Predicting future scenarios for land use in a megacity by using a model based on neural networks

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INTRODUCTION

According to the United Nations, it is expected that by 2050 most of the world's population will live in cities. In particular, Latin America is one of the most urbanized continents with about 84% of its inhabitants living in urban areas, and this percentage will continue to increase in the coming years. Bogotá will have a population of 14 million inhabitants by 2050.

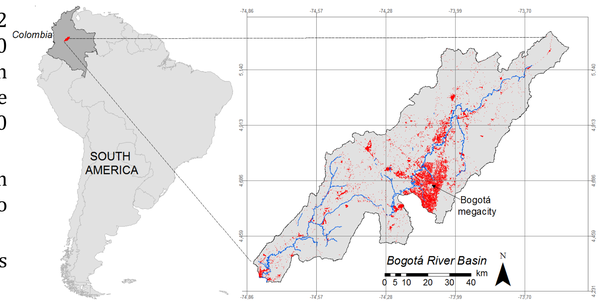
The development of megacities generates important changes in the demand of natural resources and in the land use in the catchments where they are located.

The objective of this research is to study dynamic of the evolution of land use in urban basin, using the Land Change Modeler, which is based in neural networks.

CASE STUDY

Bogotá River Catchment

- Bogotá river has a catchment of 5472 km2, begins at an elevation of 3400 m.a.s.l., has a length of 270km2, runs in direction southwest and flows into the Magdalena River at an elevation of 280 m.a.s.l.
- The annual precipitation varies from minimums of approximately 600 mm to maximums of 1700 mm.
- The annual temperature varies between 10 ºC and 27 ºC.

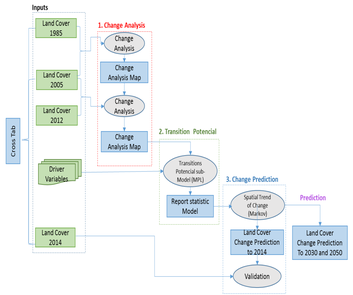


- In terms of land use, Bogotá megacity has a high population density. The heterogeneity characterizes its expansion as happen with most of megacities. Dureau et al. (2002) describes how some metropolitan areas in the Bogotá megacity experienced a huge urban densification while suburbs and agricultural areas have suffered diverse dynamics of urban development. In 2015 Bogotá had a population of 7.9 million inhabitants within its urban surface and 1.45 million in its metropolitan area.

METHODOLOGY

To determine the dynamics of land use changes, historical data from the megacity of Bogotá for the period from 1985 to 2014 were used and scenarios were generated at 2030 and 2050.

The model selected was the Land Change Modeler (LCM) extension for ArcGIS developed by Clark Labs University. This model integrates neural network algorithms Multilayer Perceptron (MLP) for the calculation of transition potentials, and Markov chains for the prediction of land use scenarios.



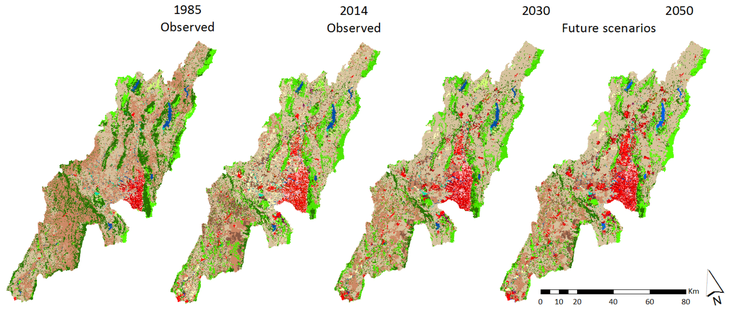
Structure of the model LCM

Parameters and performance of the MLP neural network implemented

	Sub-models	
Parameters and performance functions	*green-urb* $_{BRc}$	*agri-urb* $_{BRc}$
Input layer neurons	1	4
Hidden layer neurons	7	6
Output layer neurons	2	8
Requested samples per class	500	190
Final learning rate	0.0005	0.0010
Momentum factor	0.5	0.5
Sigmoid constant	1	1
Stopping criteria: Iterations	10000	10000
Training RMS	0.4126	0.2487
Testing RMS	0.4045	0.2509
Accuracy rate	93.21%	56.76%
Skill measure	0.8643	0.5058

RESULTS

Dynamics of change of land uses in the prediction of scenarios to 2030 and 2050.



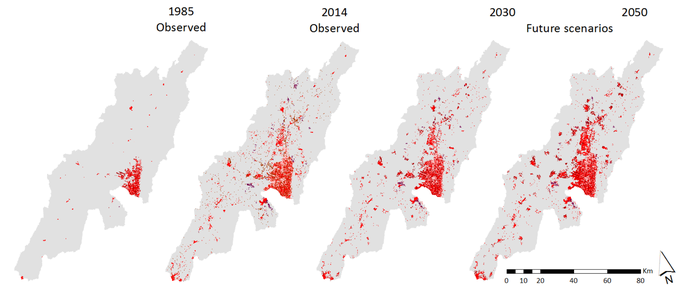
Land use evolution along the predicted future scenarios for the Bogotá River Basin

1.1 Urban fabric
1.2 Industrial, commercial and transport units
1.3 Mine, dump and construction sites
1.4 Artificial, non-agricultural vegetated areas
2.1 Arable land
2.2 Permanent crops
2.3 Pastures
2.4 Heterogeneous agricultural areas
3.1 Forests
3.2 Scrub and/or herbaceous vegetation associations
3.3 Open spaces with little or no vegetation
5.1 Inland waters

Category	*Area (Km²)*			*Land Use of the Catchment (%)*			*Gain and Losses between 2050 and 2014*	
	2014	*2030*	*2050*	*2014*	*2030*	*2050*	*Km²*	*%*
1. urban areas								
1.1 Urban fabric	216,4	248	328	4	4,5	6	111,6	51,6
1.2 Industrial, commercial and transport units	157	140,7	191,5	2,9	2,6	3,5	34,6	22
1.3 Mine, dump and construction sites	31,4	17,7	17,7	0,6	0,3	0,3	-13,6	-43,3
1.4 Artificial, non-agricultural vegetated areas	162,7	104,3	89,5	3	1,9	1,6	-73,2	-45
Total urban areas	***567,5***	***510,7***	***626,7***	***10,4***	***9,3***	***11,5***	***59,3***	**10,4**
2. Crops and Pastures areas								
2.1 Arable land	237,6	48,8	48,8	4,3	0,9	0,9	-188,9	-79,5
2.2 Permanent crops	277,2	83,2	105,3	5,1	1,5	1,9	-171,9	-62
2.3 Pastures	2.449,30	2.779,60	2.802,00	44,8	50,8	51,2	352,6	14,4
2.4 Heterogeneous agricultural areas	485,9	657,7	589	8,9	12	10,8	103,1	21,2
Total Crops and Pastures areas	***3.450,00***	***3.569,30***	***3.545,00***	***63,1***	***65,2***	***64,8***	***95***	***2,7***
3. Forests, Scrubs and Open spaces								
3.1 Forests	462,4	574,6	615,3	8,5	10,5	11,2	152,9	33
3.2 Scrub and/or herbaceous vegetation associations	855,2	679,7	547,3	15,6	12,4	10	-307,9	-36
3.3 Open spaces with little or no vegetation	35,9	36,7	36,7	0,7	0,7	0,7	0,8	2,22
Total Forests, Scrubs and Open spaces	***1.353,50***	***1.290,90***	***1.199,20***	***24,7***	***23,6***	***21,9***	***-154,3***	***-11,4***
4 Inland wetlands	22,4	22,4	22,4	0,4	0,4	0,4	0	0
5 Inland waters	77,9	77,9	77,9	1,4	1,4	1,4	0	0
Total area of the catchment	***5.471,30***							

Percentage of validation in areas of simulated land use versus actual land use for 2014.

Category	*Areas 2014 (Km²)*		*% Success*	*% of land use in the catchment*
	Actual	*Simulated*		
1. Urban Areas				
1.1 Urban fabric	216,4	185,2	85,6	4
1.2 Industrial, commercial and transport units	157	104,6	66,6	2,9
1.3 Mine, dump and construction sites	31,4	17,7	56,5	0,6
1.4 Artificial, non-agricultural vegetated areas	162,7	118,7	73	3
Total urban areas	***567,5***	***426,2***	***72,5***	***10,7***
2. Crops and Pastures Areas				
2.1 Arable land	237,6	48,8	20,5	4,3
2.2 Permanent crops	277,2	98,3	35,5	5,1
2.3 Pastures	2449,3	2229,1	91	44,8
2.4 Heterogeneous agricultural areas	485,9	1181,5	243,2	8,9
Total Crops and Pastures areas	***3450***	***3557,6***	***103,1***	***63,1***
3. Forests, Scrubs and Open Spaces				
3.1 Forests	462,4	517,8	112	8,5
3.2 Scrub and/or herbaceous vegetation assoc	855,2	832,7	97,4	15,6
3.3 Open spaces with little or no vegetation	35,9	36,7	102,2	0,7
Total Forests, Scrubs and Open Spaces	***1353,5***	***1387,1***	***102,5***	***24,7***
4.1 Inland wetlands	***22,4***	***22,4***	***100***	***0,4***
5.1 Inland waters	***77,9***	***77,9***	***100***	***1,4***
Total area				***5471,3***



Urban uses evolution along the predicted future scenarios for the Bogotá River Basin

1.1 Urban fabric
1.2 Industrial, commercial and transport units
1.3 Mine, dump and construction sites
1.4 Artificial, non-agricultural vegetated areas

CONCLUSIONS

1. Knowing the dynamics of land use evolution as a function of the different action scenarios will allow territory managers to define and implement management policies in highly altered environments such as the Bogotá river catchment .
2. There is an important influence of the expansion of the megacity of Bogotá in the change land uses, especially in land agricultural vocation that have become in urban land.
3. LCM is considered an adequate model for the prediction of urban land use change. It is a useful tool for professionals and researchers interested in prospective and actual scenarios in territories with a significant dynamic of transformation.
4. Future analyzes could include some socioeconomic variables, which are not included in this study due to lack of information.

ACKNOWLEDGEMENTS AND REFERENCES

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