Land use change modeling for scenarios of the MAR region

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Overview of presentation

- Multi-scale modeling approach
- Overview of the three models used
- Land use classifications and source data
- CLUE-S land use allocation methodology
- Scenario results

Methodology

Multi-scale modelling of **scenarios** of land use change

Multi-scale

• Address
land use sy

• Link glob

• Address
discussion

Modelling

• Structured ana

• Explore dynam

• Projections of

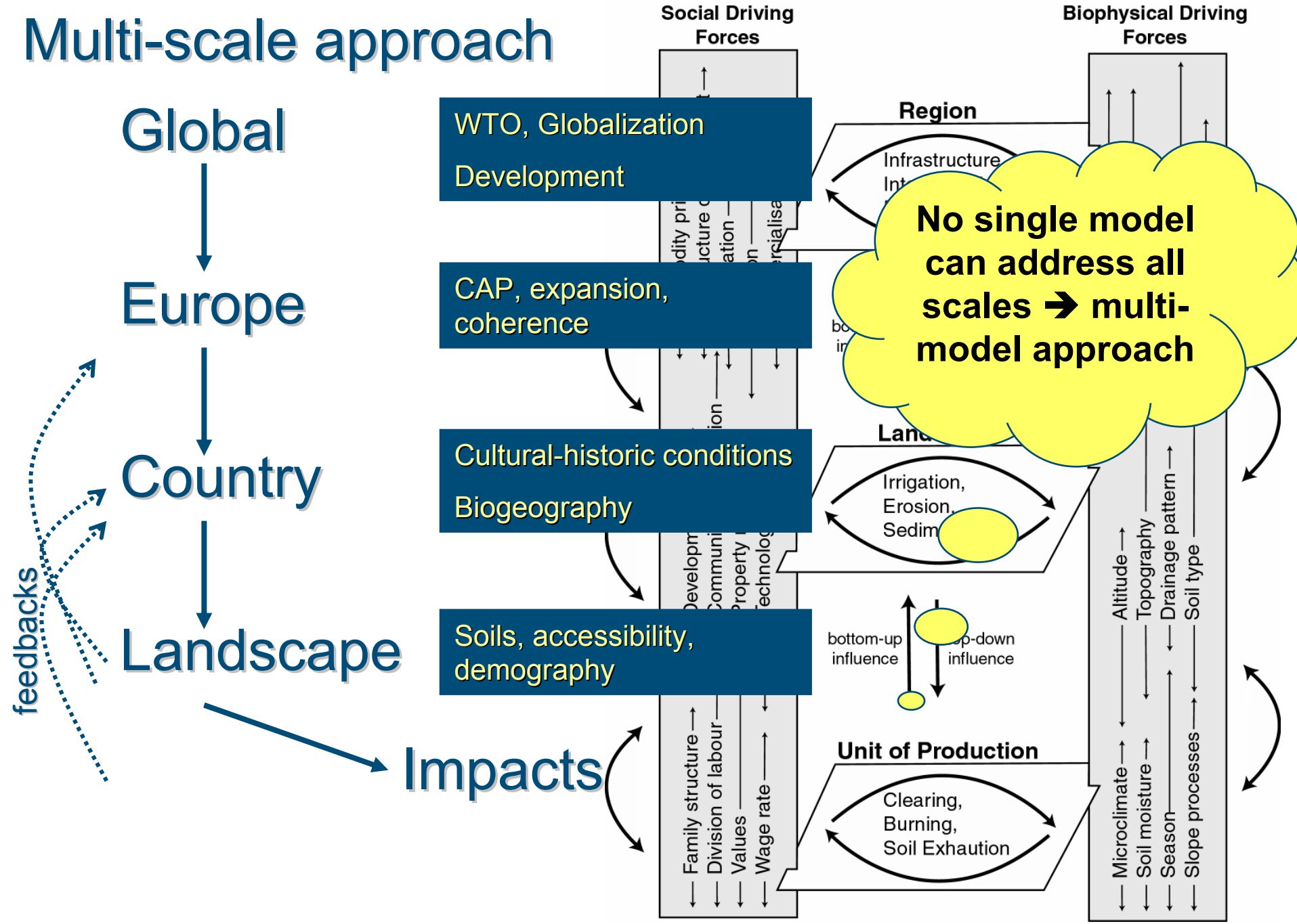
Scenarios

• Deal with uncertainty in development/policy

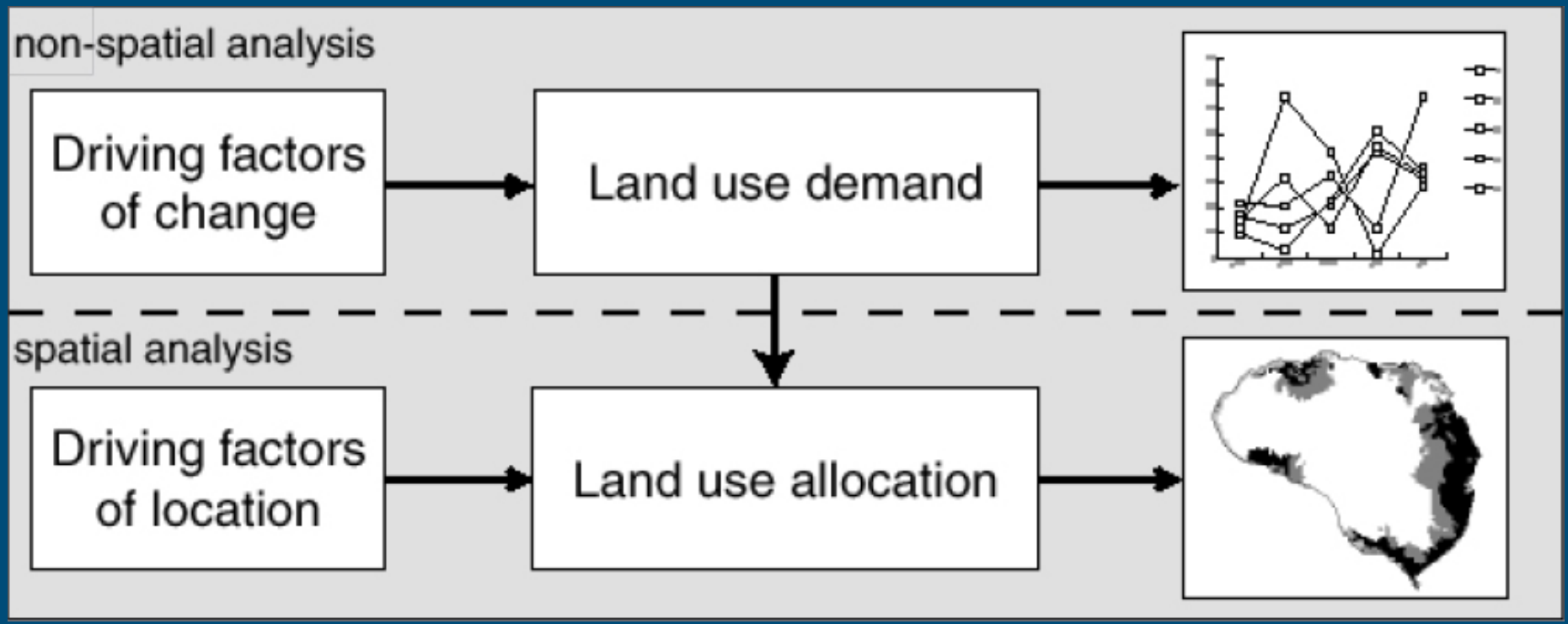
• Plausible futures

• No ‘desired’ future (no ‘doom or gloom’)

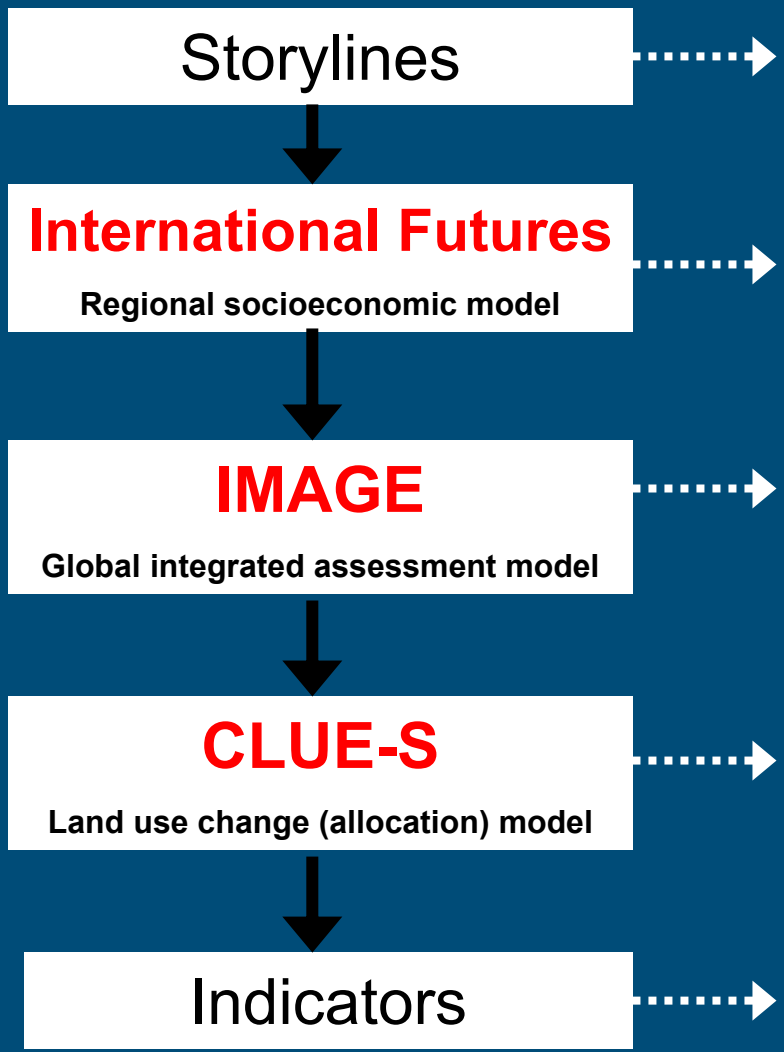
Multi-scale approach



Models: spatial and non-spatial



Scenario and land use change models



Following global GEO-4 scenarios

Model provides socioeconomic drivers to IMAGE. What proportion of regional change occurs in each country?

Quantification of the rates change in ecosystems (e.g. forest, agricultural area, etc) on a grid cell basis.

Calculation of where changes occur in landscape, on a grid cell basis. Shows local effects of regional change.

Quantification of impacts

International Futures model

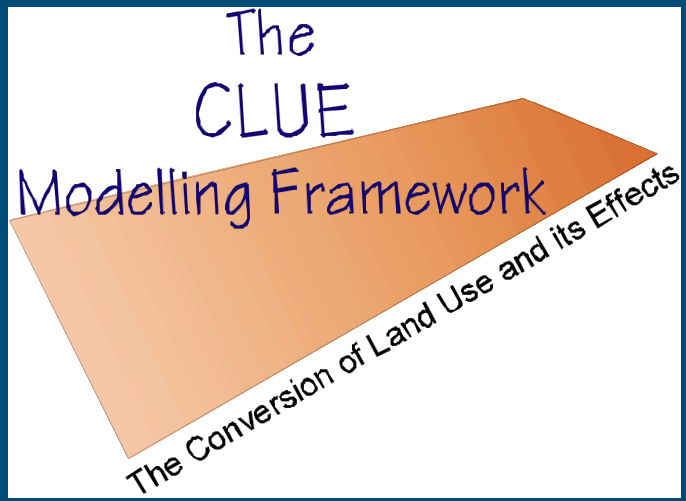
- A ‘macro-agent’ based model that represents major agent classes (households, governments, firms), simulating relationships in a variety of global structures (demographic, economic, social, and environmental).
- Operates at the global scale, but at the resolution of countries rather than on a spatial grid.
- Available online for use in scenario exploration and teaching.
- Provides the socio-economic driver variables for the IMAGE model

IMAGE-2

- A gridded integrated assessment model, operating at the global scale. It is able to simulate issues like the impact of global climate change on crop production.
- Projects land use based on the drivers and other interrelated factors, using a half-degree grid, but its outputs are intended to be interpreted on a regional scale.
- Quantification of the rates of change in ecosystems (e.g. forest, agricultural area, etc) on a grid cell basis.
- Annual land demand (hectares) of each crop type can then be calculated. This is input for CLUE-S land use change model.

CLUE (Conversion of Land Use and Its Effects)

- Model for regional analysis of land use change.
- Original model developed in mid 1990s by scientists at Wageningen University, the Netherlands.
- Modified in 2001/2002 for application at a smaller regional scale and at a fine spatial resolution → **CLUE-S.**
- Results are inputs to N-SPECT hydrologic model.



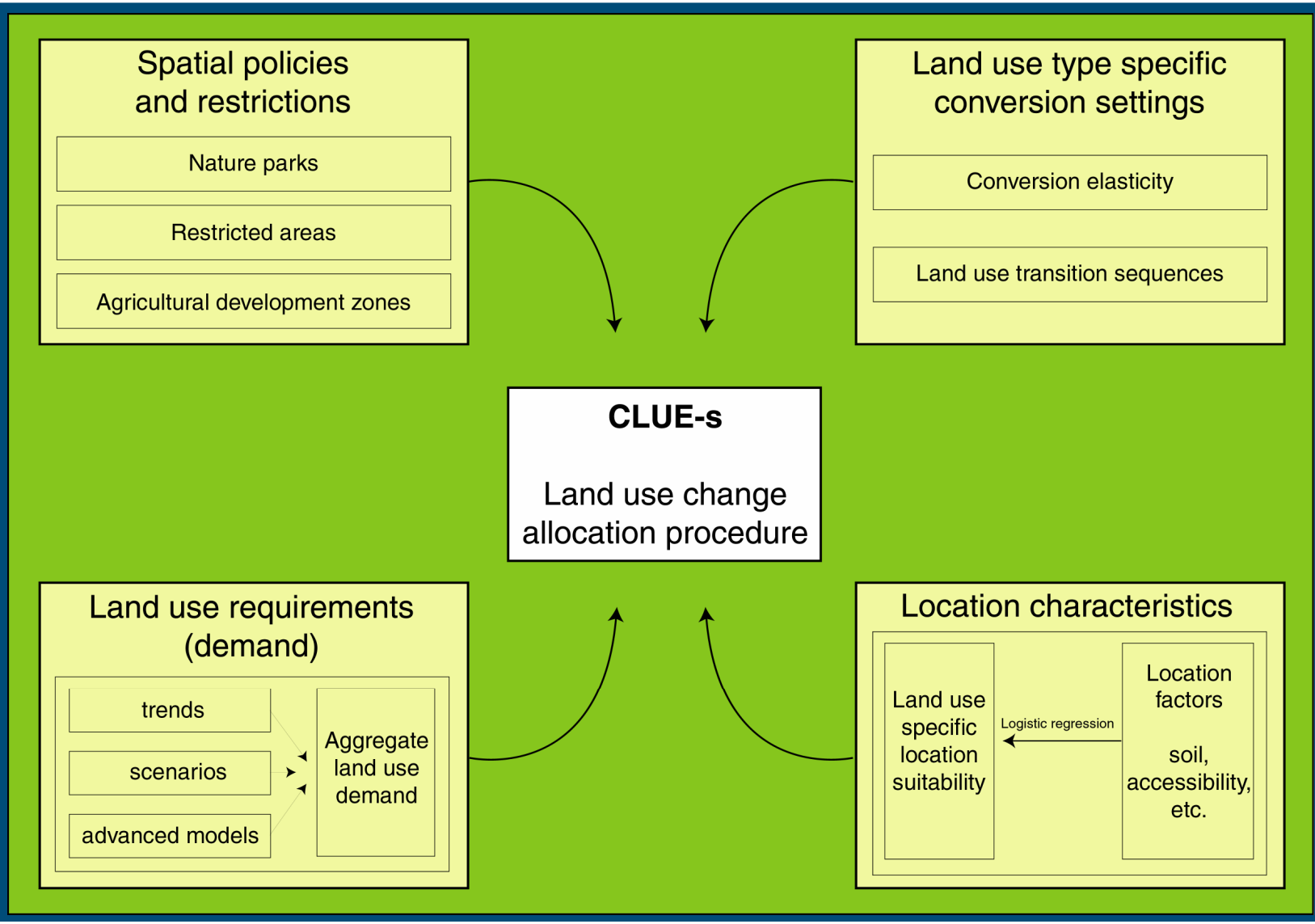
CLUE application worldwide

How does CLUE work?

- Methodology that model future changes in land use patterns by extrapolating the spatial relationships between current pattern and a set of "*explanatory factors*" or "*location factors*"

- CLUE is a hybrid methodology, combination of:
  - Statistical Analysis
  - Decision Rules
  - Cellular Automata
  - Markov Chains

CLUE-S


Spatial policies and restrictions
Nature parks
Restricted areas
Agricultural development zones
Land use type specific conversion settings
Conversion elasticity
Land use transition sequences
CLUE-s
Land use change allocation procedure
Land use requirements (demand)
trends
scenarios
advanced models
Aggregate land use demand
Location characteristics
Land use specific location suitability
Logistic regression
Location factors
soil, accessibility, etc.

Baseline (current) land use classification

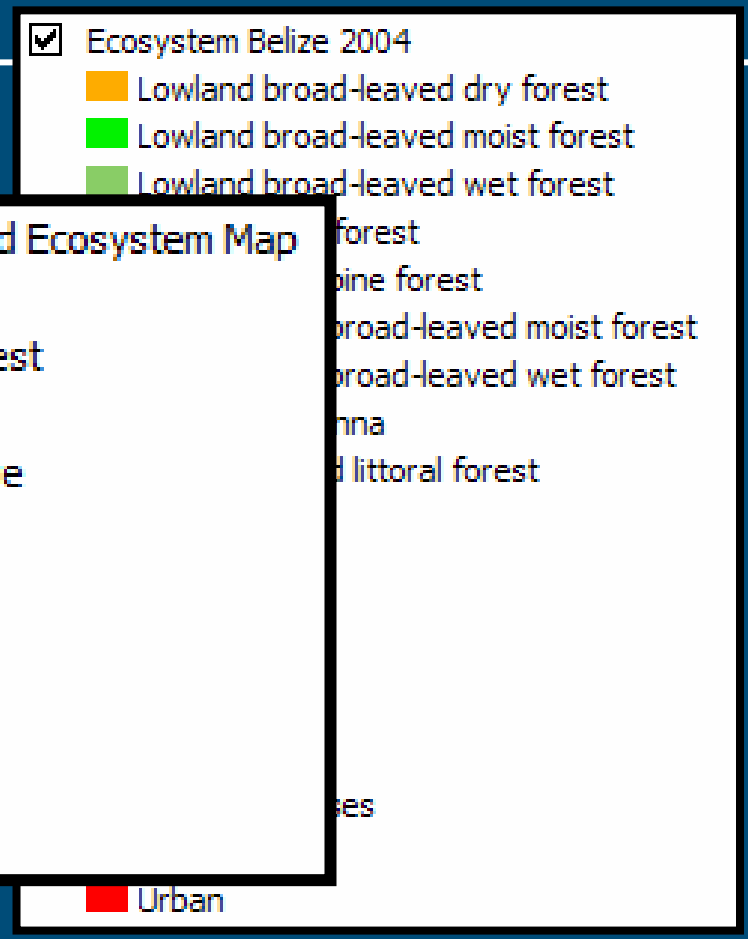
- Extensive evaluation of potential availability and use of various land cover datasets:
  - GLC 2000. (22 classes; 1 km grid too coarse)
  - GeoCover (12 classes; quality concerns - agriculture)
  - NASA Servir Landsat based (not available)
  - Ecosystem Map for Central America (2000/03) and 2004 Ecosystem Map for Belize (varying source dates 1992-1999)
  - Miscellaneous other land use for a country or a particular land type often generally good quality, for example:
    - BZ: CZMAI 2004 mangroves. Very detailed but discrepancies with EcoMap
    - MZ: National Forest Inventory 2000.
    - GT: 2001 land classification by MAGA. Requested but not received

Baseline land use classification

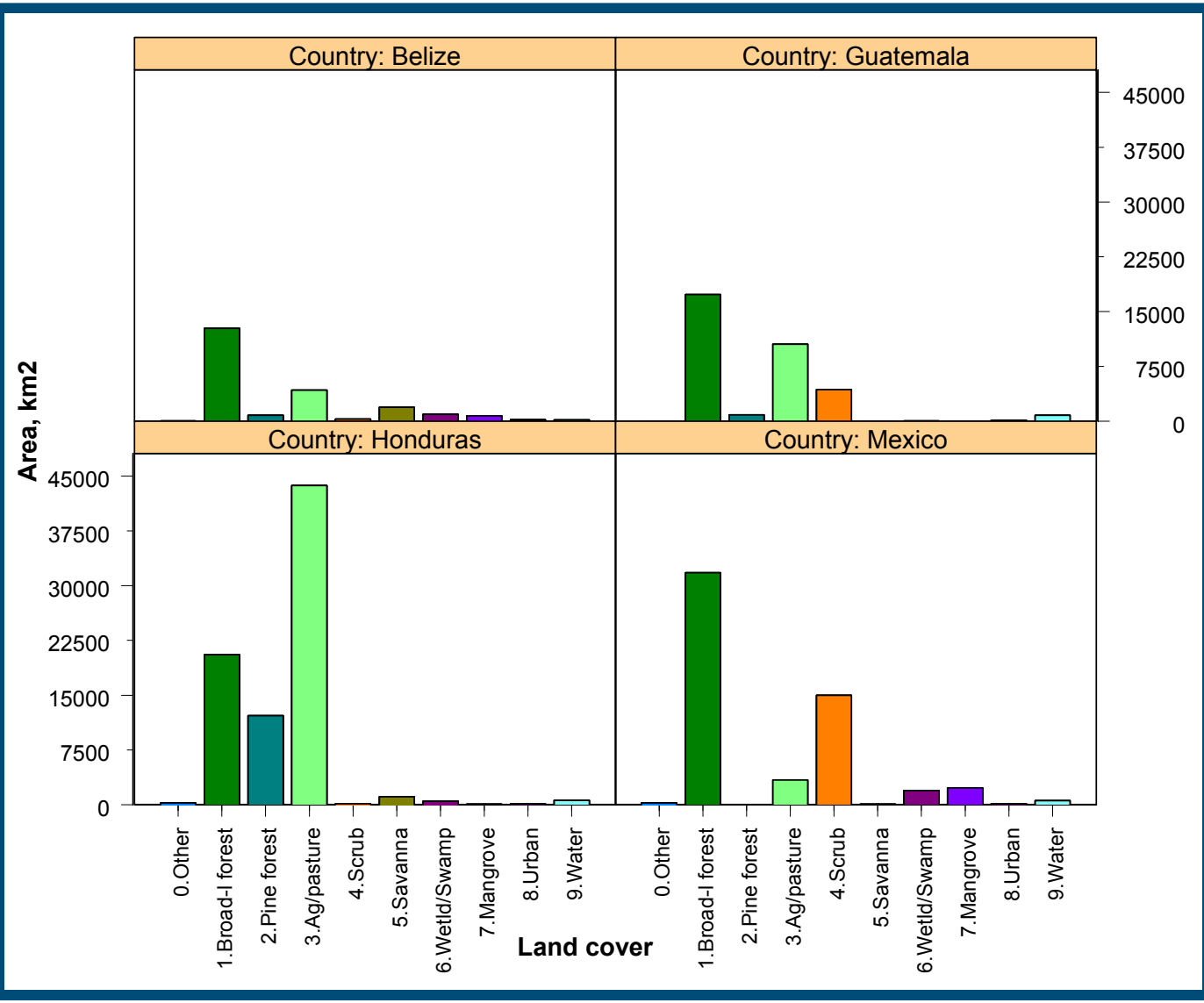
- Difficult to combine data from multiple sources
  - Discrepancies in location (e.g. mangroves, BZ)
  - Different land classification schemes
  - Different image classification methods
- Late 2005, project partners (WRI, UNEP-WCMC decided to use the Ecosystem Map data.
- Developed and agreed upon a reduced classification for use in the modelling.

2003 Ecosystem Map C.A.

2004 BZ Ecosystem Map



Land cover at baseline (2004 for BZ; 2000 for GT/HN/MX)



Reclassifying land cover types between models

Land cover type (CLUE-S)	Land cover type (IFs)	Land cover types (IMAGE)	Assumptions for CLUE-S application
0. Other/Unknown	N/a	N/a	CLUE-S requires no change to this class
1. Broad-leaved forest 2. Pine forest 7. Mangroves	Forest	Carbon plantations Regrowth forest (abandoned) Regrowth forest (timber) Warm mixed forest Tropical woodland Tropical forest [On a global scale, this category would include other forest types not present in the Meso-America region]	Equal probability of change of CLUE-S types
3. Agriculture/ pasture	Crop	Food crops Biofuel crops	IFs types are subtypes of CLUE-S type
	Grazing	Grass and fodder	
4. Scrub	Other	Scrubland	
5. Savanna 6. Wetland/swamp	Other	IMAGE savanna, desert, grassland/steppe [on basis that it will include wet grasslands]	Equal probability of change of CLUE-S types
8. Urban	Urban	Excluded from IMAGE by reducing land area per cell accordingly; not modelled in future.	IFs increase in urban area is applied directly with the expansion reducing the 'other' category.
9. Water	N/a	N/a	CLUE-S requires no change to this class

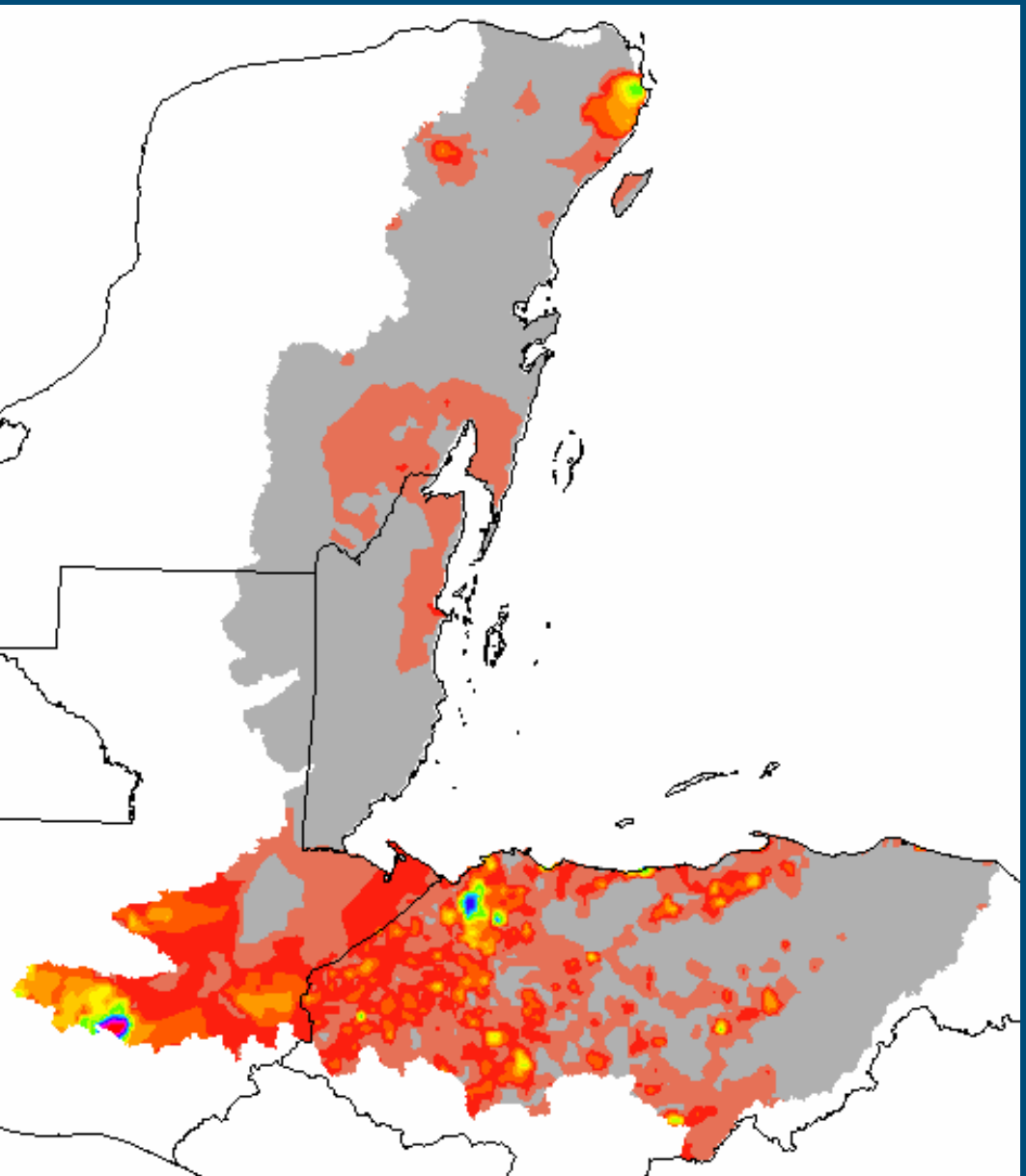
CLUE-S land allocation method

- For every simulated year, CLUE-S allocates the “demanded” area of each land use type.
- Land suitability is defined by a large, integrated, set of location factors (proxies) that are specific for the scale and specific conditions in the case study.
- The relation between suitability and the location factors is determined with empirical/statistical methods supplemented with decision rules based on knowledge of the processes or the scenario conditions (e.g., neighborhood conditions)
- Thus, extrapolation of current trends using probability surfaces.

Location factors

1. Population density
2. Soil depth
3. Soil drainage
4. Mean annual rainfall
5. Length of dry season (months)
6. Elevation
7. Slope
8. Accessibility to markets (travel time)
9. Accessibility to roads (travel time)
10. Tourism hotspots / coastal areas of development
11. Protected Areas (full protection)
12. Protected areas (partial protection)

LF: Population density

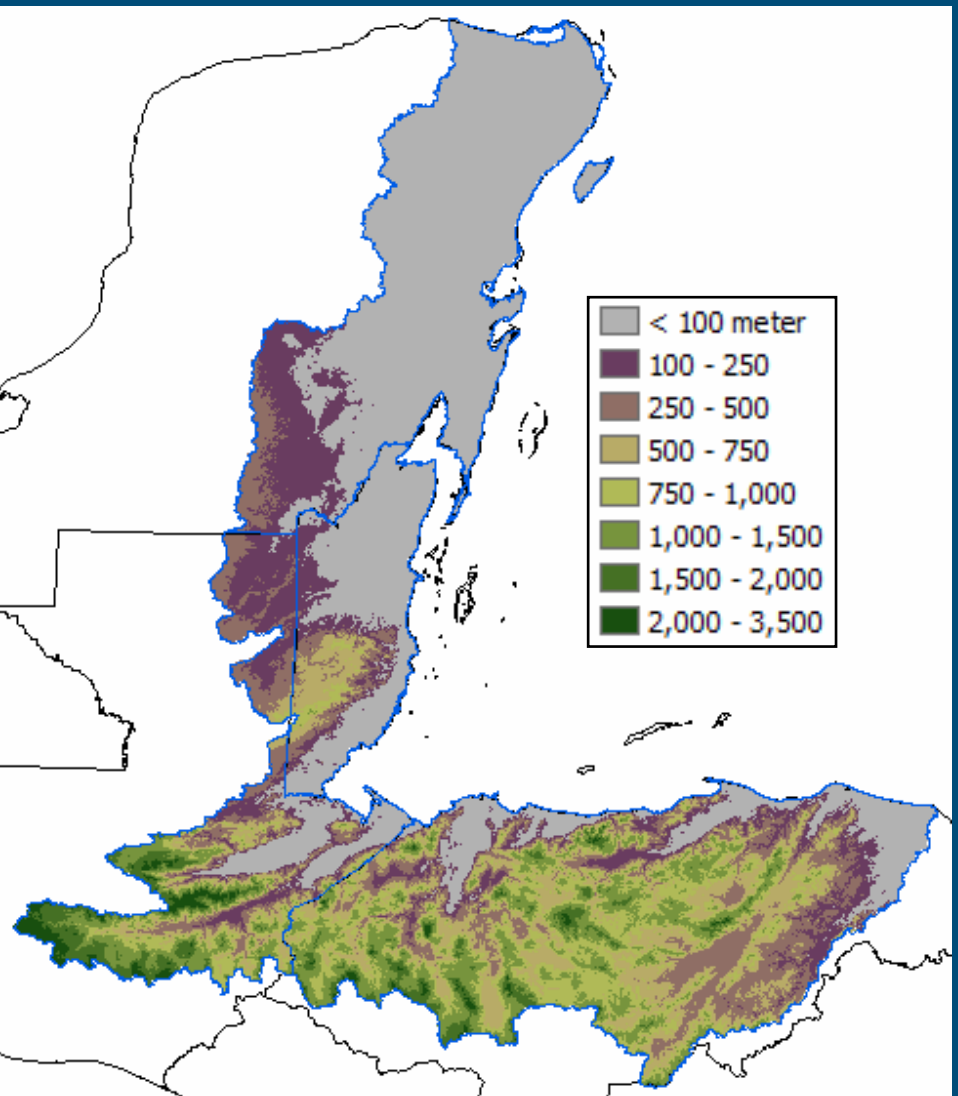


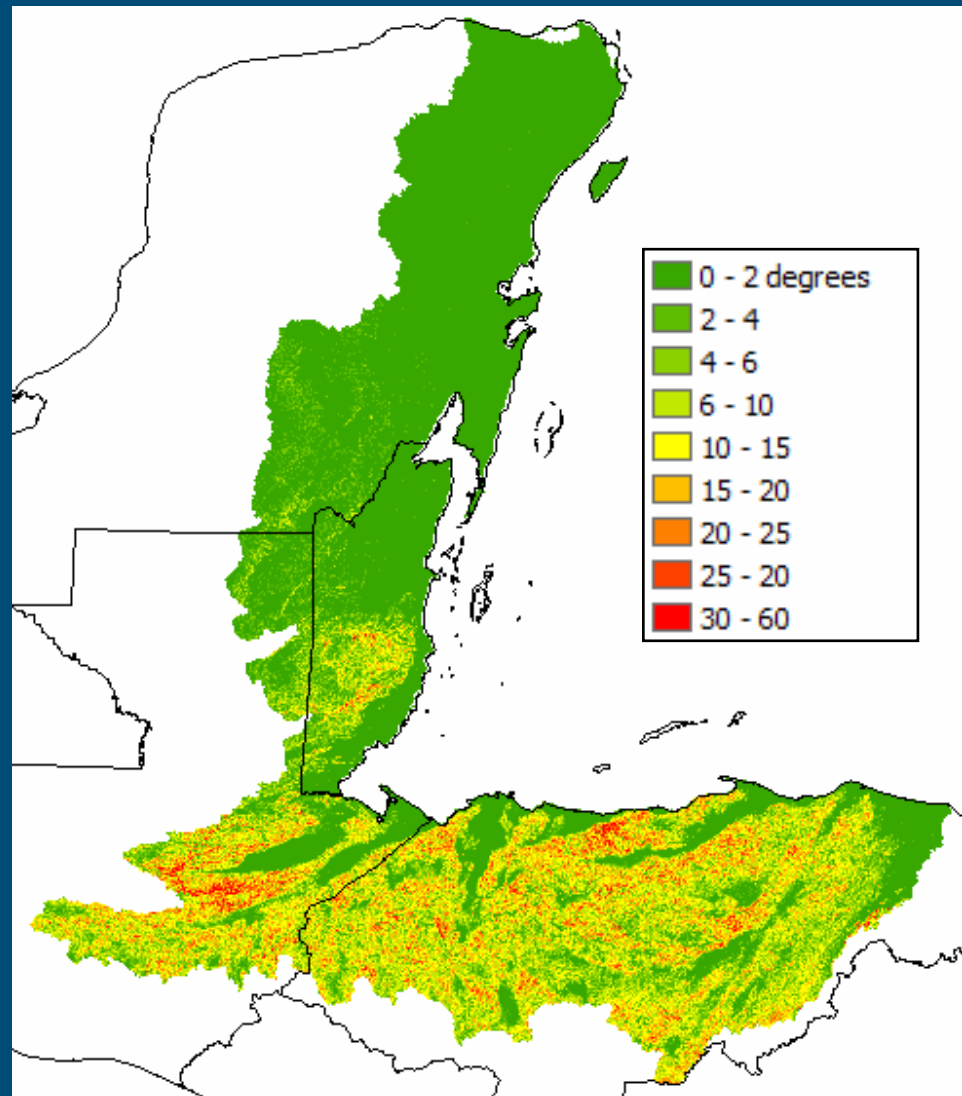
Data source: WDP v3 (CIESEN); Latin American and Caribbean (LAC) Population Database,2005

Population density
Value
0 - 21
21.00000001 - 55
55.00000001 - 107
107.0000001 - 184
184.0000001 - 288
288.0000001 - 419
419.0000001 - 576
576.0000001 - 760
760.0000001 - 979
979.0000001 - 1,231
1,231.000001 - 1,513
1,513.000001 - 1,817
1,817.000001 - 2,138
2,138.000001 - 2,457
2,457.000001 - 2,774
2,774.000001 - 3,144
3,144.000001 - 3,550
3,550.000001 - 3,924
3,924.000001 - 4,275
4,275.000001 - 4,534

LF: Elevation and slope

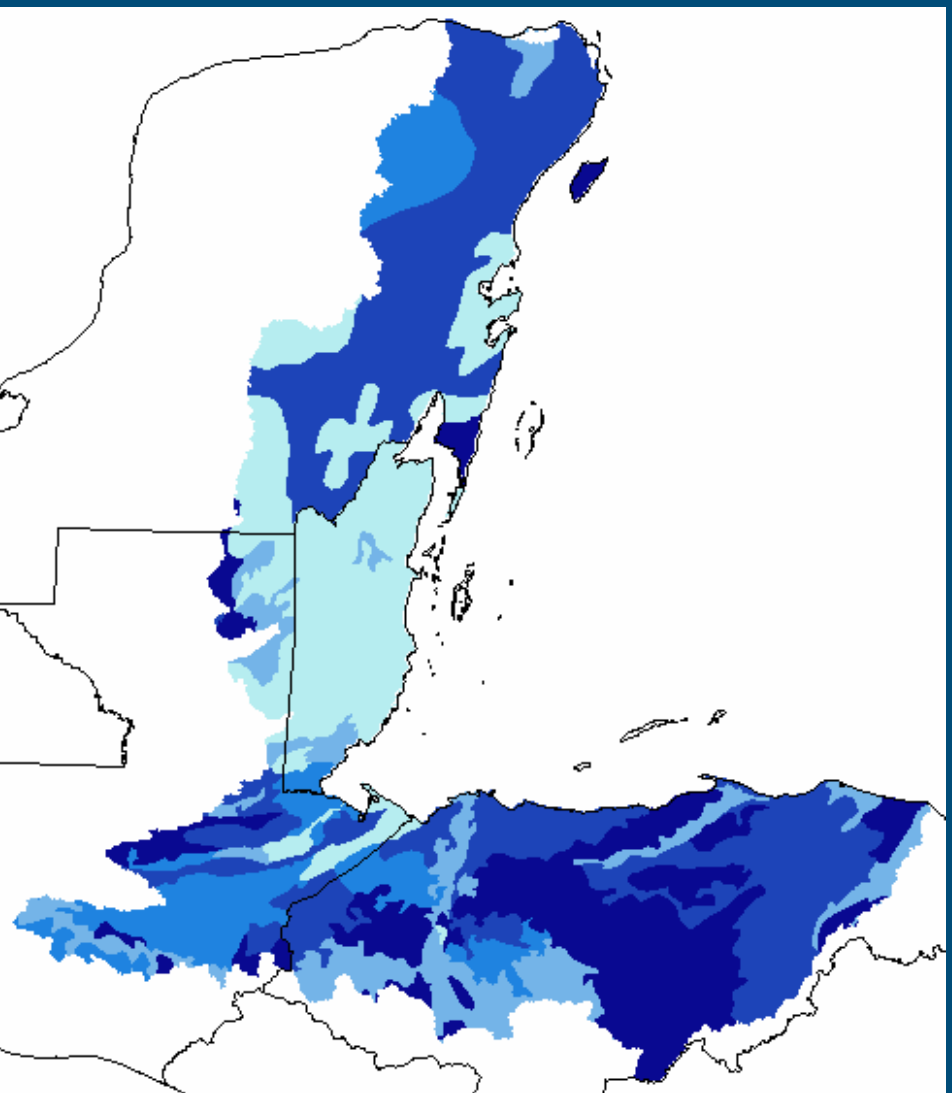
Data source: improved version of 90m SRTM (from CIAT)

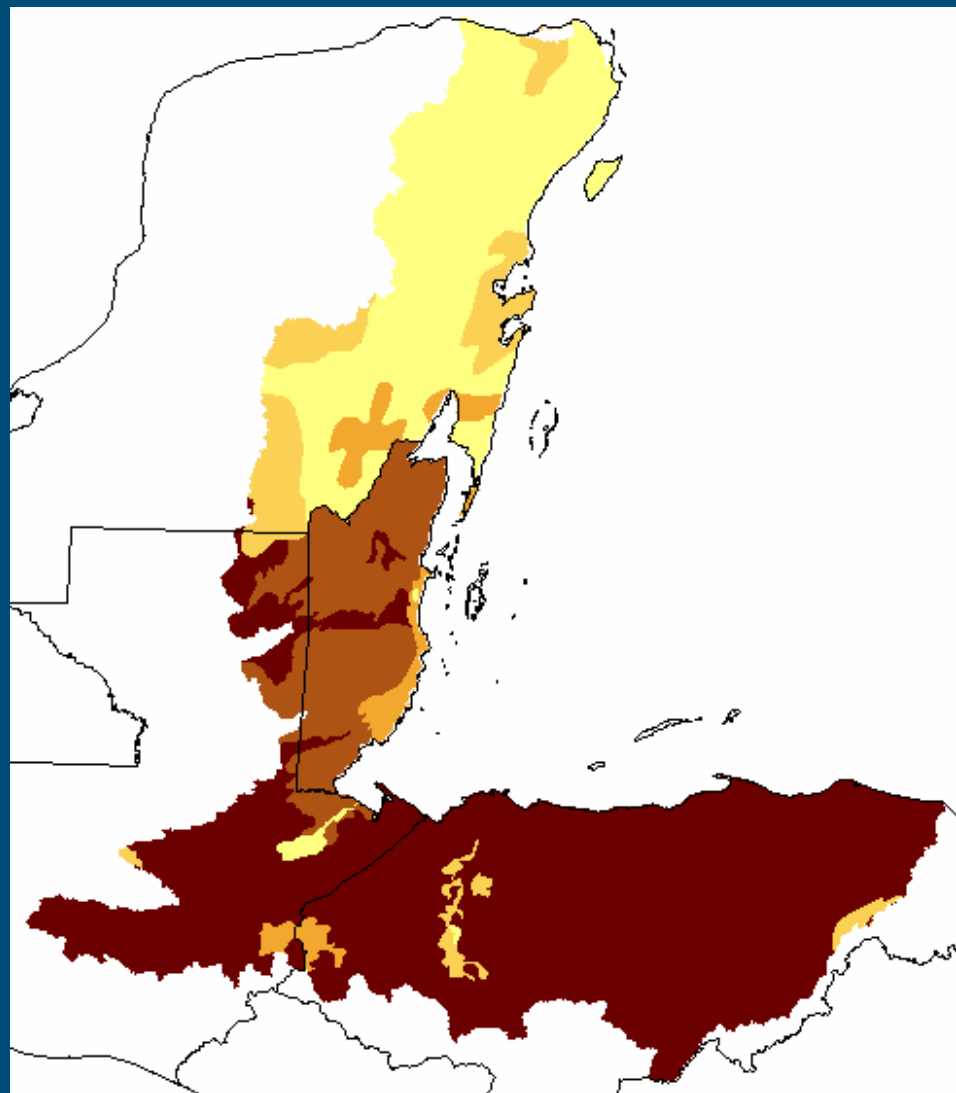




LF: Soil depth and drainage

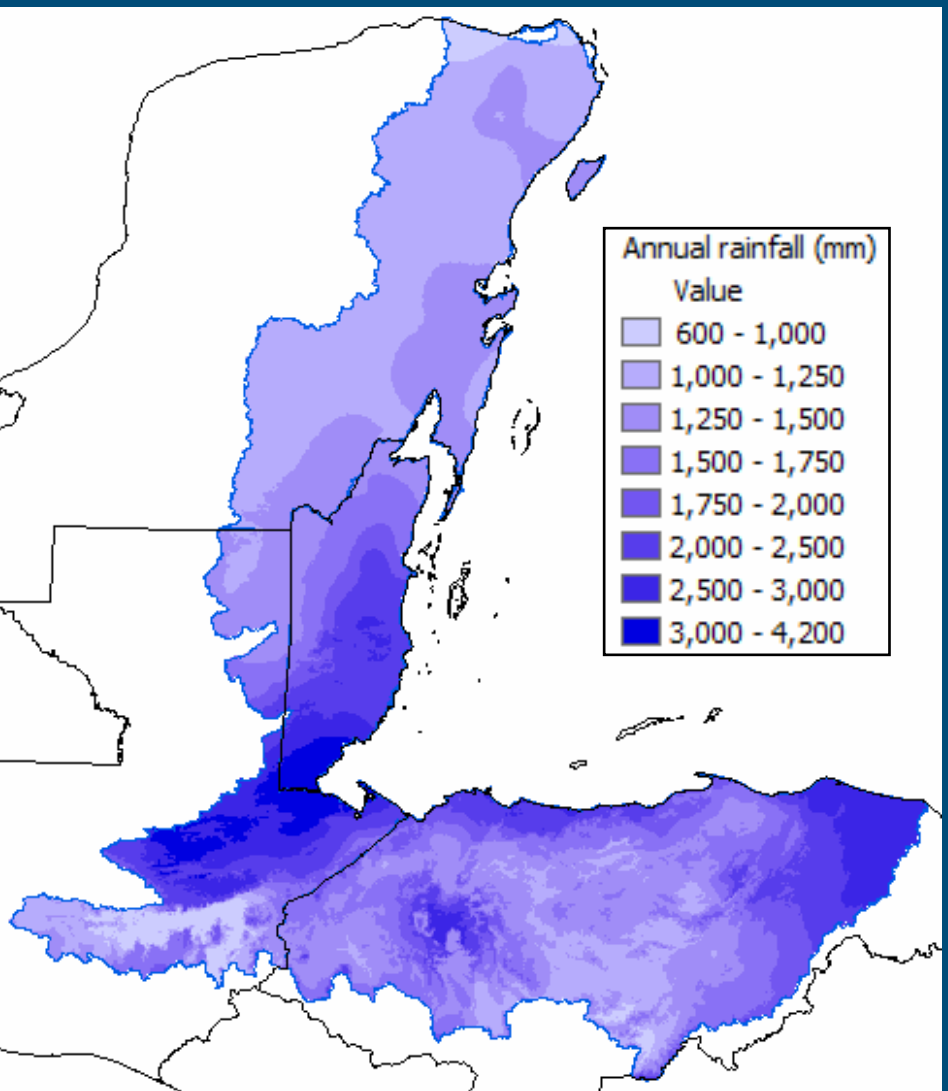
Data source: FAO / SOTERLAC world soils database

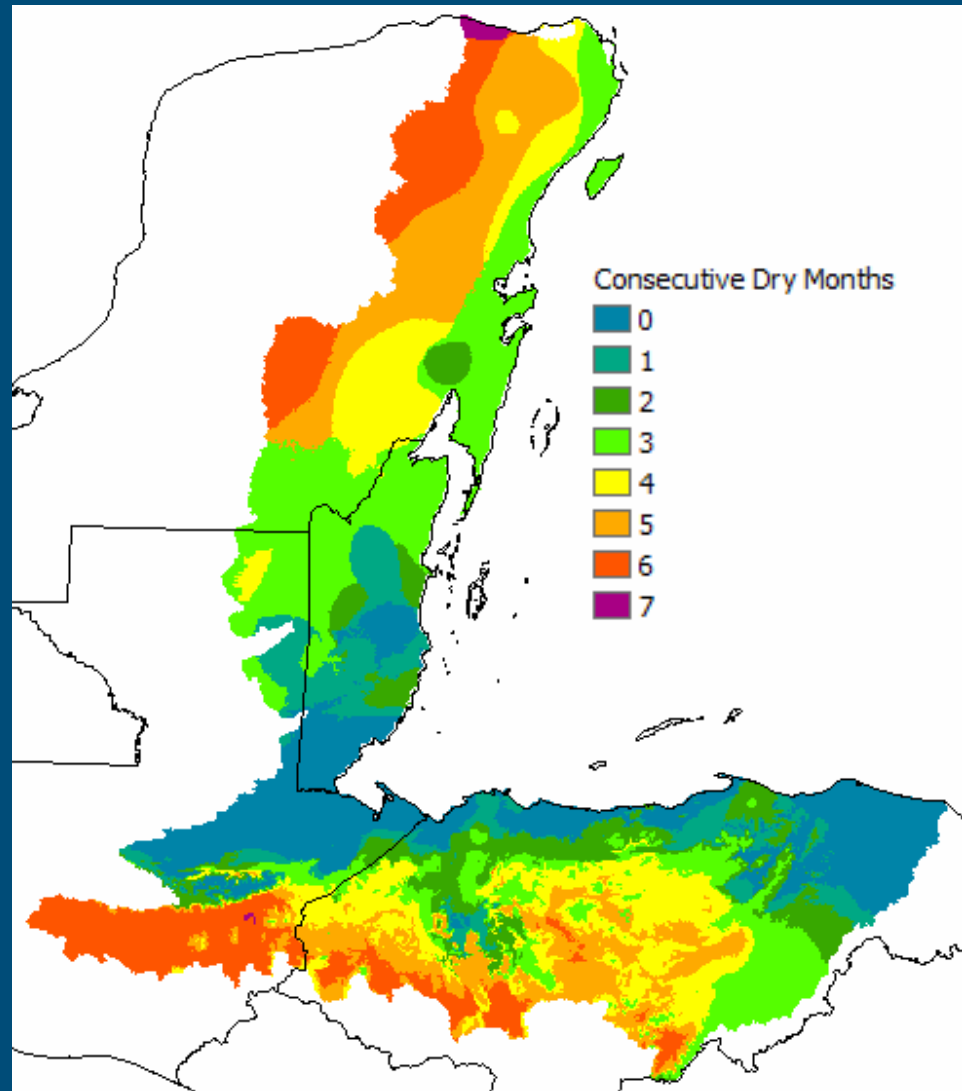




LF: Monthly precipitation and length dry season

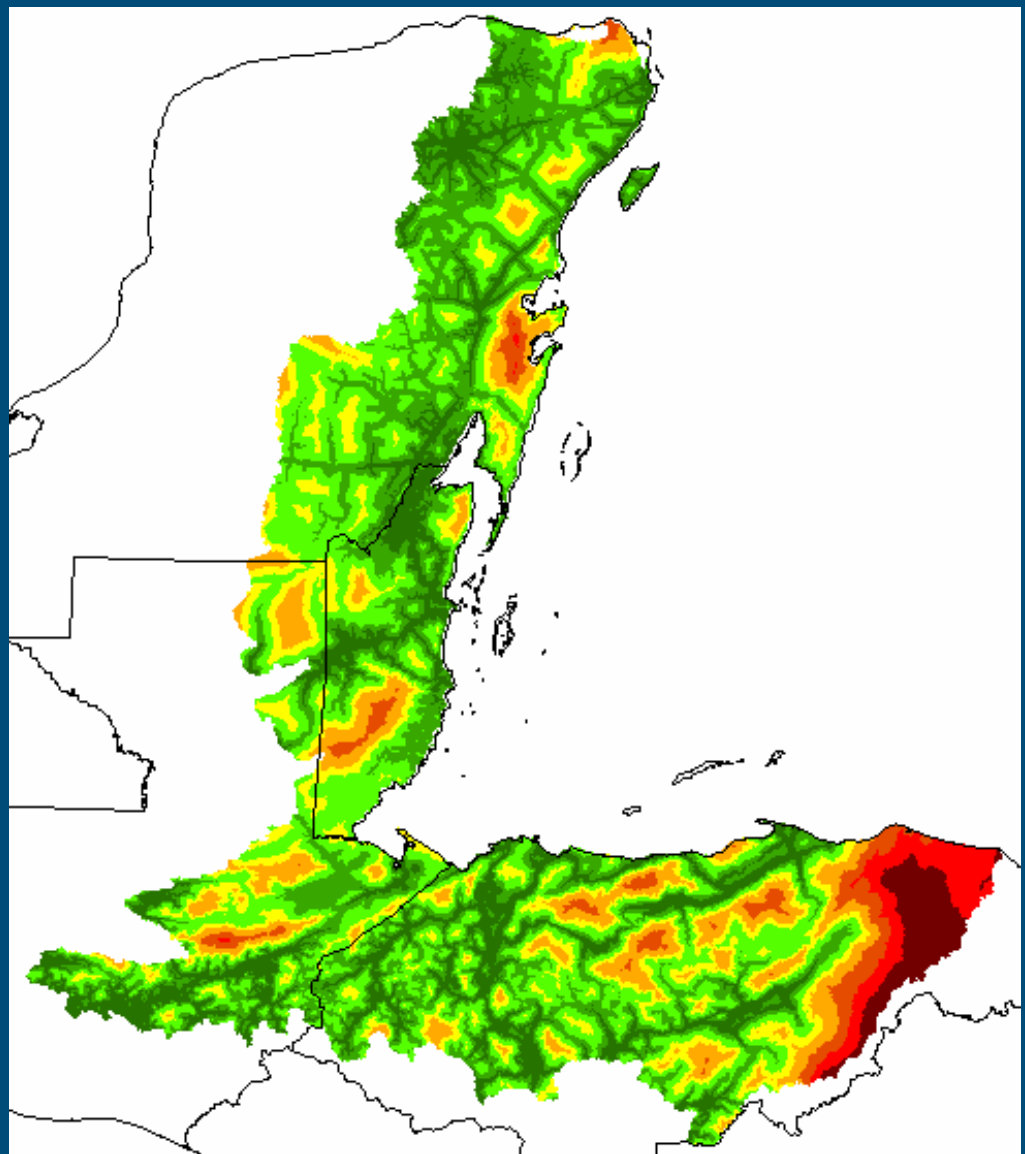
Data source: CIAT, WorldClim database





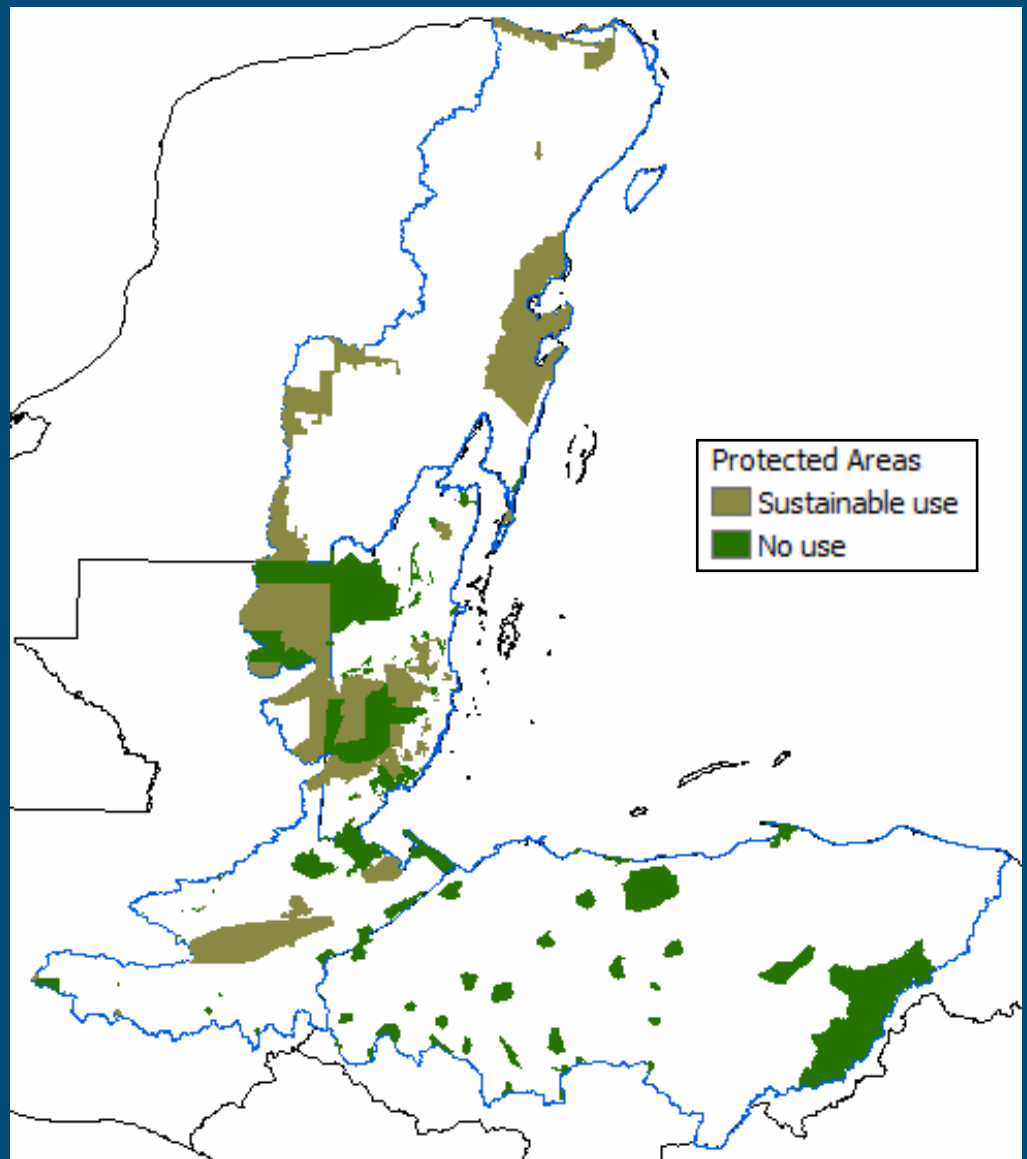
LF: Accessibility/travel time to markets, roads

Data source: Non-existent; self created



LF: Protected Areas

Data source: UNEP-WCMC, World Dataset of Protected Areas



Regression analysis

- Must be done separately using statistical software (e.g. SPSS, SAS).
- Identifies the statistically significant explanatory factors of a land use ….. ? out of 12.
- Separate analysis for each land use type, by country (40 x).
- Regression equations are inputs to CLUE-S.

Regression analysis

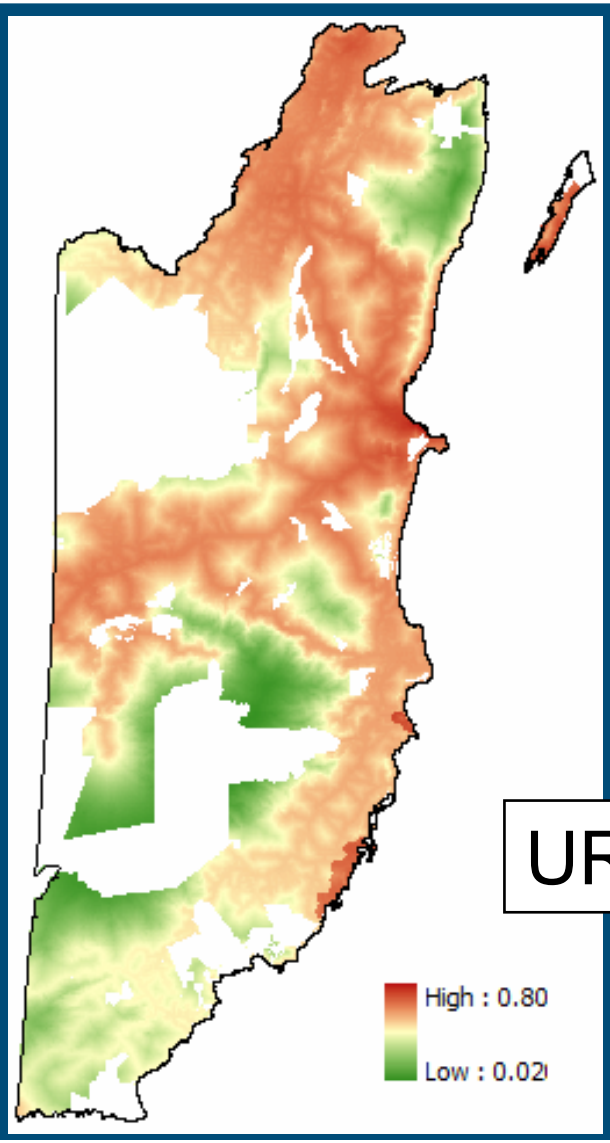
Example regression equation for Urban:

$$Prob = 0.5 + 0.01\ LF_1 - 0.37\ LF_8 + 0.70\ LF_{10}$$

Where LF=location factor:

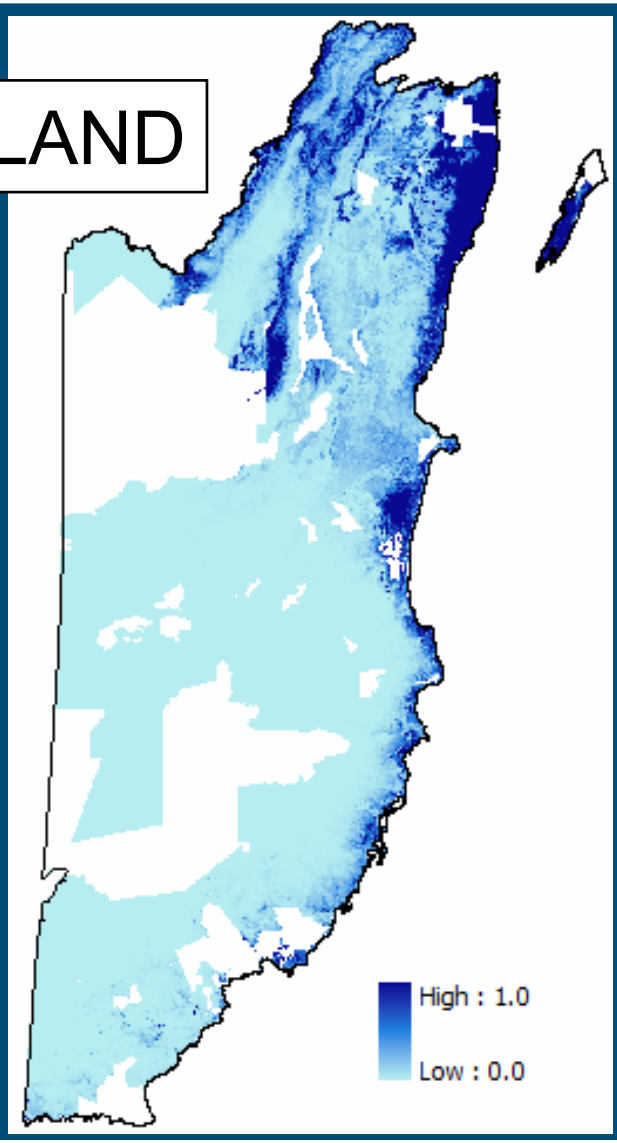
- LF_1 = Population density
- LF_8 = Accessibility to markets (travel time)
- LF_{10} = Tourism hotspot \ coastal development

Example probability surfaces



URBAN

WETLAND



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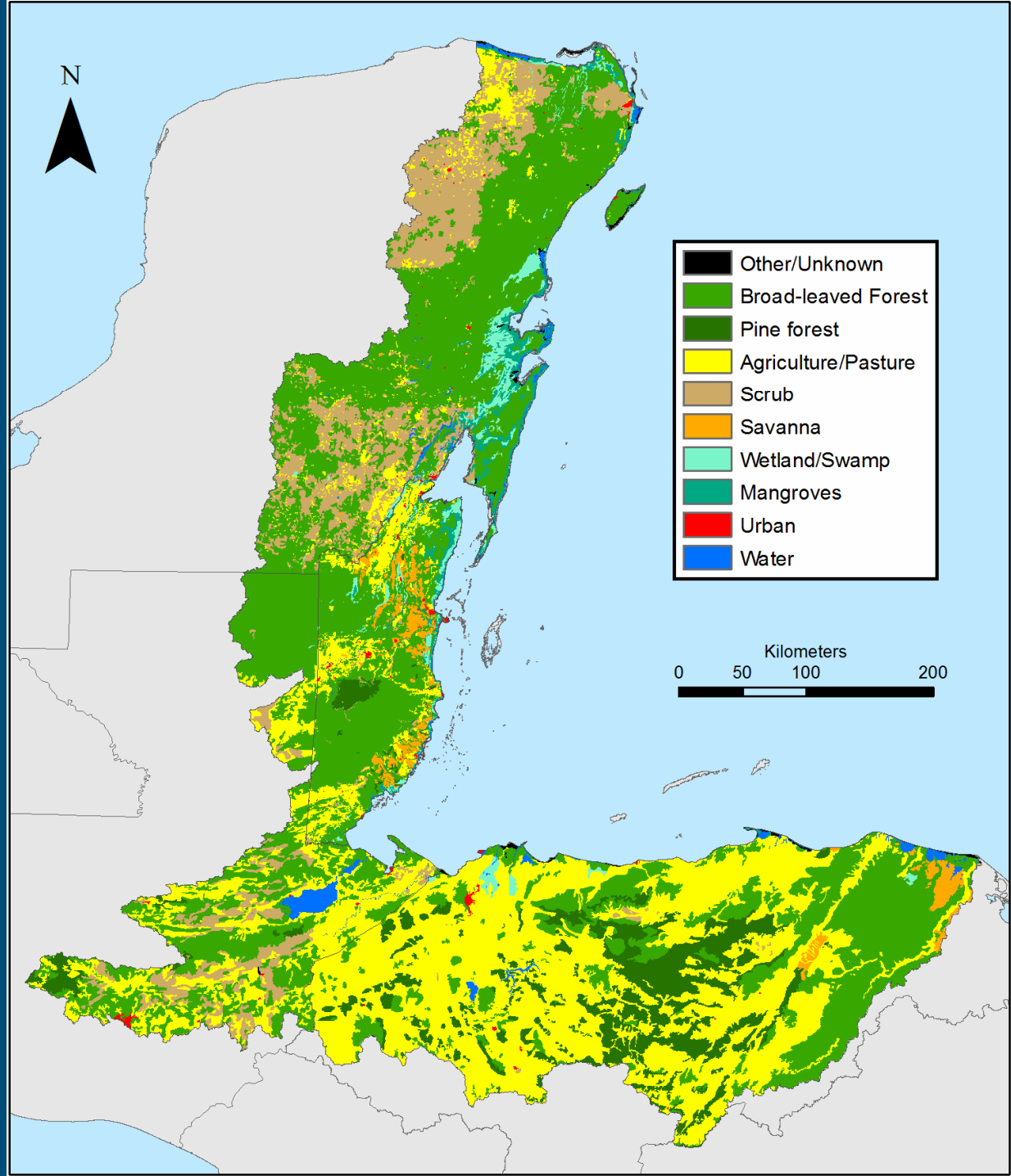
Protected areas

- Special case because CLUE-S model is able to handle them in different ways:
- Fully protected areas → "*restricted areas*", i.e., no changes allowed at all.
- Fully protected + partially protected area → may be included in regression equations, i.e. their location is an explanatory factor (- or +) for the presence of one or more land use types

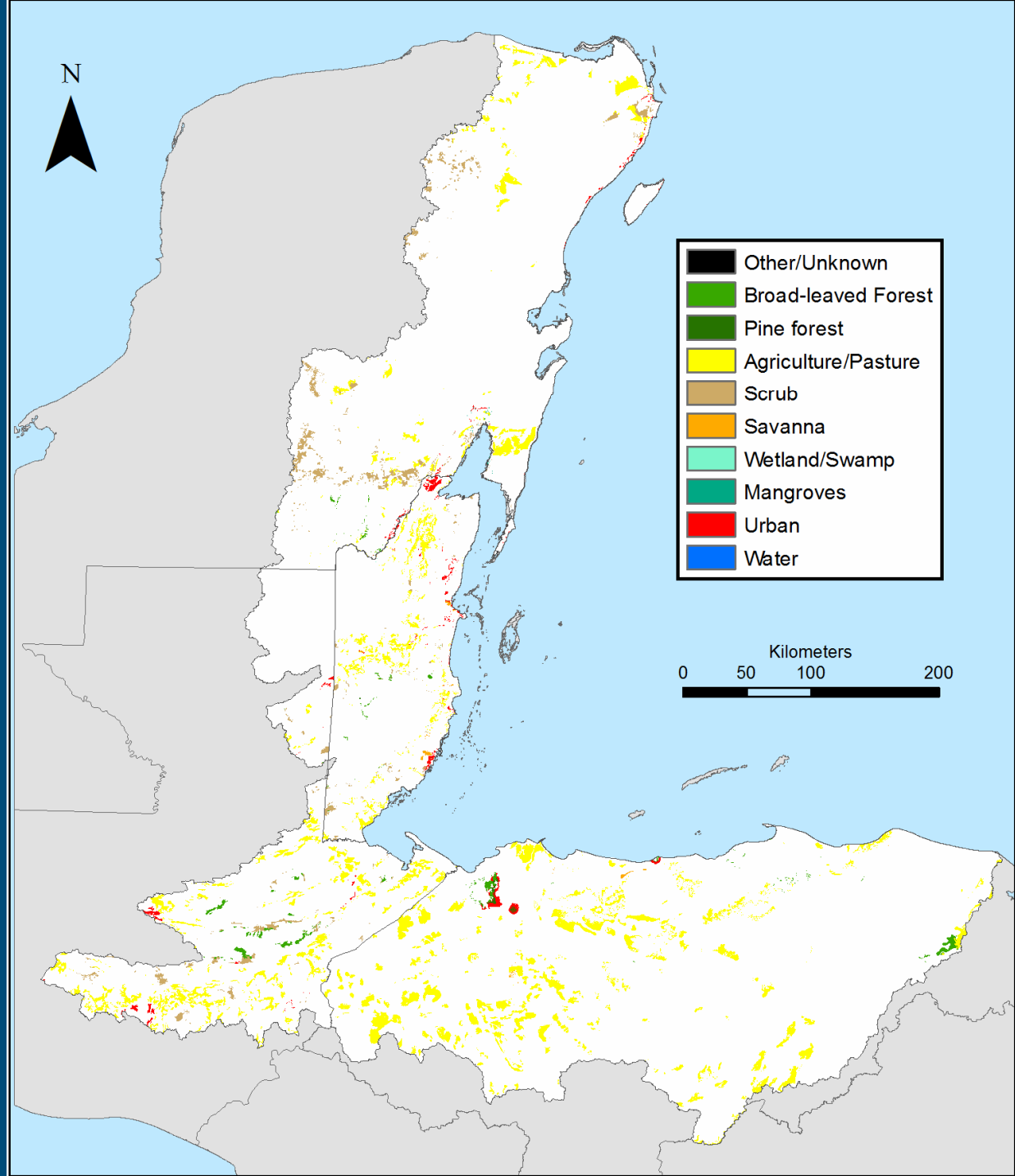
Results: estimated land demand in 2025

LAND COVER TYPE	Present	Markets 1st	Policy 1st	Sustain. 1st
Other/Unknown *(no change)*	0.3%	0.3%	0.3%	0.3%
Broadleaved forest	43.2%	39.5%	42.1%	42.4%
Pine forest	7.3%	6.3%	6.8%	7.4%
Agriculture/pasture	32.5%	36.7%	34.4%	31.4%
Scrub	10.4%	10.7%	9.9%	11.9%
Savanna	1.6%	1.5%	1.5%	1.6%
Wetland/swamp	1.8%	1.7%	1.7%	1.8%
Mangroves	1.6%	1.6%	1.6%	1.6%
Urban	0.3%	0.6%	0.6%	0.5%
Water *(no change)*	1.1%	1.1%	1.1%	1.1%

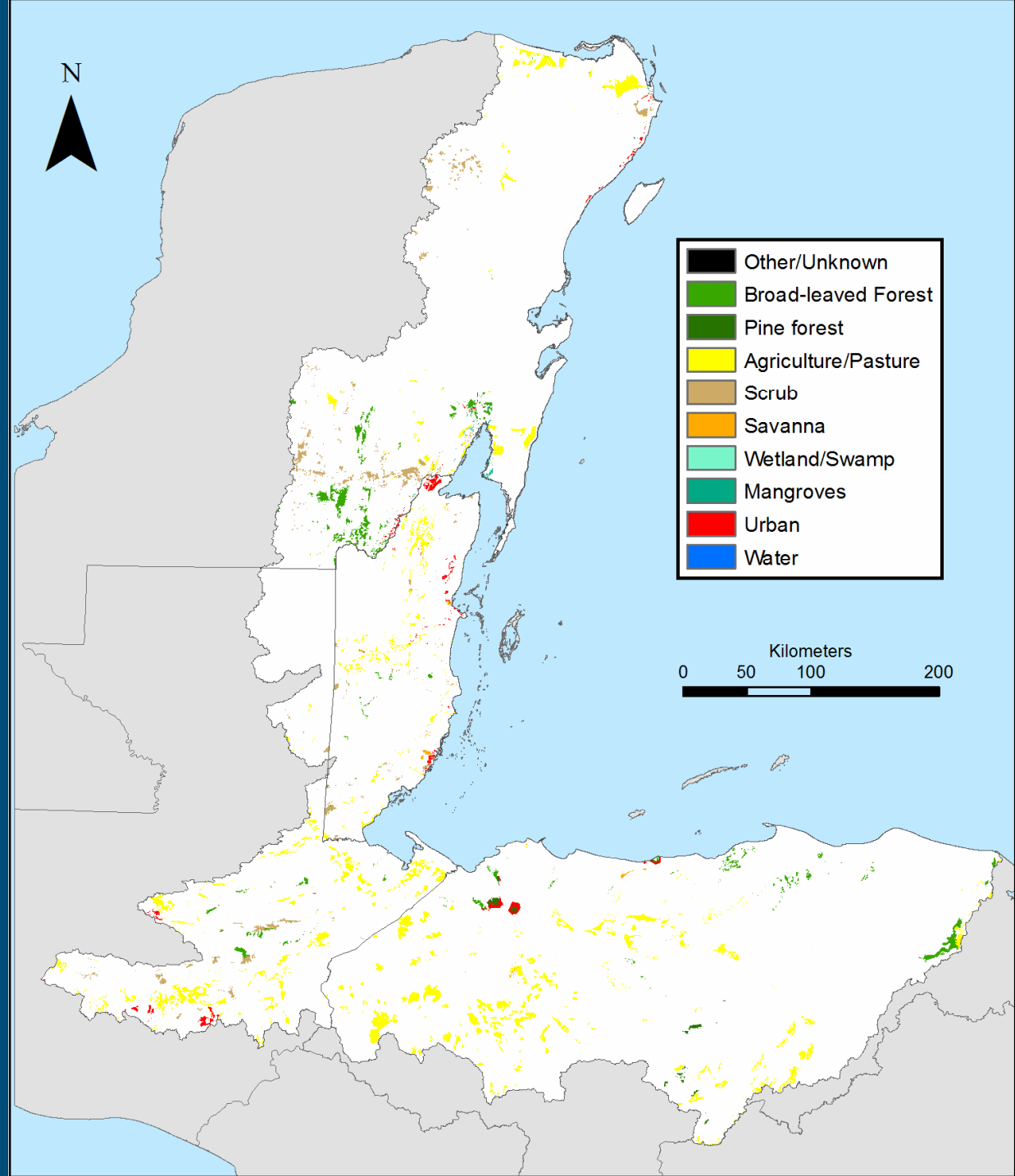
Baseline land use (2000/04)



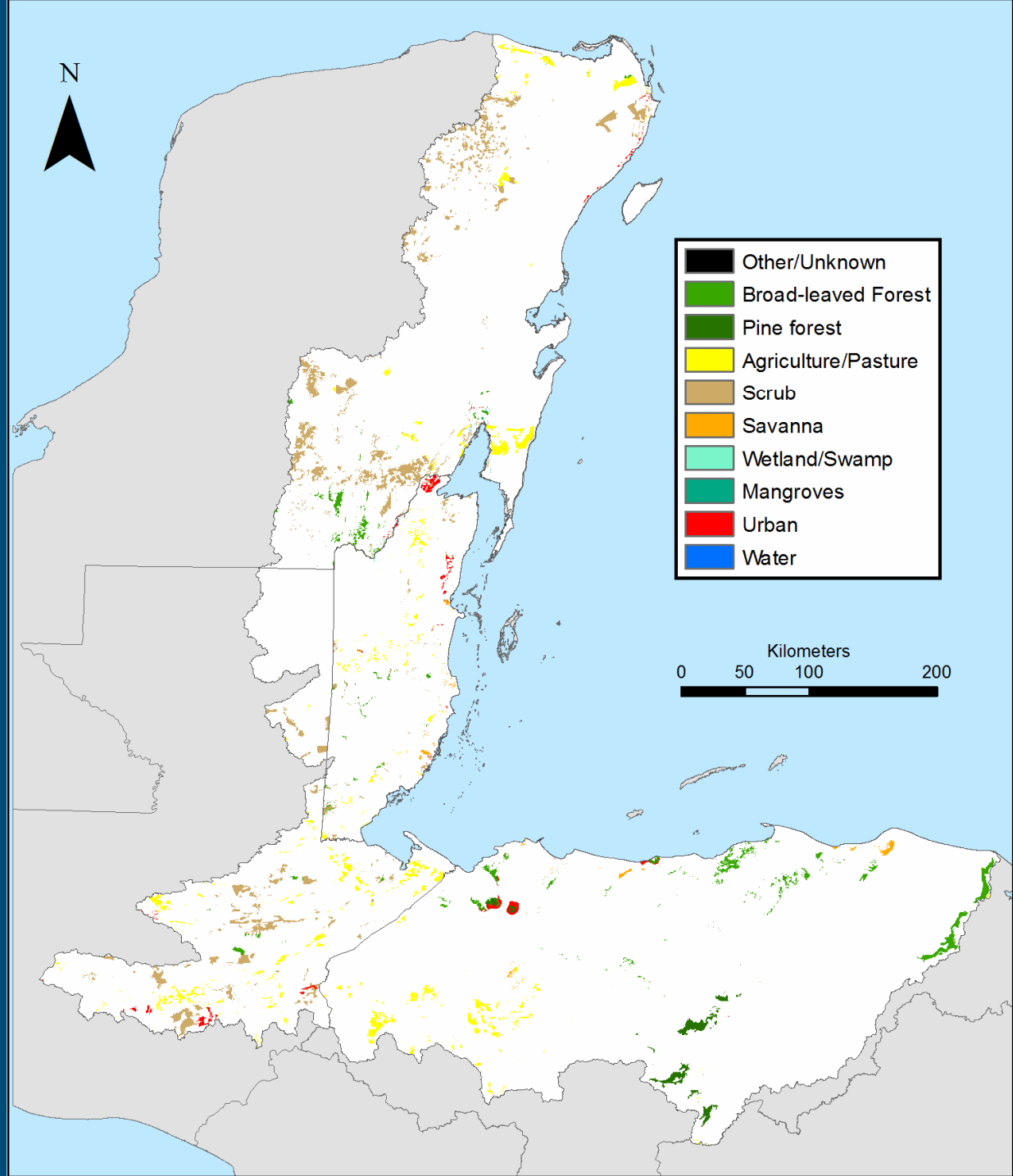
Markets First 2025



Policy
First
2025



Sustainability First 2025



Forest cover change (%) by scenario

	Markets First	Policy First	Sustainability First
IMAGE Central America	**-12.5**	**-5.1**	**+1.6**
Belize	-6.2	-2.2	-0.2
Guatemala	-9.2	-3.9	-1.3
Honduras	-14.1	-7.0	+0.8
Mexico	-3.5	+1.7	-2.1

Conclusions

- Complex yet successful multi-model approach.
- CLUE-S model behaviour (=allocates land) is based on the regression analysis.
  - Useful for understanding current land use pattern.
  - Very, very important to base analysis on good data.
- Simulated land use clearly changes in different directions under the three scenarios.
- Broadleaved forest and agriculture/pasture show the greatest changes (also largest % cover).

Challenges / potential enhancements

- Aggregate “agriculture/pasture” class not ideal. Need for spatial explicit data of different types of crops across the region. Where do they grow?
- Need a more recent, more accurate and uniform land use/land cover dataset for the region.
- Not all field-level changes in use or management can be analyzed because of regional scale and relatively large 250m grid (6.25 ha).
- Possible scale effects.

Thank you!