SPATIAL SIMULATION

MODELLING URBAN GROWTH IN LUJAN DE CUYO EMTROPOLITAN AREA

COPERNICUS MASTER IN DIGITAL EARTH

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FINAL PROJECT

MODELING URBAN GROWTH IN LUJAN DE CUYO METROPOLITAN AREA

INTRODUCTION & RESEARCH QUESTION

Cities are in constant development. More than 50% of the world's population live in urban environments and the percentage keeps on growing. Cities in consequence too. City growing it's a non-stoppable phenomenon that we should face as a society, and specially as urban planners. The question is not if cities are growing, it is how they grow, and what factors determines its development. Urban sprawl is a particular form of urban development that can be described as a complex multi-causal phenomenon, depending on various natural, social and administrative factors. These different aspects determine the way population density is distributed throughout the urban space and how fragmented the land is (OECD, 2018).

Mendoza is the 4th biggest city in Argentina. With a population bigger than 1 million inhabitants in its metropolitan region, and a geographic setting characterized by a dry climate and mountainous terrain, it is constantly facing the urban sprawl challenge. The most peripheral districts, which used to be rural areas, are the ones most affected nowadays, facing a fast development, with a lot of private housing projects moving towards de historically cultivation areas. Lujan de Cuyo is one of these districts.

Considering what was said before, the aim of this project is to understand which are the physical factors that have a major influence in the way the city is developing in the metropolitan area of Lujan de Cuyo, considering that this would be a key insight for a better territorial development planning. Therefore, the research question that will guide the simulation projects is the following:

What are the most influential physical factors in determining the characteristics of urban sprawl process in the metropolitan area of Lujan de Cuyo municipality?

METHODOLOGY

A. INPUT DATA AND RELEVANT PARAMETERS

For the purposes of this model, only a fewphysicalinfluential aspects are going to be taken into account in order to simplify the experiment, being aware that for a more precise prediction, other elements such as urban codes and land prices should be also considered.

Following this logic, the evolution of the model is based on a composite parameter "Constructability", which is, in turn, composed by the four main considered factors for the experiment, which are described below.

1. **Distance to metropolitan city center:** The main regional downtown, located in the central district of the province.
2. **Distance to local city center:** A local downtown, where the city of Lujan de Cuyo started developing, being an independent small district in its beginnings.
3. **Distance to main roads:** National and provincial routes and main highways and avenues in the area.
4. **Distance to mountain area:** It is considered as "mountain area" the zone that is specified as "mountain environmental reserve zone", in which it is allowed to develop some housing projects, but with several restrictions.

Considering the described parameters, the input data should fulfil two purposes: in one hand, it should give the necessary information to model and analyse the previously described factors; in the other hand it must allow analysing the extension of the city in, at least, two different periods of times, in order to compare them, and be able to validate the model. Therefore, the following datasets are going to be used in the model:

1. **Study area:** Geojson file containing a polygon of the study area, which is the metropolitan zone of Mendoza (administratively defined as “Unicipio”), that is located inside Lujan de Cuyo Department.
2. **Urban areas 2010:** Geojson file containing the urbanized parts of the study area in the year 2010. This dataset is obtained from the provincial cadastral source.
3. **Urban areas 2017:** Geojson file containing the urbanized parts of the study area in the year 2010. The dataset is obtained from the provincial cadastral source
4. **Main Roads:** Geojson file containing the network of main roads in the study area.
5. **Mountain Area:** Geojson file containing the polygon that defines the boundaries of the mountainous zone, following the criteria previously described.
6. **Lujan de Cuyo’s center:** Geojson file containing the point of Lujan the Cuyo’s main square, which can be considered as the most central point of the downtown.
7. **Mendoza’s center:** Geojson file containing a line, which is the boundary of the study area in direction to the downtown.

Apart from the previous variables, the other constant parameter that is needed for establishing the way the model works is the “Built cells per step”. This establishes the speed of urban growing, setting how many cells are constructed in each step. The parameter is obtained based on real values, calculating the difference of built area between the official cadastral records of 2010 and 2017, and obtaining a monthly value of built area.
According to this, a total of 422Ha are built per year, meaning 35Ha per month. This value is converted to the working 2x2 Ha grid scale, obtaining a final value of 9 built cells per month, which is the "cycle" period considered in the model.

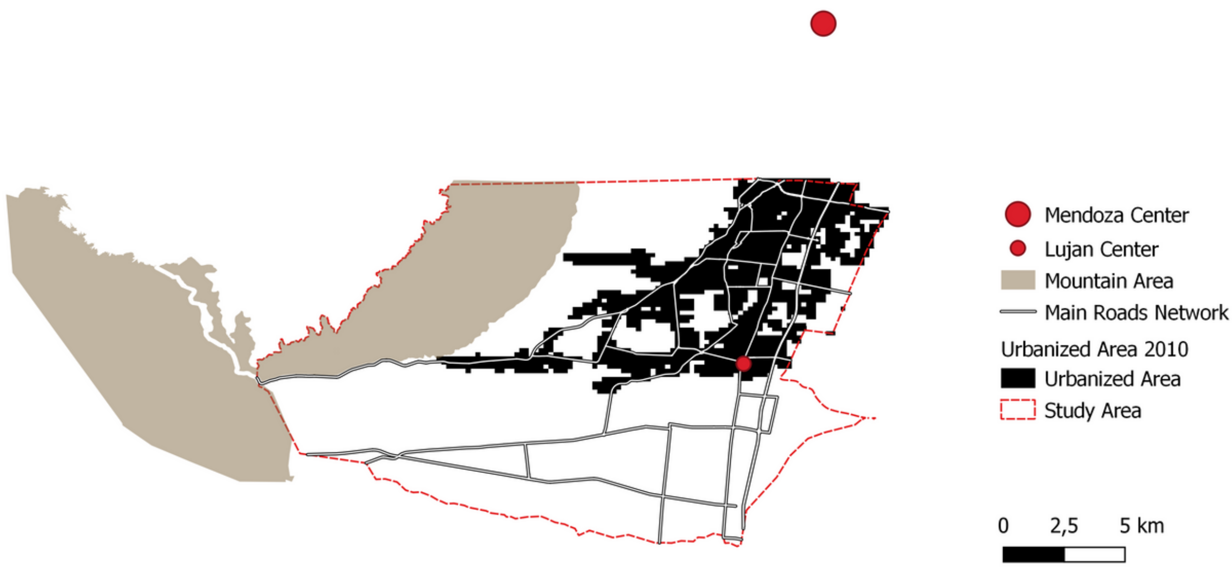


Figure 1. Model input layers,

B. BUILDING THE MODEL

The development of the model is based on the general assumption that the city grows in an expansive way, extending from the already urbanized areas and advancing to the vacant areas according to the previously described “Constructability” parameter.

Following the described logic, the general workflow consists of 3 main repeating steps: identifying the cells next to an already built cell (**const_cells**), calculating the **constructability** parameter for each one of these cells and sorting them descendingly, and urbanize the ones that have higher Constructability. The whole process workflow is detailed in the UML model in Figure 2.

To implement this in GAMA, the simulation is developed with a Cellular Automaton model based on a grid containing the urbanized and not urbanized areas in the year 2010. This grid is generated inside the model, as a "grid agent" based on the **urbanized_2010_geosjson** and **study_area_geojson** files, with a resolution of 2x2Ha. The other physical elements, such as the road network, the mountain area and the local and regional centre points, are modelled as species agents that interact with the grid for calculating the distances.

Once the species and the grid are defined, the simulation workflow is defined through three main parts: the global initialization, the global reflex, and the grid section.

The global initialization establishes the creation of the species, assigns values to the grid (1 for urbanized and 0 for not urbanized cells), and executes the **normalize_distances()** action, which makes the distances to the different species comparable.

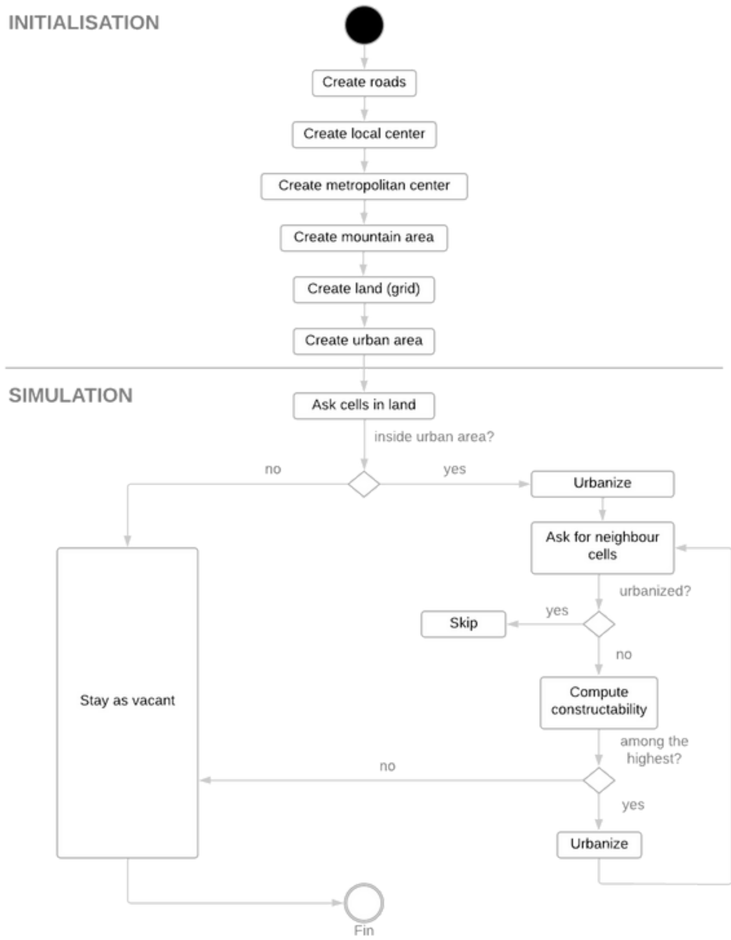


Figure 2. UML diagram of model's workflow

The grid section contains the **compute_distances()** action which, based on the species location and the **distance_to()** built function, calculates the distance values from each cell. After that, a **compute_constructability()** action takes the already normalized distances and calculates the constructability parameter for the constructable cells (**const_cells**) each time step. Moreover, the section also contains a **const{}** reflex which is responsible for assigning, in each cycle, a true value to the const_bool boolean for the cells that are neighbouring a built cell.
The core function of the code is developed through a series of global reflexes: **build{}** creates a **const_cell** list containing on the cells neighbouring a built cell (the ones with **const_bool=true**), sorts them by their constructability, selects the 9 with the higher constructability value and "builds" them, assigning a **grid_value=1**. The reflex **update_built_cells{}** adds all the cells containing a **grid_value=1** to the **urban_cells** list. Finally, the **update_const_cells{}** reflex, empties all the lists and returns the boolean variables to false for starting a new cycle.

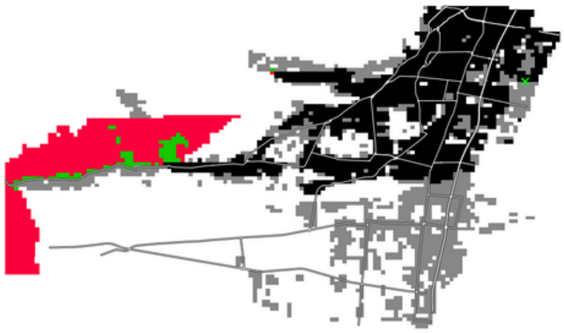
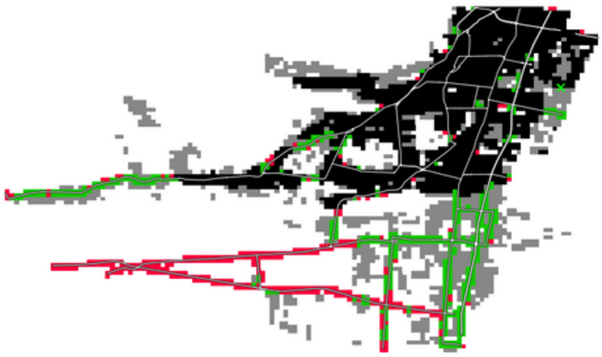
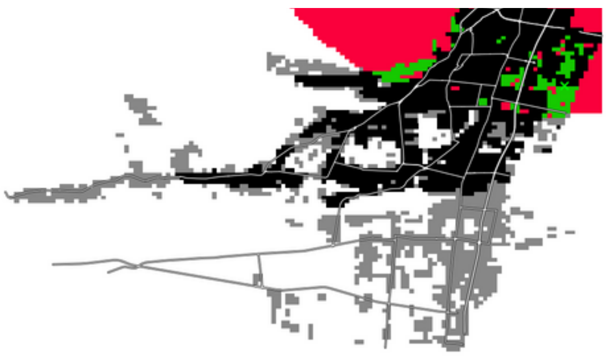
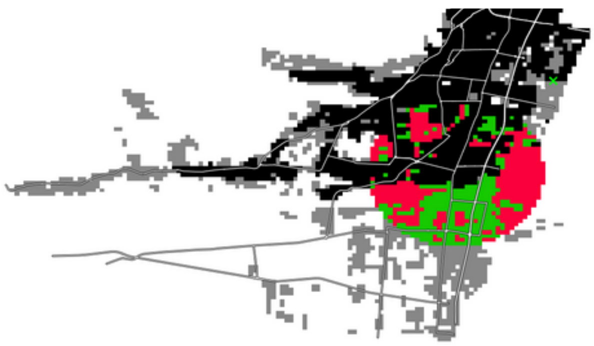
C. SCENARIOS, OUTPUTS AND VALIDATION

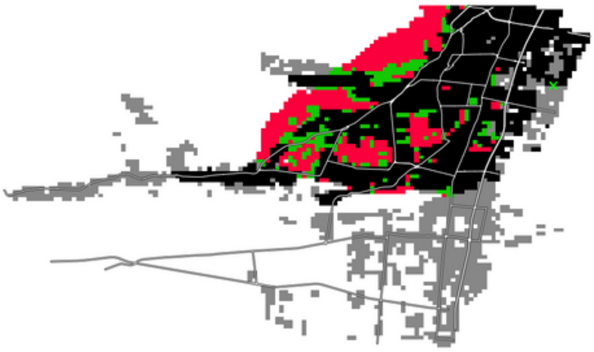
For obtaining results, the model is run, in the first stage, under 6 different combinations of parameters' values. The combinations seek to analyse the model's performance if the growth only depends on each one of the factors separately and if it depends on the four factors with the same weight.
The analysis of the results and validation of the model is achieved through two methods:

- **Visual Comparison:** A visual-morphological comparison between the predicted and the real urban expansion footprint. The main elements to take into account are the occupied area and the growing shape and directions.

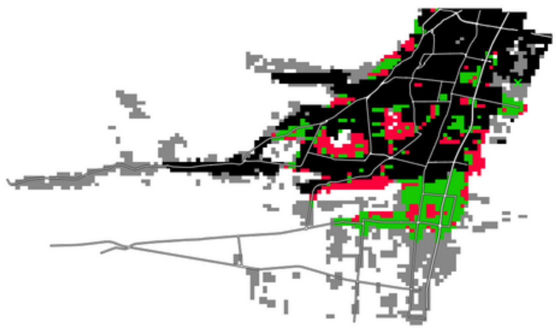
- **Total urban footprint difference:** The result of a symmetrical difference geoprocessing between the predicted urban footprint and the real one, for the whole study area, measured in Ha. The analysis of this indicator allows obtaining the percentage of "Correct predicted area" (cells predicted as urbanized in areas that are really urbanized) and "Incorrect predicted area" (cells predicted as urbanized in areas that are vacant in the reality)

INCORRECT PREDICTED AREA   CORRECT PREDICTED AREA   URBANIZED 2017   URBANIZED 2010

	PARAMETERS	GRAPHIC RESULT	RESULTS
1	Mountain Area = 1 Roads = 0 Mendoza Center = 0 Lujan Center = 0		Correct Predicted Area 300Ha (9,9%) Incorrect Predicted Area 2724Ha (90,1%)
2	Mountain Area = 0 Roads = 1 Mendoza Center = 0 Lujan Center = 0		Correct Predicted Area 1659ha (54,9%) Incorrect Predicted Area 1365Ha (45,1%)
3	Mountain Area = 0 Roads = 0 Mendoza Center = 1 Lujan Center = 0		Correct Predicted Area 608Ha (20,1%) Incorrect Predicted Area 2416Ha (79,9%)
4	Mountain Area = 0 Roads = 0 Mendoza Center = 0 Lujan Center = 1		Correct Predicted Area 1360Ha (45%) Incorrect Predicted Area 1664ha (65%)

5	Mountain Area = 1 Roads = 1 Mendoza Center = 1 Lujan Center = 1		Correct Predicted Area 920Ha (30,4%) Incorrect Predicted Area 2104Ha (69,6%)

The obtained results allow to clearly identify the most influential physical factors in the city growth process by analysing the accuracy of the results. In this sense, it is possible to affirm that the proximity to the main roads network is the main influential factor, followed by the proximity to Lujan de Cuyo local centre, Mendoza Center and finally, and almost with no influence, the proximity to the Mountain Area.
Having a better idea of how this individual factors affect the model, an additional sixth output is obtained as the result of calibrating the parameters according to the previously obtained values.

6	Mountain Area = 0.1 Roads = 1 Mendoza Center = 0.2 Lujan Center = 0.4		Correct Predicted Area 1772Ha (58,6%) Incorrect Predicted Area 1252Ha (41,4%)

CONCLUSIONS AND DISCUSSION

After having carried out the complete process of project definition, workflow design, modelling and obtaining and validating results, it can be concluded that the model achieved the expected objectives, since it allowed answering the research question and obtaining new information about the phenomenon under study.
The model definition and development stage was extremely interesting and allowed learning about the system. It required the analysis of a complex phenomenon, such as urban growth, to understand its behaviour and to be able to model the intervening factors.
The results obtained allowed a deeper understanding of the elements that condition urban growth in the region of Luján de Cuyo. In this sense, some of the results correspond to what was expected according to the existing theoretical knowledge of the area, such as the preponderance of the factor of proximity to the main street network. However, others yield interesting new data, such as the clear preponderance of the factor of proximity to the regional center of Luján de Cuyo as opposed to proximity to the center of Mendoza.
Although the results obtained were satisfactory for a first approximation, the modelling process provided new perspectives on other elements that should be considered, such as street hierarchy, land value and accessibility.
In summary, it can be concluded that the project met the proposed objectives and provided a base model with great potential to be improved, extended and applied to different areas and objectives.

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