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The Significance Of Socio-Economic Variables In Urban Growth Modeling

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The escalating impacts of climate change pose complex challenges for communities (Murphy et al., 2018). Diverse scientific disciplines have formulated numerous climate change scenarios to evaluate the evolving risks and associated threats faced by communities (Gardoni, 2019). A recurring limitation in many risk assessments is their reliance on the existing built environment, which may undergo profound transformations in time. Notably, the rapid expansion of urban areas often surpasses the pace of climate change, emphasizing the critical need for models tailored to the dynamic nature of urban growth (UG).

This research aims to devise a novel mathematical model for UG that integrates variables from both the built and social environments. To accomplish this, we present a model in the context of cellular automata-based models, a common approach in the literature for analyzing UG (Yeh et al., 2021). The adoption of a CA model is driven by its computational efficiency and its emphasis on grid modeling of land use. The grid, or cell space, utilized in the model represents a two-dimensional geographic area composed of regular cells, serving as the fundamental entities of the model. In particular, our proposed model employs a hexagonal grid (see Fig. 1) and temporal discretization using 5-year frames. The selection of a hexagonal grid is motivated by its efficacy in depicting neighborhood connectivity levels. This grid spans the entire area of interest, providing insights into the quantity of neighborhood connections and maintaining optimal distances between hexagon centers, as emphasized by (Burdziej, 2019). Within the grid, each cell is characterized by various land uses or growth patterns. In each time frame, the cells are categorized into five classes based on the percentage of Urbanization Density (UD).

a)

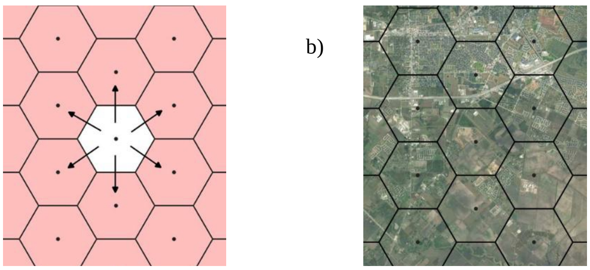

Fig. 1. (a) Scheme of the hexagonal grid used in the study; (b) Grid applied to part of the study area.

Exploring the interplay between urbanized region expansion and diverse land-cover and socio-economic factors within distinct grid cell classes constitutes the focal point of our investigation. Land-cover predictors, sourced from the National Land Cover Database (NLCD) in collaboration with the Multi-Resolution Land Characteristics Consortium (MRLC), offer valuable insights. The MRLC, a collaborative effort among Federal agencies, is dedicated to producing consistent land-cover products for the United States. Focusing on a specific geographic area and time frame, the NLCD facilitates the extraction of information pertaining to land-cover classes, including pixel count, surface value, and density. This database facilitates cross-temporal comparisons of land-cover class extensions, presenting crucial indicators for urban growth (UG). Complementing this, socio-economic predictors are derived from data provided by the United States Census Bureau, which consistently compiles annual data on various socio-economic factors such as age, gender, and race. These factors form the bedrock for our socio-economic predictors across five key domains: Population, Race, Housing, Education, and Employment.

Within each of the five Urbanization Density (UD) classes, we delineate the behavior of cells, specifically the increase in UD, through the application of a multilinear logistic model. This model, a generalization of the logistic model adapted for multiclass problems, serves as a comprehensive framework for elucidating the dynamics of UD within different urbanization contexts.

The proposed model is applied to the Houston urban area (HUA) and its adjoining counties (Montgomery, Liberty, Chambers, Galveston, Brazoria, Fort Bend, and Waller, shown in Fig. 2) and unfolds across four distinct temporal steps: 2001, 2006, 2011, and 2016. The first three time steps provide the predictors used as input in the model, while the latter three provide the UD values needed to train and validate the predicted Urbanization Density (UD) increases. Initial findings affirm the efficacy of the chosen predictors in characterizing potential urbanization within each class. Notably, land-cover predictors exhibit relevance across all classes, echoing established urban growth models that primarily hinge on land-cover variables (e.g. Herold et al., 2002). Our model advances this paradigm by incorporating the influence of socio-economic predictors, marking a notable departure.

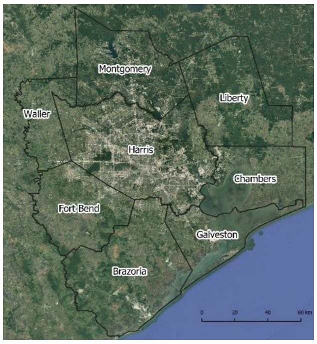

Fig. 2. Seven counties of the HUA considered as case-study.

The outcomes underscore the distinct relevance of socio-economic predictors for each urbanized class. Particularly in less urbanized cells, significant socio-economic predictors extend beyond cell boundaries, emphasizing the influence of neighboring cells. This phenomenon is pronounced due to the lower Urbanization Density corresponding to lower population density, rendering socio-economic characteristics of more populated neighboring cells particularly impactful. Taking a bottom-up approach, the subsequent research steps involve modeling local interactions among close cells and global modeling across the entire grid scale. Integrating information on the temporal variation of the infrastructure network and insights/constraints from urban planning becomes crucial in expanding the relevant predictors.

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