AN URBAN GROWTH MODEL FOR CITIES SEPARATED BY RIVERS AND CANALS

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ABSTRACT

In developing countries like Vietnam, economic development is closely linked to urbanization speed. This reality puts urban managers on the challenges of managing and orienting for urban development. Thus, understanding the urban growth will help the managers to build the urbanization plans. This study focused on developing an urban growth model where the cities are divided by complex canals in the Mekong Delta of Vietnam. The model was built with the GAMA platform based on the agent-based modeling approach. In the model, urban development is examined according to some urban development criteria such as the built-up density index, the proximity index of the administrative center, and the infrastructure criteria such as the distance from an available cell to the roads and to the residential areas;the location of cell in separated area by rivers and canals. The model was calibrated and was verified with the urban maps in 2017 of Nga Bay Town of Hau Giang province, Vietnam.

Keywords: *Urbanization, Urban growth model, Agent-based model, GAMA platform*

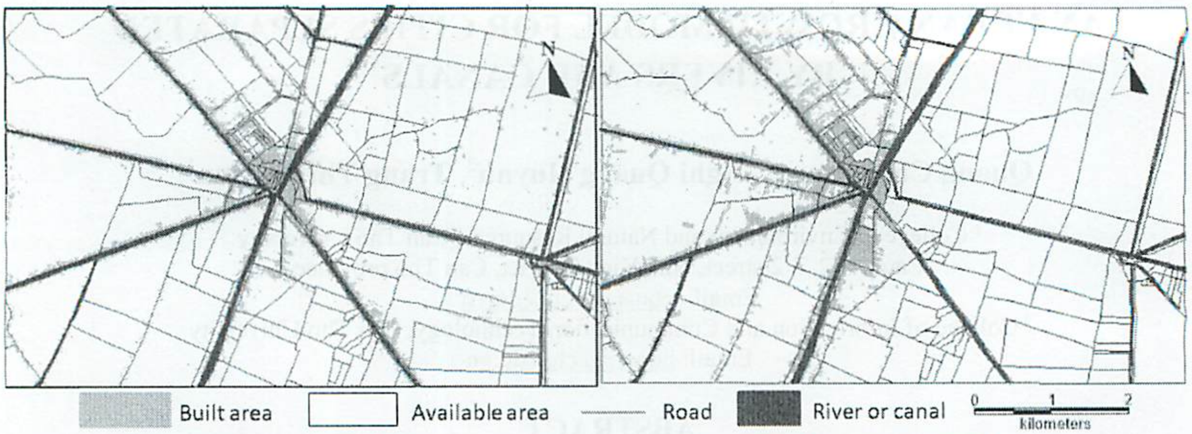
1. INTRODUCTION

Socio-economic development policies in Vietnam are currently linked to urban development. This policy aims to improve the quality of life of the citizen. Urban development plans takes the key role in infrastructure investments. For complex river network regions like the Mekong Delta, infrastructure development is the main condition for urbanization. The government therefore needs tools to forecast the development of cities according to socio-economic and infrastructural factors. However, there is a lack of tools to test urban growths in order to predict urbanization, especially for small towns separated by many rivers and canals such as Nga Bay Town, Hau Giang Province. This typical city locates at the intersection of seven canal branches in the Mekong Delta of Vietnam. For this reason, we proposed a model of urban growth model taking into account characteristics of the rivers.

2. MODEL IMPLEMENTATION

2.1 Input data

Model's input data was collected from Google Earth software to generate urban maps of Nga Bay Town. Due to historical characteristics, the images are recorded only in 2006 and 2017 as input data for the model. Based on the downloaded images, the maps of built areas of 2006 and 2017 was digitized as in Figure 1. The maps shown that the total built area in 2006 was 291.5ha, compared to 413.9ha in 2017. The area therefore increased 122.4ha for 11 years. On average, the urban area of the town increased by 11ha per year during the observed period.



Built area in 2006 **Built area in 2017**

Figure 1. Maps of the built area in 2006 and 2017 of Nga Bay Town.

Urban land data is rasterized with a resolution of 10x10m (100m^2) which is the popular size of houses in the area. The value of pixels on the maps is encoded according to three categories indicated in the legends of Figure 1: urban built-up area, available area for urban growth and rivers.

2.2 Model implementation

The model is based on a basic model (Taillandier et al., 2016) which is provided in the library of the GAMA platform (Grignard et al., 2013). Our extended model is developed using the Graphical Modeling plug-in (Taillandier, 2014) as shown in Figure 2. The plots (considered as agents) are loaded from the pixels in the built raster map; road agents represent main traffic including national highways, streets and residential roads; the agents of administrative center indicate the location of the administrative and economic centers of the municipality.

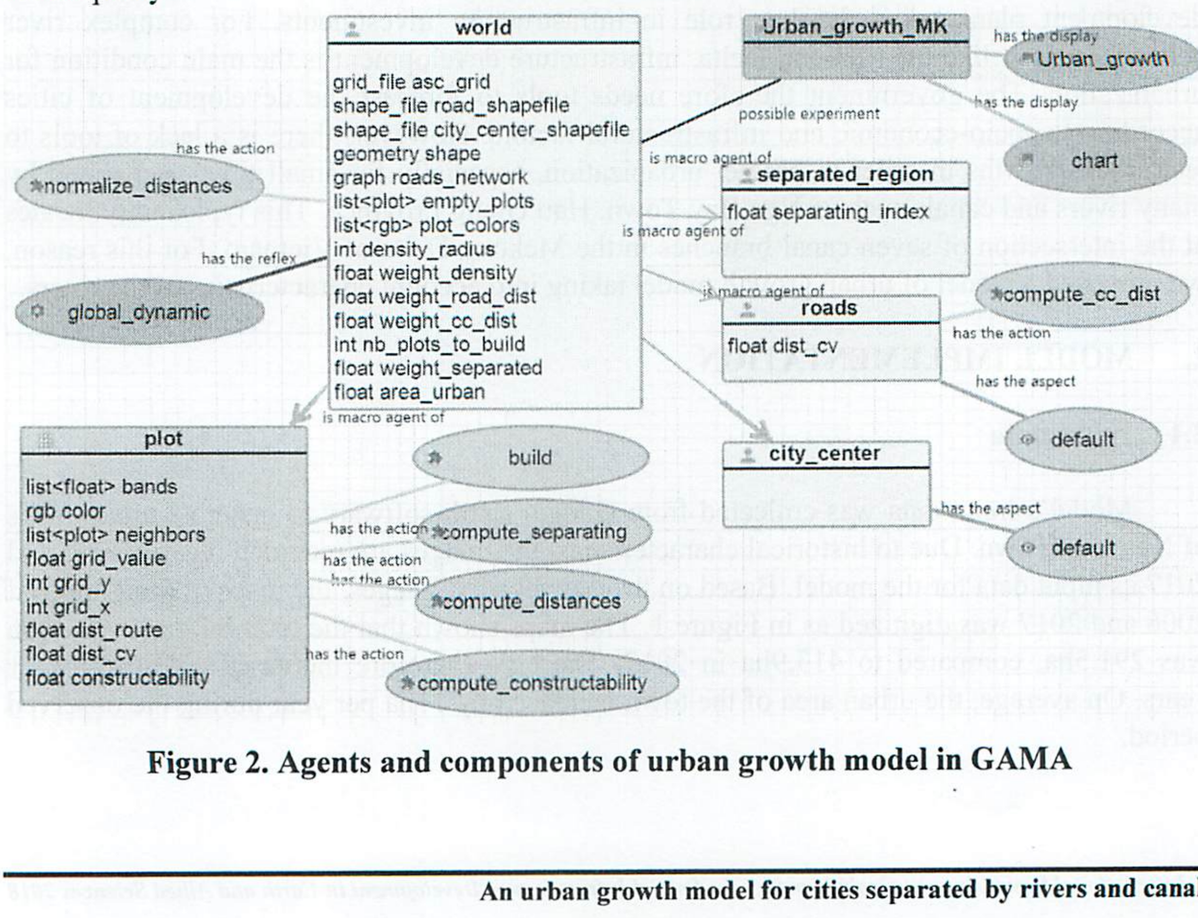


Figure 2. Agents and components of urban growth model in GAMA

According to Taillandier et al. (2016), the simulation of urban growth depends on many factors such as: the density of built areas, the position of a plot in relation to roads, the distance to the administrative and cultural centers. In this model, we added an index to measure the development of regions within residential and regions separated by rivers and canals.

The simulation step of the model is defined for one year. At each cycle, the main process (global dynamic) requires all available plots to calculate the indices, including the constructability index. The plots are then sorted in descending order of constructability values. Next step, a number of plots that have the high value of the constructability index are selected to be converted to the constructed land.

The Constructability Index (CI) and the indices are calculated as the following equations:

$$CI = \frac{W_1C_1 + W_2C_2 + W_3C_3 + W_4C_4}{W_1 + W_2 + W_3 + W_4} \quad (1)$$

$$C_2 = \frac{number\ of\ built\ cells\ in\ the\ neighborhood}{number\ of\ cell\ in\ the\ neighborhood} \quad (2)$$

$$C_2 = 1 - \frac{dist(plot, nearest_{road})}{\max\_dist_{plot\_road}} \quad (3)$$

$$C_3 = 1 - \frac{dist(plot, center\_city)}{\max\_dist_{plot\_center}} \quad (4)$$

With:
C_1: The percentage of built plots (cells) in the neighborhood. Each cell in the model have 8 neighbors. The percentage is determined by the number of constructed plots per total number of neighbors.
C_2: Distance from a plot to the nearest road. It is calculated as (3) based on the distance to nearest road divided by the maximum distance of a plot to the road.
C_3: Distance from a plot to the city center. This factor is calculated as (4) via the road network.
C_4: The index measures the isolation of regions of the city. Areas surrounded by residential roads have a higher index than the region isolated by rivers and canals.
W_1, W_2, W_3, W_4 are the weights of the factors C_1, C_2, C_3, C_4.

2.3 Evaluation of model

Model is evaluated using Kappa coefficient (Cohen, 1960). The coefficient is calculated based on the simulated map and the observed map. In the case study, we compared the simulated map of the built area of Nga Bay Town with the actual map of 2017.

3. EXPERIMENTS

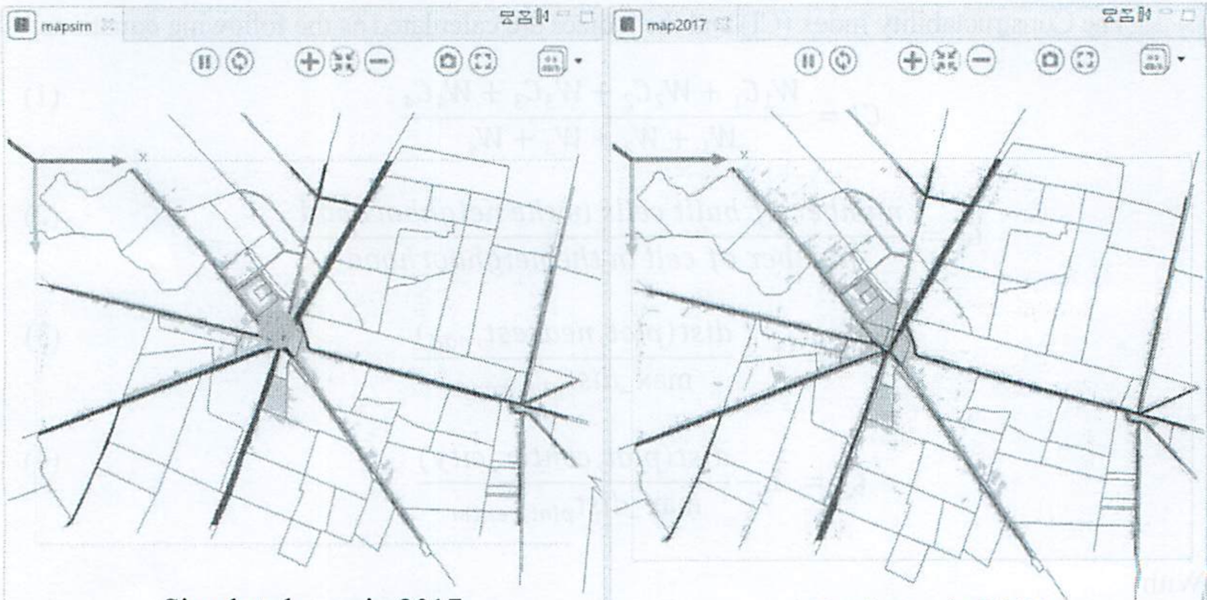
3.1 Calibration of model

The calibrated experiment was built on GAMA using the Genetic Algorithm to explore all 4 parameters. The calibration process has tested set of parameters giving the maximum value of the Kappa coefficient as follows:

- Weight of density of built areas: 0.6
- Weight of distance to main road: 0.3
- Weight of distance to center city: 0.7
- Weight of isolated region: 1.0

3.2 Simulation of urban growth of Nga Bay Town

The simulated results of the built areas of Nga Bay in 2017 are shown as Figure 3. The simulated area is 422.8ha while the real area is 413.9ha. The difference between the simulated result and the actual result is 8.9ha.



Simulated map in 2017 Real map in 2017

Figure 3. Simulated map compared with real map of Nga Bay Town in 2017

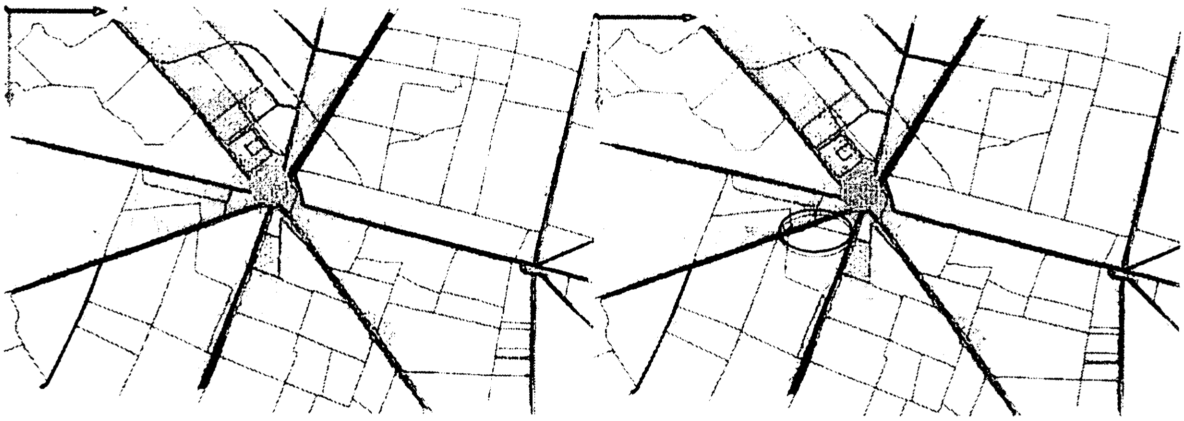
The kappa coefficient in this case is 0.70. This rate is not too high, but it can be used to explain the urban growth in the study area.

3.3 Simulation of urban area in 2027

To predict the future development of Nga Bay Town, two scenarios have been implemented: Urbanization scenarios based on existing infrastructure and urbanization scenario base on the development of bridges and road that link the separated regions (isolated regions) by tributaries.

In the first scenario, the urban simulation of the town of Nga Bay in 2027 according to current infrastructure shown that the urban development could be more and more developed as Figure 4. The area of built land in 2027 will be 522.36ha. Land area increased by 108.46 hectares compared to 2017. The constructed land will be developed along main roads but will not be developed in the regions separated by rivers and canals.

In the second scenario, the bridges and roads will be constructed to connect the isolated regions, indicated by the red circle in Figure 4. However, the simulated result shows that this area is still not developed, the main development zone of this area will be also concentrated in the north of the town where the main roads and the residential area are located.



Scenario 1 Scenario 2

Figure 4. Simulated urban area of Nga Bay Town in 2027

4. CONCLUSION

With the characteristics of being separated by complicated rivers and canals, small towns such as Nga Bay Town have relatively slow urbanization rates. The model explained the development of small urban areas of the Mekong Delta with features that were severely separated by rivers and canals.

The model was calibrated according to the urban built area collected in 2017 and was used to estimate the urban growth of Nga Bay Town.

In order to expand the model, it is possible to further classify all types of urban land use, giving priority to the development of land types that are likely to be converted to urban land for inclusion in the transition.

5. REFERENCES

Cohen, J., 1960. A Coefficient of Agreement for Nominal Scales. Educ. Psychol. Meas. 20, 37–46. doi:10.1177/001316446002000104

Grignard, A., Taillandier, P., Gaudou, B., Vo, D.A., Huynh, N.Q., Drogoul, A., 2013. GAMA 1.6: Advancing the Art of Complex Agent-Based Modeling and Simulation, in: Boella, G., Elkind, E., Savarimuthu, B.T.R., Dignum, F., Purvis, M.K. (Eds.), PRIMA 2013: Principles and Practice of Multi-Agent Systems. Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 117–131.

PCNB, 2014. Report of land-use inventory in 2014 of Nga Bay Town, People's Committee of Nga Bay Town. HauGiang Province.

PCNB, 2016. Report of land-use statistic in 2016 of Nga Bay Town, People's Committee of Nga Bay Town. HauGiang Province.

Taillandier, P., 2014. GAMAGraM: Graphical modeling with the GAMA platform, in: The 4th International Conference on Complex Systems and Applications, Jun 2014, France. 6p.

Taillandier, P., Banos, A., Drogoul, A., Gaudou, B., Marilleau, N., Truong, Q.C., 2016. Simulating Urban Growth with Raster and Vector models: A case study for the city of Can Tho, Vietnam, in: Osman, N., Sierra, C. (Eds.), Autonomous Agents and Multiagent Systems, Lecture Notes in Computer Science. Springer International Publishing, pp. 154–171. Doi: 10.1007/978-3-319-46840-2_10.