Spatial modeling of urban sprawl using remote sensing images in Wuhan, China

ZENG Chen [1], LIU Yao-lin [1, 2], LIU Yan-fang [1, 2,*], ZHOU Peng[1], CUI Jiaxing[1]

(1. *School of Resource and Environment Science, Wuhan University, Wuhan 430079, China;* 2. *Key Laboratory of Geographical Information System, Ministry of Education, Wuhan University, Wuhan 430079, China*)

Abstract: Chinese cities are experiencing rapid urban expansion and being transformed into more dispersed urban form which necessitate the spatially explicit analysis and modeling of urban patterns. In our research, spatio-temporal models are developed for measuring urban sprawl in Wuhan, a typical metropolitan area in Central China using multi-temporal remote sensing images. We first extract urban built-up land from Landsat TM (1995 and 2005), ETM+ (2000) and ALOS (2010) satellite images over four periods. Object-oriented segmentation, SVM classification algorithm and post classification correction based on auxiliary data such as land use survey data and DEM are employed to improve accuracy. The interpreted built-up land, as the proxy for urban sprawl indicator and dependent variable for further analysis, has been decomposed to district level to produce a spatio-temporal dataset for modeling. Then exploratory data analysis techniques are used to identify the relationships between urban sprawl and its causative factors such as population, GDP, fixed assessment investment and revenue. After that, we perform spatial autoregressive models: mixed spatial autoregressive model (SAR), spatial error model (SEM) and spatial dublin model (SDM) to establish these relationships quantitatively. We argue that these models can be more effective in modeling urban sprawl when prior information about spatial and temporal characteristics of urban development can be applied. As a result, we devise four types of weight matrices with values of 0, 0.5 and 1 to identify the spatial and temporal relationships among these districts in these four time periods and applied them to SAR, SEM and SDM respectively. In the meantime, we also undertake the casetti distance expansion model, which employs a vector of distances to accommodate spatial heterogeneity. The distance is measured from the mean center of district weighted by their built-up area to the urban center. The results reveal that population density (PopD), non-agricultural population ratio (NAPR) and per capita GDP (PGDP) are the primary causes for urban sprawl and they are significantly positively correlated to PB in most cases. Spatial regression models with the combination of different weight matrices have produced different results and we are not attempting to recommend one than the other, since they have demonstrated their respective strengths and drawbacks. For example, SDM has higher R^2 but the log-likelihood is lower than SEM, and present inconsistent coefficient for the independent variable NAPR. However, the spatio-temporal model shows superiority than the empirical OLS regression model, not only in the goodness of fit, but also in exploring the spatio-temporal lagged effect. Comparatively, casetti distance spatial expansion produce better result with R^2 reaching 0.96. PopD, NAPR and PerGDP are positively correlated to PB, whereas population has negative effect on urban sprawl. It is concluded that 1) built-up land in Wuhan have expanded and dispersed tremendously in the past two decades and most of them are around the urban core area; 2) to curb urban sprawl, regulations or policies are not confined to the prevention of further encroachment from non-urban land to urban land, but also extend to achieve a compact

urban form; 3) spatial regression models, especially the distance-based one, show superiority in exploring the relationships between urban sprawl and its factors.

Keywords: Urban sprawl spatial modeling remote sensing Wuhan

Reference:

Braimoh A K, Onishi T, 2007, "Geostatistical techniques for incorporating spatial correlation into land use change models" *International Journal of Applied Earth Observation and Geoinformation* **9** 438–446

Bhatta B, Saraswati S, Bandyopadhyay D, 2010, "Urban sprawl measurement from remote sensing data" *Applied Geography* **30**(4) 731–740

Herold M, Goldstein N C, Clarke K C, 2003, "The spatiotemporal form of urban growth: measurement, analysis and modeling" *Remote Sensing of Environment* **86**(3) 286–302

Jat M K, Garg P K, Khare D, 2008, "Monitoring and modelling of urban sprawl using remote sensing and GIS techniques" *International Journal of Applied Earth Observation and Geoinformation* **10**(1) 26–43

Jiang F, Liu S, Yuan H, Zhang Q, 2007, "Measuring urban sprawl in Beijing with geo-spatial indices" *Journal of Geographical Sciences* **17**(4) 469–478

Kaya S, Curran P J, 2006, "Monitoring urban growth on the European side of the Istanbul metropolitan area: A case study" *International Journal of Applied Earth Observation and Geoinformation* **8**(1) 18–25

Lau J C Y, Chiu C C H, 2013, "Dual-track urbanization and co-location travel behavior of migrant workers in new towns in Guangzhou, China" *Cities* **20** 89–97

Lenney M P, Woodcock C E, Collins J B, Hamdi H, 1996, "The status of agricultural lands in Egypt: The use of multitemporal NDVI features derived from landsat TM" *Remote Sensing of Environment* **56**(1) 8–20

LeSage J P, 1999, "The Theory and Practice of Spatial Econometrics" Department of Economics, University of Toledo.

Ma Y, Xu R, 2010, "Remote sensing monitoring and driving force analysis of urban expansion in Guangzhou City, China" *Habitat International* **34**(2) 228–235

Sudhira H S, Ramachanadra T V, Jagadish K S, 2004, "Urban sprawl: metrics, dynamics and modeling using GIS" *International Journal of Applied Earth Observation and Geoinformation* **5** 29–39

Taubenb öck H, Wegmann M, Roth A, Mehl H, Dech S, 2009, "Analysis of urban sprawl at mega city Cairo, Egypt using multisensoral remote sensing data, landscape metrics and gradient analysis" International Symposium on Remote Sensing of Environment (ISRSE), Stresa, Italy.

Xiao J, Shen Y, Ge J, Tateishi R, Tang C, Liang Y, Huang Z, 2006, " Evaluating urban expansion and land use change in Shijiazhuang, China, by using GIS and remote sensing" *Landscape and Urban Planning* **75** 69–80

Yang F F, 2004, "Services and metropolitan development in China: The case of Guangzhou" Progress in Planning **61** 181–209

Yu X J, Ng C N, 2007, "Spatial and temporal dynamics of urban sprawl along two urban–rural transects: A case study of Guangzhou, China" *Landscape and Urban Planning* **79**(1) 96–109

Zha Y, Gao J, Ni S, 2003, "Use of normalized difference built-up index in automatically mapping urban areas from TM imagery" *International Journal of Remote Sensing* **24** (3) 583–594