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The effects of socio-economic variables in urban growth simulations

Benedetto Manganelli[a,*], Flavia Di Palma[a], Federico Amato[a], Gabriele Nolè[b], Beniamino Murgante[a]

[a] *School of Engineering, University of Basilicata, Viale dell'Ateneo Lucano 10, Potenza, 85100, Italy*
[b]*Italian National Research Council, IMAA C.da Santa Loja, Tito Scalo, Potenza 85050, Italy*

Abstract

Urban sprawl phenomenon is one of the higher threats to the preservation of soil resources. Soil consumption is strongly related to social and economic factors that characterize a territory. Several models have been developed to recreate future scenarios based on past expansion development dynamics. Among cellular automata models for urban growth simulation, SLEUTH is considered as an effective tool to support urban management. However, the model does not explicitly include demographic dynamics and socio-economic ones. This paper compares the results of two different simulations performed on the same study area through the SLEUTH model. While the first simulation is performed using the classical method of calibration of the model, the second one proposes the inclusion of some socio-economic variables within the simulation process. The results show a better match with the actual development trends of settlement by the simulation that takes into account the social and economic aspects of the analysed territory.

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Keywords: Land use change models; soil consumption; urban policies; socio-economic variables; urban sprawl; AHP;

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* Corresponding author. Tel.: +39-0971-205171; fax: +39-0971-204313.
E-mail address: benedetto.manganelli@unibas.it

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1. Introduction

The environment is the setting in which naturalistic, landscape, anthropological and economic elements relate to each other, to varying degrees. Urban areas as places of concentration of the world's population define territorial areas that condense high levels of pressure on the ecosystem; and their development creates growth that is directly proportional to such pressure. Usually, one thinks of urban sprawl as a phenomenon characterized by a vigorous expansion of urban areas, a symptom of erroneous economic choices (Brueckner, & Fansler, 1983). In more or less negative ways, they impact urban energy efficiency, producing psychological and social costs that result in the loss of a sense of community while contributing to the decline of the compact city (Ewing, 1994). It should be recognized that the processes of urbanization and settlement transformation are encouraged not only by economic and financial dynamics, but, above all, by demographic dynamics. These, in addition to defining the increase or decrease in the population, explain more fully the transformation of a society and its needs. Nevertheless, in recent decades urban sprawl has presented notable developments where no significant demographic growth has been recorded (Nolè, Murgante, Calamita, Lanorte, & Lasaponara, 2014). Consequently, it is essential to make judgments based on further dynamics that are directly related to demography and urbanization and trigger the phenomenon. The literature describes numerous models that can effectively simulate urban growth. However, the main criticism of these models is related to their weak ability to integrate explicit variables in the simulation process, not so much ones that are spatially explicit as those of a socio-economic nature. This paper intends to use the socio-economic variables that have the greatest impact on the process of urban expansion within the known SLEUTH model. The results show that simulations that consider these variables ensure a greater degree of coherence with respect to the actual socio-political scenarios that guide the transitions between land use classes.

2. Materials and Methods

2.1. SLEUTH model

The literature recognizes several groups of geo-computational methods applied to the modeling of urban phenomena (Clarke & Gaydos, 1998; Manganelli, Pontrandolfi, Azzato & Murgante, 2014; Von Neumann, 1996). Cellular automata methodology was developed in 1940 by John von Neumann. In recent times, due to the prodigious development of hardware technology, wider applications of it have been developed (Caglioni, Pelizzoni, & Rabino, 2006).

Among the cellular automata models for the simulation of changes in land use, and for modeling dynamic urban models (White, & Engelen, 1993; Papini, & Rabino, 1997). Sleuth is one of the best known. It is a probabilistic model with Boolean logic that describes four behavioural space models that predict a change of land use or urban growth (Martellozzo, & Clarke, 2011), based on five parameters (Ding, & Zhang, 2007): dispersion, breed, spread, slope, and road-gravity. The growth cycle adopted by the model as a unit of time corresponds to one year; for each unit of time the model processes four types of growth dynamics in urban areas, classifiable as: spontaneous growth; the emergence of new centers of expansion; growth on the edge; and growth influenced by the presence of road infrastructure (Clarke, Hoppen, & Gaydos,1997). SLEUTH is an acronym that defines the six spatial inputs that form the layers required by the model. In order, they are: Slope, Land Use, Excluded, Urban extend, Transportation network and Hill shade. The robustness of the model is based on its application as an effective support tool of urban management and experimentation with complex urban structures (Candau, 2003). Calibration explores all the possible iterations of the five parameters that drive simulation. Therefore, it is particularly complex in computational and temporal terms. The values during calibration are constantly modified through a journey that runs from the first date to the end date of the forecast. The parameters used to measure an improved calibration at the end date are considered, and they will initialize the forecast. Several approaches have been used to restrict the space of coefficients; weighing-up a number of parameters more heavily than others and putting them in order according to only one metric (NCGIA, 2011). Each metric represents the value between simulated growth and the growth evaluated in the control years. In particular, Optimum SLEUTH Metric (Dietzel, & Clarke, 2004), adopted to limit the range of the coefficients, is produced by: a comparison (set of molded end pixels); the population (number of