THE MORPHOLOGICAL CONSTRAINTS OF THE SETTLEMENT GROWTH/DEGROWTH PROCESSES. AN INTERPRETATION OF THE CONCEPT OF TERRITORIALISATION CYCLE

Giampiero Lombardini, Assistant Professor of Town and Regional Planning, University of Genova (I),

ABSTRACT

In many geographical areas, the demographic transition has led to a situation of relative stability of urban and regional settlement. The phase of rapid population growth that generated the urbanization process has stabilized. In these conditions of stability, however, arise very complex dynamics in which growing paths alternate with decreasing periods and urban regions. In a context of strong competition between cities and urban regions, a general selective phenomenon of use /reuse / abandon is observed. Resuming the theories of territorialisation cycles (Muratori, Caniggia, Cataldi) it is possible to propose an interpretation of the history of the territory as a succession of cycles. Both the economic and geographic models and the morphological models allow us to grasp those interesting allometric relations between cities and urban systems that characterize the different development cycles. The aim of the paper is to analyze the long-term urban plan for the territory of Albenga area (Liguria, Italy. Settlements are analyzed together with the basic territorial structures that have generated them during the historic long period. The study starts from the diachronic reading of cycles of territorial development that have gradually formed the present settlement. An important role is played by the morphological conditions in which the growth/degrowth process takes place. Given that these dynamic change phenomena occur in territories where previous settlement development processes had determined specific morphological conditions, it is hypothesized that the role played by morphogenetic phenomena of selective reuse /abandon (studied through morphological models, such as cellular automata) is of great relevance.

INTRODUCTION

The main purpose of this contribution is to understand and represent the current territorial structures (settlement fabric), characterized by a post-metropolitan condition. The research attempts a description of a post-metropolitan territory, trying to highlight some salient features that, according to E. Soja can be identified in a poly-nucleated urbanization, a frequently absence of dominant centers, settlement dispersion / diffusion, fragmentation and segregation of uses. The hypothesis carried out by the research is that the territory can be analyzed as the stratification of successive settlement cycles (according to Muratori and Caniggia). Then the question is to understand territorial change and how to represent it. Another hypothesis concerning the role that physical space play in determining settlement forms. The research is based on the idea that human settlement, in its historical evolution, is conditioned by the physical and morphological characteristics of the territory, as well as by the quantity and quality of environmental resources. The creativity of human activities (technology, civil development, aesthetic aspirations) creates the special symbiosis between man and environment that characterizes every human environment. Moreover, the history of the settlement is the story of the continuous and changing adaptations that the anthropic structure (in its material and cultural dimensions) operates towards the stratifications inherited from the precocious ages. In this sense, the history of the settlement can be interpreted as the succession of a series of cycles over time, in which, in every age, original equilibrium relations are manifested between local communities, environment and resources. Another question is, then, how the ‘sediments’ left by previous cycles are used and/or reused. Similarly, the research the research tries to understand What are the relationships between economic and social cycles and settlement territorial cycles. Here, the hypothesis is if it’s possible to think a method that knows how to understand the territorial settlement cycles as a path dependent process, but at the same time in an innovative way.

BACKGROUND

The post-metropolitan territory (and the territory in general) can be read as a succession of cycles of territorial settlement. The material history of the territory is the history of the forms of its settlement and is not linear, but it's characterized by cycles of innovation / consolidation, centralization / dispersion, employment / abandonment, colonization / restructuring. Sometimes these settlement dynamics act simultaneously (they are synchronous), in other cases they alternate over time and are differentiated in space (diachronic changes). The geographical space (the physical and morphological characteristics of the territory), condition the different territorial cycles (above all the first cycles) that are always the result of an uncertain and unstable equilibrium between population and environmental resources. The forms of settlement inherited from the past also condition future developments, sometimes posing as constraints sometimes as opportunities (reuse of previously shaped structures).

METHODOLOGY

The most recent land use/cover change models (Basse et al., 2014; Batty, 2015; Briassoulis, 2000; White et al., 2012;) are usually based on different empirical techniques (e.g., artificial neural networks, agent-based models, genetic algorithms) or statistical techniques (e.g., multi-criteria analysis, regression models) and underlying theories have significantly increased researcher's interest because they can (1) explore dynamic processes of the land use system; (2) build models of relationship among changes and spatial and non-spatial variables; (3) can make explicit the weight and the role that the different variables taken into account have in determining the changes in land use; (4) predict future land use development over space and time; (5) simulate trajectories of land use changes and feedback loops through the implementation of land use scenarios.

For the study of the succession of the different territorial cycles, the starting information base was constituted, by the analysis of changes in land use and land cover. Through the reading and analysis of variations in land use maps it is indeed possible to elaborate a description of the spatial structure of the settlement. The land use maps developed in this way are then the basis for developing simulations on possible future territorial structures. The method adopted allows to represent the dynamic settlement structure of a territory in an historic way, allowing to describe and observe the phenomena of centralization / dispersion, occupation / abandonment, colonization / restructuring. Briefly, the workflow consists of the following steps:

- Obtain landcover map for few time slices and a set of potential explanatory variables;
- Calculate probabilities of transitions from class to class;
- Build a model using ANN, logistic regression, Weights of evidence or Multi-criteria evaluation to describe transitions based on factor variables;
- Use this model for forecasting;
- Validate the result with real data
- More precisely, the proposed method consists of six processing steps (Tab.1):

Elaboration of data sets and land use and land cover maps in different time stages	Institutional open data maps, image interpretation of aerial photos, survey on site, GIS
Searching of the potential spatial variables	Spatial analysis thruogh GIS
Evaluation of the statistical correlation between land use change and explanatory spatial variables	Spatio - statistical indices: Pearson's correlation
Modeling the temporal transition rules between the different land use maps	Artificial Neural Network (ANN) (Multi-layer-perceptron)

Simulation of change through geosimulation methods	CA- Cellular Automata
Calibration and validation of the model results	CA- Cellular Automata

Figure 1 Spatial analysis of territorial cycles: steps of the proposed method

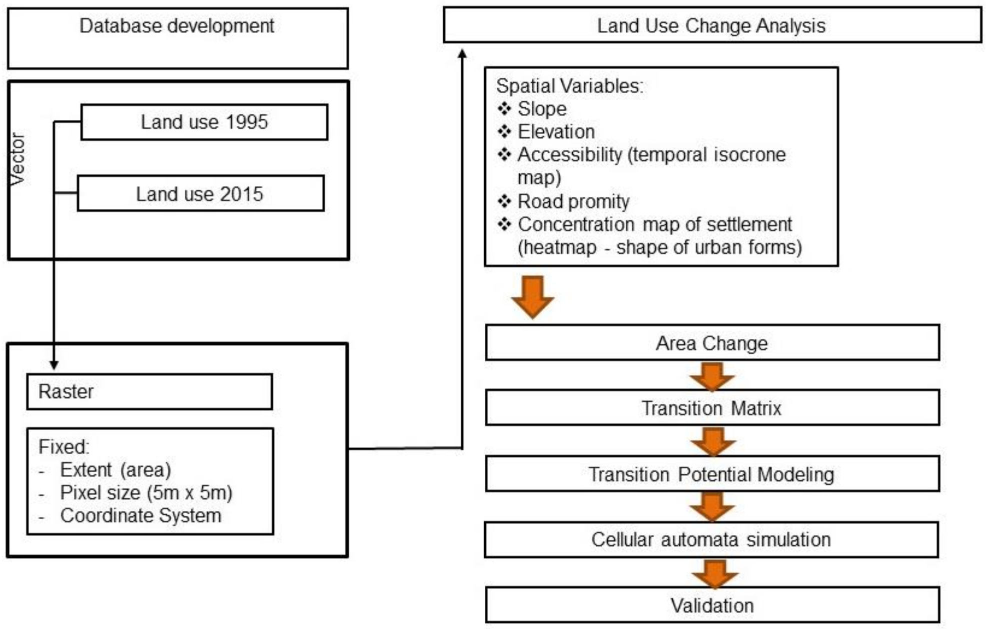


Figure 2 The phases for the development of land use change model

THE STUDY AREA AND THE ANALYSIS OF TERRITORIAL CYCLES

The study area concerns a western region of Liguria (Albenga and its region), characterized by the presence of an important coastal plain that has been formed, from a geomorphological point of view, from the confluence of some mountain streams. It is one of the few flat areas of Liguria and its shape has influenced the forms of settlement over the centuries. The history of human occupation in the area is very ancient and even in Roman times the area was characterized by an intense process of colonization. The vivacious agricultural and productive characteristics have been maintained and consolidated, up until today.

Albenga is an area of ancient human colonization. We can recognize almost fuor phases of human territorial occupation. The first phase of settlement structure (3.000-2000 years ago) is characterized by the presence of small residential areas on the heights, near the ridges (centers of the promontory). The second phase of settlement evolution is characterized by the descent towards the valley of the settlements and by the progressive occupation of the hillsides. This is the period in which large terraces are built and it is the period in which agricultural production consolidates itself and specializes. The paths now descending from the ridges become mid-way routes. The first long-distance foothills paths are also built. The third phase is characterized by the intensive occupation of the lowland areas of the valleys. The agricultural structure now occupies all the flat coastal areas and the valleys, thanks to the drainage of previously swampy areas. The road network becomes dense and even urban centers rise in rank (population, markets, activities). In this period (1300-1950) also begins a phase of organization of the territory that focuses on some new foundation urban centers. The fourth phase coincides with the urbanization process of the modern era. On the basis of the settlement structures built in previous periods, the agricultural activity becomes more and more intensive (industrialized agriculture) and this primary activity is flanked by various other functions such as trade and industry, which tend to occupy large areas with increasingly large building artifacts.

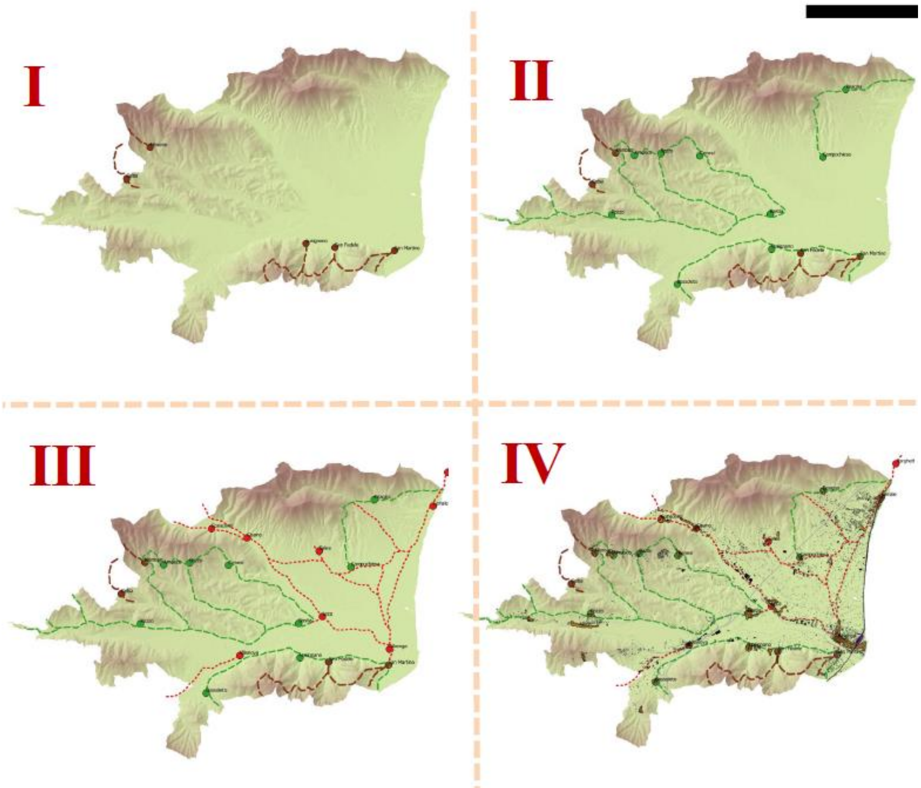


Figure 3 Albenga, an area of ancient human colonization

The first phase of settlement structure (3.000-2000 years ago) is characterized by the presence of small residential areas on the heights, near the ridges (centers of the promontory). The second phase of settlement evolution is characterized by the descent towards the valley of the settlements and by the progressive occupation of the hillsides. This is the period in which large terraces are built and it is the period in which agricultural production consolidates itself and specializes. The paths now descending from the ridges become mid-way routes. The first long distance foothills paths are also built. The third phase is characterized by the intensive occupation of the lowland areas of the valleys. The agricultural structure now occupies all the flat coastal areas and the valleys, thanks to the drainage of previously swampy areas. The road network becomes dense and even urban centers rise in rank (population, markets, activities). In this period (1300-1950) also begins a phase of organization of the territory that focuses on some new foundation urban centers. The fourth phase coincides with the urbanization process of the modern era. On the basis of the settlement structures built in previous periods, the agricultural activity becomes more and more intensive (industrialized agriculture) and this primary activity is flanked by various other functions such as trade and industry, which tend to occupy large areas with increasingly large building artifacts. dimension.

About modern settlement dynamics, we can recognize three phases in the last 60 years. The first phase of the modern era (1950-1975) is characterized by the strong presence of traditional agriculture conducted on small plots. Production is concentrated mostly on fruit and vegetables and the outlet market is mainly local. The other activities (which materialize themselves in specific uses) are weak, except for the residential function that emerge in strong increase during this period. The population is increasing (from 12,000 to 19,000 inhabitants). The second period (1975-1995) is characterized by a strong conversion of agricultural activity towards industrialized production forms with great growth of greenhouse plants and specialized crops. Agricultural activities are now flanked by the productive and commercial functions (often entering into competition with the agricultural land uses) that tend to occupy great spaces, especially near the main roads. The quantitative growth of the building continues. The population continues to increase, but at a slower rate: from 19,000 to 21,000 inhabitants. The third period (1995-2015) is characterized by a strong expansion of service industry, productive and commercial functions to the detriment of agriculture. The more specialized agriculture resists and consolidates itself, but the agriculture conducted in more extensive forms, on the one hand is replaced by new urban activities (increasingly widespread in the territory), on the other side is subject to abandonment, with the consequent growth of forest and natural areas. Building development is remarkable and even the population continues to increase (from 21,000 to 23,000 inhabitants).

To investigate what were the main trends in the transformation of the territorial structure of the case study area in the recent past, it has been hypothesized that a fundamental tool of knowledge is constituted by the analysis of changes in land uses over time. In fact, an anthropized territory can be read as the organic overlap between a structure of land uses, a subdivision plot and settlement morphologies. Undoubtedly the mosaic of land uses is the one that most conditions (and is in turn conditioned) the other two components. Therefore, reconstructing the succession of changes in land use over the medium to long term allows us to provide a cyclical reading of territorial evolution. The modifications that can be read in the physical structure of the territory can also be linked to the more general socio-economic dynamics of the study area, also characterized by strongly cyclical trends. In particular, the cycles of change in land use destinations (the role of agriculture, the crisis of traditional agriculture, the dynamics of abandonment of the higher areas, the growth of dispersed urbanization, the increase of tertiary functions) can, in a broader perspective of research, link to some general scenarios such as: continuity of current trends, growth of innovative agricultural activities, growth of tertiary activities, consolidation of the residential function. In this contribution we will illustrate the scenario of continuity of current trends.

OPERATIONAL STEPS FOR LAND USE SIMULATION

The land uses used in this study were vector data and classified into 8 categories: compact residential, other urban uses, dispersed settlement, urban green areas, intensive and extensive agriculture, forest and natural areas, water. Most of spatial variables were loaded in vector format, where the MOLUSCE deals with raster data. So, first thing was to convert all vector data to raster data to be able to deal with plugin. Other terms to deal with plugin is to set the same coordinate system for all layers. Applied resample process for all layers to determine the same pixel size, in this study the pixel size chosen is 5 x 5 mt.

1° step - Inputs - Data preparing

The initial (period 1: 1995) and final (period 2: 2015) land use/ land cover maps as well as spatial variables such as slope, road proximity, elevation, and settlement density and form are loaded in the panel of spatial variables (Fig. 2). The land use/ cover change information and the spatial variable are been used for modeling and simulating land use/ cover changes in area-studio. In this step, it was crucial checking geometry if all inputs matched (pixel dimension, coordinate systems, scale and so on).

2° step - Evaluation correlation

This step comprises three methods, namely the person's correlation, joint information uncertainty, and crammer's coefficient, which are used to check correlation among the spatial variables. The analysis (table 2) shows the correlation ratio between the five variables (slope, road proximity, elevation, built concentration and accessibility -isocrones-). It is noticed from the result that the slope and elevation layers are inversely related to the other variables, which are inversely affected. The roads often need an equal area in order to facilitate street construction. The other variables are linked by direct links.

3° step - Area change

In this tab, land use/ cover change (Fig. 4) and transition probabilities are computed. Also land use/ cover change map produced. The land use/ cover units have been expressed in hectares.

4° step - Transition potential modeling

The method for computing transitional potential map is Artificial Neural Network (ANN). This method uses land use/cover information and the spatial variable as inputs for calibrating and modeling land use / cover change. The resulting data show the correlation ratio between the six variables (slope, road proximity, elevation, built concentration and accessibility -isocrones-). It is noticed from the result that the slope and elevation layers are inversely related to the other variables, which are inversely affected. The roads often need an equal area in order to facilitate street construction. The other variables are linked by direct links.

5- Cellular Automata simulation:

To build simulation maps, Molusce uses as a method of projection (among others) a neural network. In order to develop a network with adequate predictive capacity, it was necessary to train and test the ANN with different input data. Training involves presenting input values and adjusting the weights applied at each node according to the learning algorithm (e.g. back-propagation). ANNs were applied to the prediction of land use change in four phases: (1) design of the network and of inputs from 5 spatial variables and a spatial historical map; (2) network training using a subset of inputs; (3) testing of the neural network using the full data set of the inputs; and (4) using the information from the neural network to forecast changes. Transitional potential map (Fig. 5), certainty function, and simulated land use/ cover maps are generated under this process. The cellular automata approach is based on Monte Carlo algorithm.

5° step - Simulation

The MOLUSCE plug-in provides the tools to conduct an analysis of transformation potentials. In fact, starting from the change maps, the system "learns" through the ANN which are the highest probabilities, for each pixel, of permanence of the present land use or of its variation (and in which direction this variation might take place). The rules that are built through the ANNs consider the spatial variables that influence changes and their weight. Through other tools, such as multi-criteria analysis or logistic regression, we could also build different hypotheses of relevance (correlation) between the spatial variables considered and the process of change in land use. All these techniques can lead to a progressive refinement of the model's ability to predict potential future uses with an increasing accuracy.

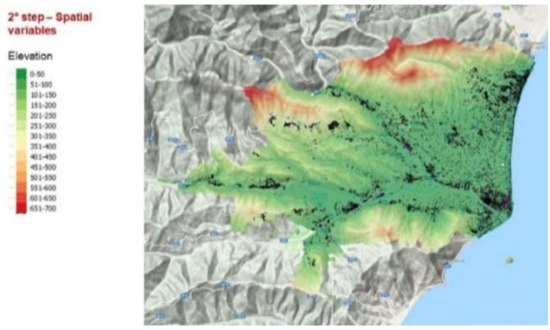
6° step - Validation

Validation computes Kappa statistics (standard kappa, kappa histogram, and kappa location), misses and false alarms are produced under this component.

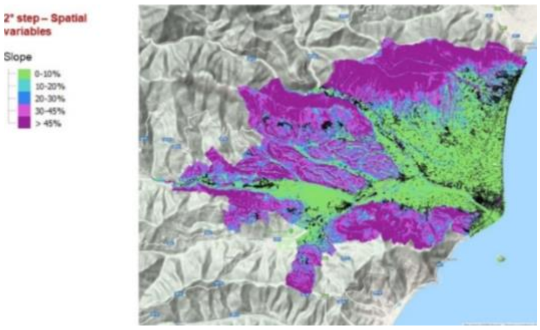
In order to predict future trends and change in the study area, we have been used transitional potential modeling (ANN) combined with Cellular Automata to forecast future changes in LU-LC between 1995 and 2015,. The result indicates that the probabilities of increasing area will be cover by settlement and forest areas (development vs abandon), and a relative permanence of intensive agriculture.

In order to predict future trends and change in the study area, we have been used transitional potential modeling (ANN) combined with Cellular Automata to forecast future changes in LU-LC between 1995 and 2015. The result indicates that the probabilities of increasing area will be cover by settlement and forest areas (development vs abandon), and a relative permanence of intensive agriculture.

About the analysis of changing land use, the land use forecast map elaborated with the combined system of ANNs and cellular automata, clearly shows how, in the scenario of the persistence of the current trends, the opposing dynamics of over-use and abandonment will be further developed in the next 25 years. While in some areas already historically urbanized or with strong and consolidated presence of agricultural activity we will observe phenomena of substantial persistence of uses, in the fringe areas we will alternatively will observe phenomena of further settlement development or abandonment phenomena with the advance of the forests and natural areas.



Elevation



Slope

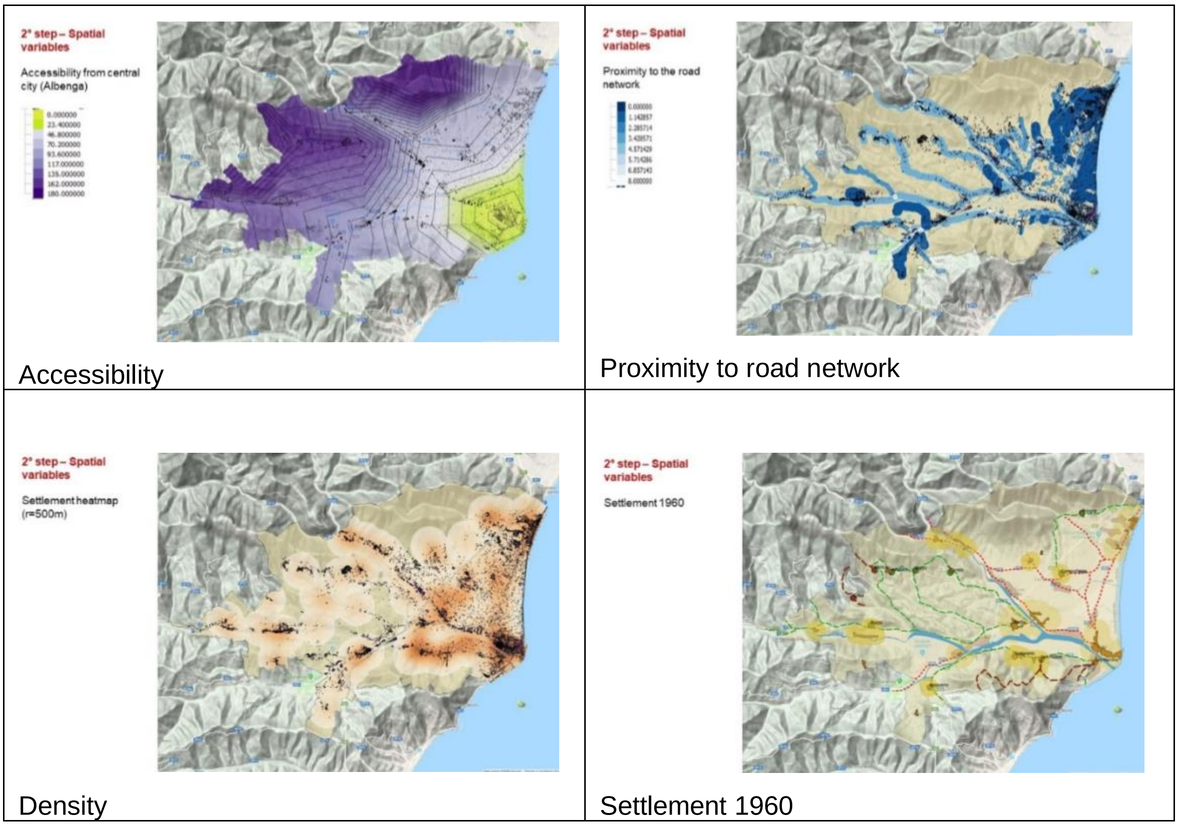


Figure 4 Spatial variables selected.

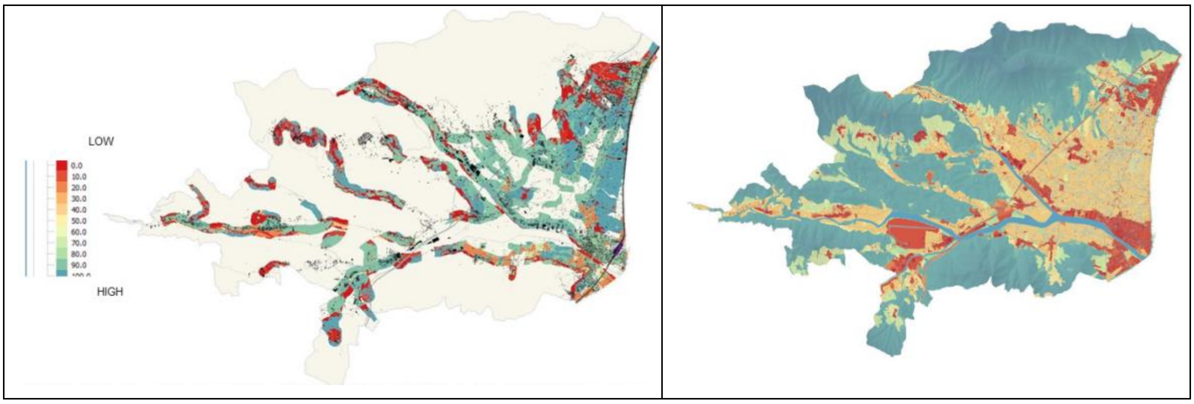


Figure 5 Transformation potential and simulation of land use at year 2040.

CONCLUSIONS

The Land Transformation Model presented in this paper examines the relationship between 5 predictor spatial variables and land use changes. The model performs with a relatively high predictive ability (46%) at a resolution of 5x 5 mt. By developing 5 versions of the LTM, each with one of the variables removed, we could assess the relative contributions of each variable on model performance. Similarly, if we set up simulations according to a different set of (spatial) variables (one set for each scenario), we could obtain different forecast results, processing a real scenario analysis. A set of alternative scenarios could then form the basis for carrying out preferential analyzes with multi-criteria methods.

Using the ANN pattern file generated for the study area, we've applied the network file created from the control run to create a file with changing likelihood values for each location in the entire area. In order to obtain a reasonable result, we made several assumptions. First, we assumed that the pattern of each predictor variable remained constant beyond all the period. Spatial rules used to build the interactions between the predictor cells and potential locations for transition are assumed to be correct and constant over time. Third, the neural network itself was assumed to remain constant over time. Thus, the relative affect of each predictor variable is assumed to be stable. Finally, the amount of urban per capita undergoing a transition is assumed to be fixed over time. Given the availability of data (e.g. new roads, more temporal information about land use change and other variables), it is possible to relax many of these assumptions in order to examine the potential effect each of these assumptions have on the performance of model forecasts. In general, the simulation model is able to represent forms and dimensions of the change in land use and therefore the settlement structure of the area, highlighting what could be important trends in the near future, where the size of the dispersed settlement will go probably growing up.

REFERENCES

Basse, Omrani, Charif, Gerber, & Bódis. (2014). Land use changes modelling using advanced methods: Cellular automata and artificial neural networks. The spatial and explicit representation of land cover dynamics at the cross-border region scale. *Applied Geography*, 53(C), 160-171.

Batty, M. (2013). *The new science of cities*. Cambridge, Massachusetts London: The MIT Press.

Benenson, I., Torrens, P. M. (2004). Geosimulation: object-based modeling of urban phenomena. *Computers, Environment and Urban Systems*, 28(1e2), 1-8.

Caniggia, G. (1976). Strutture dello spazio antropico studi e note. Firenze: Uniedit.

Engelen, G., Lavalle, C., Barredo, J. I., van der Meulen, M., & White, R. (2007). The MOLAND modelling framework for urban and regional land-use dynamics". In E. Koomen, J. Stillwell, A. Bakema, & H. J. Scholten (Eds.), *Modelling land-use change. Progress and applications* (pp. 297-320). The Netherlands: Springer.

Li, X., & Yeh, A. G. O. (2002). Neural-network-based cellular automata for simulating multiple land use changes using GIS. *International Journal of Geographical In- formation Science*, 16(4), 323-343.

Muratori, S. (1967). *Civiltà e territorio*. Roma: Centro studi di storia urbanistica.

Pijanowski, B. C., Brown, D. G., Shellito, B. A., & Manik, G. A. (2002). Using neural networks and GIS to forecast land use changes: a land transformation model. *Computers, Environment and Urban Systems*, 26(6), 553-575.

Pijanowski, B. C., Pithadia, S., Shellito, B. A., & Alexandridis, K. (2005). Calibrating a neural network-based urban change model for two metropolitan areas of the upper midwest of the United States. *International Journal of Geographical Information Science*, 19(2), 197-215.

Serra, P., Pons, X., & Sauri, D. (2008). Land-cover and land-use change in a Mediterranean landscape: a spatial analysis of driving forces integrating biophysical and human factors. *Applied Geography*, 28, 189-209.

Tobler, W. R. (1979). Cellular geography. In S. Gale, & G. Ollson (Eds.), *Philosophy in geography* (pp. 279-386). Dordrecht: Reidel.

White, R., Uljee, I., & Engelen, G. (2012). Integrated modelling of population, employment, and land use change with a multiple activity based variable grid cellular automaton. International Journal of Geographic Information System, 26, 1251-1280.

Whitehand, J. W. R., Gu, K., Conzen, M. P. and Whitehand, S. M. (2014) 'The typological process and the

CORRESPONDING AUTHOR

Giampiero Lombardini, Assistant Professor, Department of Architecture and Design, University of Genova (I).
giampiero.lombardini@unige.it