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Improving land loss modelling through incorporating neighborhood scale effects

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Abstract:

In complex natural-human system modeling, a first step is to examine the relationships between a dependent variable and several independent variables at their locations. Previous research has shown that neighborhood effects affect the reliability of analysis results, and rigorous scientific studies should take an extra step to examine the neighborhood effects for more accurate analysis and modeling. However, detecting the neighborhood effects of various variables and then incorporating them into a holistic modeling system poses a serious challenge because of the fundamental difference in properties between variables from the human component (e.g., census data) and variables from the natural component (e.g., landscape properties). A major issue of modeling neighborhood effects is determining appropriate neighborhood size, also known as the spatial context scale or the operational scale. It has been shown in the literature that neighborhood effects vary with the neighborhood size used to compute the effects. Thus, research on how to determine the neighborhood size that best captures the scale of operation of a phenomenon is needed to gain more confidence in the modeling results.

Semivariogram is a simple but effective tool used in geostatistics to depict spatial continuity and find the range of spatial autocorrelation. This study examines the use of semivariogram models in detecting the appropriate neighborhood size of the variables involved in land loss modeling in the Mississippi River Delta. Land loss has been an enduring and severe issue in this area for decades which eroded the shorelines and weakened the defense against storm surge and flooding. Although intensive research has investigated land loss drivers and predictions, most of them were derived solely from natural processes, such as sea-level rise, regional subsidence, and reduced sediment flows. Few studies have incorporated human-induced factors such as land fragmentation, urbanization, energy industrialization, and marine transportation, and even fewer have studied the scale effects. Therefore, this study aims to capture and quantify both natural and human factors and their neighborhood effects, to uncover the complex mechanism of land loss and provide a reliable and accurate spatiotemporal projection of land loss patterns and probability. Specifically, we conducted the study in three major steps as follows. First, we rasterized the data at various geographical scales into 1-km by 1-km using several spatial interpolation methods. Second, the semivariogram analysis of each variable was conducted to identify each variable's optimal neighborhood size. Third, we developed two land loss probability models (one incorporating neighborhood effects and the other one not) using logistic regressions to test if neighborhood effects could improve land loss modeling.

The results show that the model's overall accuracy was significantly improved from 65.43% to 74.43% after including the neighborhood variables. The neighborhood variables created for distance to the coastline, land fragmentation, oil and gas well density, percent of water area, pipeline density, and percent of the vacant house, along with variables elevation, land subsidence, distance to navigated waterways, % water area, % owner-occupied homes, % vacant houses, median household income, oil and gas well density, pipeline density, distance to urban areas, land fragmentation, hazard threats, NDVI, and % mobile homes, were identified as significant predictors of land loss probability. The analysis shows that scale effects are critical to better performance in land loss modeling. By comparing the predicted and actual land loss patterns from the year 2001 to 2011, the model incorporating neighborhood effects performed much better in reducing no-land-loss cells. The study findings add new insights into the complex land loss mechanism and help derive more accurate land loss predictions to inform coastal restoration and management decision-making.

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