative slopes in TSMB biome	0.80	415	-Area_km2
MexE1tsbpos	Significant positive slopes in TSB biome	0.63	675	+Area_km2 +DEM_Mean +Precip_Mean_Annual +Temp_Mean_Annual +Temp_Std_Mean_Monthly
Additions Variable Suite Models			DAICC	
MexB1	Significant slopes		1070	Benv +pemig3 +pcirc3 -pretr3 +prem3 -CPop_00 -pa4 +punemp +Ped
MexB1neg	Significant negative slopes		74	Benv -pcirc3 +pretr3 -prem3 +totalheads
MexB1pos	Significant positive slopes		964	Benv +pemig3 -pcirc3 -pretr3 +pa25 +primsect00 -punemp
MexE1despos	Significant positive slopes in DES biome		496	Benv -pemig3 -pcirc3 -pa25 +primsect00
MexE1Conpos	Significant positive slopes in CON biome		125	Benv +pemig3 -pcirc3 +prert3 +prem3 +primsect00 -ed00
MexE1tsmbneg	Significant negative slopes in TSMB biome		38	Benv -pcirc3 +prert3 +pa4
MexE1tsbpos	Significant positive slopes in TSB biome		110	Benv +pemig3 +pcirc3 +pretr3



Results - Models

- Models are excellent predictors of outcome variable.
- Environmental Suite of variables is by far the most important set of predictors, unsurprisingly.
- International Migration improves model AIC in all situations.
- Variables from other suites improve AIC in particular circumstances.
- Supports International Migrations important role in LU/CC outcomes, even over economic processes



Next Steps

- Further exploration of biomes for particular drivers?
- Contrast model results with social science lit for overlaps and missing pieces?
- More variables?
- Your suggestions?