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Dataset of Spatial Expansion of Hengyang City (2000–2017)

Hu, Z.* Wang, H. Zhao, S.

College of City & Tourism, Hengyang Normal University, Hengyang 421002, China

Abstract: Hengyang city is located in the southeastern of Hunan province of China, and it is one of the sub-centralized cities of the province. The authors constructed the Multi-factors Constrained Expanding Simulation CA (MCES-CA) using ArcGIS software, and stimulated the expansion of the main urban area in Hengyang from 2002 to 2017 by MCES-CA based on the spatial distribution of the main urban area in Hengyang in 2001, LANDSET ETM images from 2001 to 2017, SRTM 30m DEM and the urban planning data of Hengyang. It was verified that the stimulation precision of MCES-CA reaches 89.24% generally. The dataset of spatial expansion of Hengyang city includes: (1) the spatial data of the urban area in Hengyang city in 2001; (2) the stimulated expansion of the main urban area in Hengyang city from 2002 to 2017; (3) MCES-CA tool. This dataset is archived in .gdb and .tax data formats and consists of 470 data files with data size of 2 MB (compressed to one file with 177 KB).

Keywords: urban expansion; urbanization; constrained influent factors; cellular automate; Hengyang city

Dataset Availability Statement:

The dataset supporting this paper was published and accessible through the *Digital Journal of Global Change Data Repository* at: https://doi.org/10.3974/geodb.2020.04.10.V1.

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1 Introduction

China has been undergoing rapid urbanization since 2012[1]. This shows that exploring the trend of urban expansion has become the focus by linking the quantitative models or methods. Thereinto, systematic dynamic model and process-coupling model are widely employed to determine the natural features of urban expansion. The cellular automata (CA) model is one of discrete grid-based dynamic models, and is popular for its simple structures, bottom-top, and scalability.

Tobler first introduced the CA model to explore the process of urban expansion[2]. And after that, as one of the most important geoprocessing methods, CA directly contributes to the construction of geographic automata systems (GASs)[3]. Now, CA is mainly used to reveal secretes hidden in cities while simulating the process of urban expansion through com-

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***Corresponding Author:** Hu, Z., College of City & Tourism, Hengyang Normal University, fuyanghuzui@163.com
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[2] Hu, Z., Wang, H., Zhao, S. Dataset of spatial expansion of Hengyang (2000–2017) [J/DB/OL]. *Digital Journal of Global Change Data Repository*, 2020. https://doi.org/10.3974/geodb.2020.04.10.V1.

bining artificial intelligences[4–6]. For example, Yang and Li (2007)[7] developed a method to mimic the process of urban area expansion by applying multiple agents and CA. In addition, a couple of reports have tried to explore the characteristics of CA's scales by urban development and evolution, such as Changsha city[8] and Jiading district in Shanghai city[9]. In fact, urban expansion is a very complex socio-economic process. And it is easily affected by certain factors, including urban planning, geographic environments, and watersheds, etc.

Hengyang city is the sub-central city in Hunan province, with a large population, convenient transportation and specific mineral resources. However, the urbanization rate of Hengyang city over the same period is lower than that of China or Hunan province. This severely damages the socio-economic development of the whole city. It therefore is of great significance to establish a CA-based framework to simulate urban expansion with considering multiple factors, such as urban planning, landforms, and landscapes, etc. It can not only provide good suggestions for the development and construction of Hengyang city but also rich cases for other similar cities in China.

With the case of Hengyang city, this dataset was developed by a multi-factor constrained expanding simulation CA (MCES-CA) model via using geographic CA to analyze the characteristics of urban expansion from 2001 to 2017 based on the remote sensing images and several planning datasets[10]. Then, this research tests the MCES-CA model through ArcGIS software. And the whole simulation accuracy is 89.24% according to the test results.

This dataset mainly includes related files of MCES-CA model established in ArcGIS, the urban expansion process data of Hengyang city from 2001 to 2017, and the basic data extracted from remote sensing images in 2001.

2 Metadata of the Dataset

Table 1 lists the metadata of the "Dataset of spatial expansion of Hengyang (2000–2017)[11]"

Table 1 Metadata summary of the "Dataset of spatial expansion of Hengyang (2000–2017)"

Items	Description
Dataset full name	Dataset of spatial expansion of Hengyang (2000–2017)
Dataset short name	ExpansionHengyang_2001-2017
Authors	Hu, Z., College of City & Tourism, Hengyang Normal University, fuyanghuzui@163.com. Wang, H., College of City & Tourism, Hengyang Normal University, 1220976895@qq.com Zhao, S., College of City & Tourism, Hengyang Normal University, 1271733734@qq.com
Geographical region	Main urban area of Hengyang city in Hunan province, China
Year	2002–2017 Temporal resolution 1 year
Data format	.gdb, .tax Data size 177 KB (after compression)
Data files	One geodatabase file and one model toolkit in ArcToolBox
Foundations	National Natural and Science Foundation of China (41771188, 41701163); Hengyang Normal University (HIST20K01)
Data publisher	Global Change Research Data Publishing & Repository (http://www.geodoi.ac.cn)
Address	No. 11A, Datun Road, Chaoyang District, Beijing 100101, China
Data sharing policies	***Data*** from the Global Change Research Data Publishing &Repository includes metadata, datasets (in the *Digital Journal of Global Change Data Repository*), and publications (in the *Journal of Global Change Data & Discovery*). ***Data*** sharing policy includes: (1) ***Data*** are openly available and can be free downloaded via the Internet; (2) End users are encouraged to use ***Data*** subject to citation; (3) Users, who are by definition also value-added service providers, are welcome to redistribute ***Data*** subject to written permission from the GCdataPR Editorial Office and the issuance of a ***Data*** redistribution license; and (4) If ***Data*** are used to compile new datasets, the 'ten per cent principal' should be followed such that ***Data*** records utilized should not surpass 10% of the new dataset contents, while sources should be clearly noted in suitable places in the new dataset[12]
Communication and searchable system	DOI, DCI, CSCD, WDS/ISC, GEOSS, China GEOSS, Crossref

3 Materials and Research Area

3.1 Data Sources

Based on the remote sensing images (LANDSAT ETM image data)[13] from 2001 to 2017, and the image data pre-processing (mostly for the geometric image correction), the information about the spatial distribution of the urban area of Hengyang city were attracted. They were used as a benchmark for running the MCES-CA model. It is worth mentioning that while checking the simulation results, this work extracted the spatial form of the main urban area of Hengyang city from 2001 to 2017 as the corresponding inspection data.

3.2 Study Area

Hengyang city is the sub-central city of Hunan province, located in the central-south area of Hunan province, the middle reaches of Xiangjiang River and the south of Hengshan. The main urban area of Hengyang city is situated in the interior area of Hengyang basin. Because the Leishui River and Zhengshui River merge into the Xiangjiang River here, the city has formed a typical spatial pattern "three-outlets-shaping-one-river"[14]. Hengyang city has convenient transportation location and is a national-level transport hub. And it therefore is a famous industrial center in the central-south part of Hunan province.

According to the yearbook, by the end of 2017, the urbanization rate of Hengyang city reached 52.46%[14]. However, in comparison, the urbanization rate is still very low.

The urban area of Hengyang city is composed of two parts. One is the main urban area, which includes four districts, Yanfeng, Shigu, Zhuhui and Zhengxiang, respectively. The other is Nanyue district, which is located in the suburb area and far away from the main urban area. So, this dataset only focuses on the main urban area.

3.3 Methods

To more accurately simulate the main urban expansion process of Hengyang city, this dataset employs the following factors as constrained elements, which mainly includes SRTM DEM dataset with 30-m resolution, the urban area land use planning of 2001 to 2017, rivers and watersheds. By connecting object-oriented analysis methods, this work establishes multiple factors constrained expansion simulation CA (MCES-CA), and further makes the flow chart (Figure 1) for running MCES-CA in ArcGIS software.

This work sets the land use dataset of the main urban area of Hengyang city in 2001 as the initial cell dataset. Then, this work further sets the neighbor, slope, planning, and watersheds as the constrained conditions for triggering the status transformation of cells. To refine the simulation results, this work extends the Moore neighbor set to a 5×5 neighbor while determining the neighbor factor. In this work, please note that the iteration interval is set to one year and the initial threshold for transformation is one third of the overlay values of the initial cell and the constrained factor.

We run the MCES-CA model after setting the initial threshold value. We set the cells whose value is less than the transformation threshold as the non-urban area after iteration, and vice versa. Then, we increase the transformation threshold before initiating the next iteration.

It is noted that the iteration will be terminated once the corresponding simulation results are very close to the spatial form of the main urban area of Hengyang city (extracted from the remote sensing image of the related year). At the same time, the optimal threshold value for transformation can be determined.

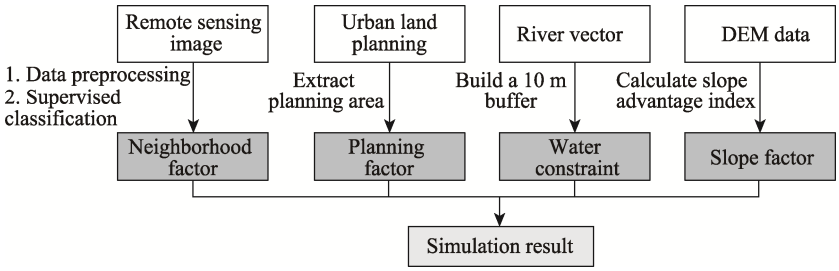

Figure 1 The running flow chart for the MCES-CA model

4 Data Results and Validation

4.1 Data Composition

The dataset includes two parts. One of them is from the MCES-CA model which can be set up and run in the ArcGIS software. The other part is the data from the simulation results of urban area expansion of Hengyang city via running MCES-CA model. And these results are archived in .tif format, including MN2002.tif, MN2003.tif, and MN2004.tif.

4.2 Data Results and Analysis

Through running the MCES-CA model, from the perspective of relative error (which is less than 5%), this dataset shows that the number of simulation cells is very close to the real status (Figure 2). Figure 3 details the variations between the simulation results and real status. In terms of Figure 3, the amounts of cells in the main urban area are increasing every year, while the non-urban area is decreasing.

According to Figure 4, from 2001 to 2017, during the expansion of the main urban area of Hengyang city, two key features are proved. One is the clear directions. The other is the definite stages.

(1) The directional features of urban spatial expansion can be clearly divided into three stages. The first one is from 2001 to 2006. At this stage, the main urban area is mainly expanded to the west. The second one is from 2006 to 2011. At this stage, the main urban area shows a trend of eastward development. The last one is from 2011 to 2017. At this stage, the development and construction of the main urban area are mostly concentrated in the north.

(2) The differences in the speed of urban area expansion can be investigated. According to the simulation results, the speed of urban area expansion shows the features of different stages. The first stage can be clearly defined as period from 2001 to 2004. At this stage, the speed of urban area expansion is very low. However, the speed of urban area expansion in the second stage (2004–2017) is high. At this stage, there are great significances for distinguishing different speeds in 2004 and 2011. From 2004 to 2006, the area of the main urban area of Hengyang city is almost twice that of before 2004. It therefore shows a rapid expansion trend. However, from 2006 to 2011, the spatial expansion of the main urban area of Hengyang city experiences slow development again. Surprisingly, from 2011 to 2017, the main urban area of Hengyang city is still at a high rate of expansion. In addition, this work employs urban dynamic expanding index (UDEI) to interpret the expansion features of the main urban area of Hengyang city during the entire research period (Figure 5). This work determines UDEI through setting one year as the related time unit. At the same time, this work connects the initial urban land use area to calculate the mean annual variation rate of UDEI. And the relevant results can reflect the corresponding variation rate of

urban expansion.

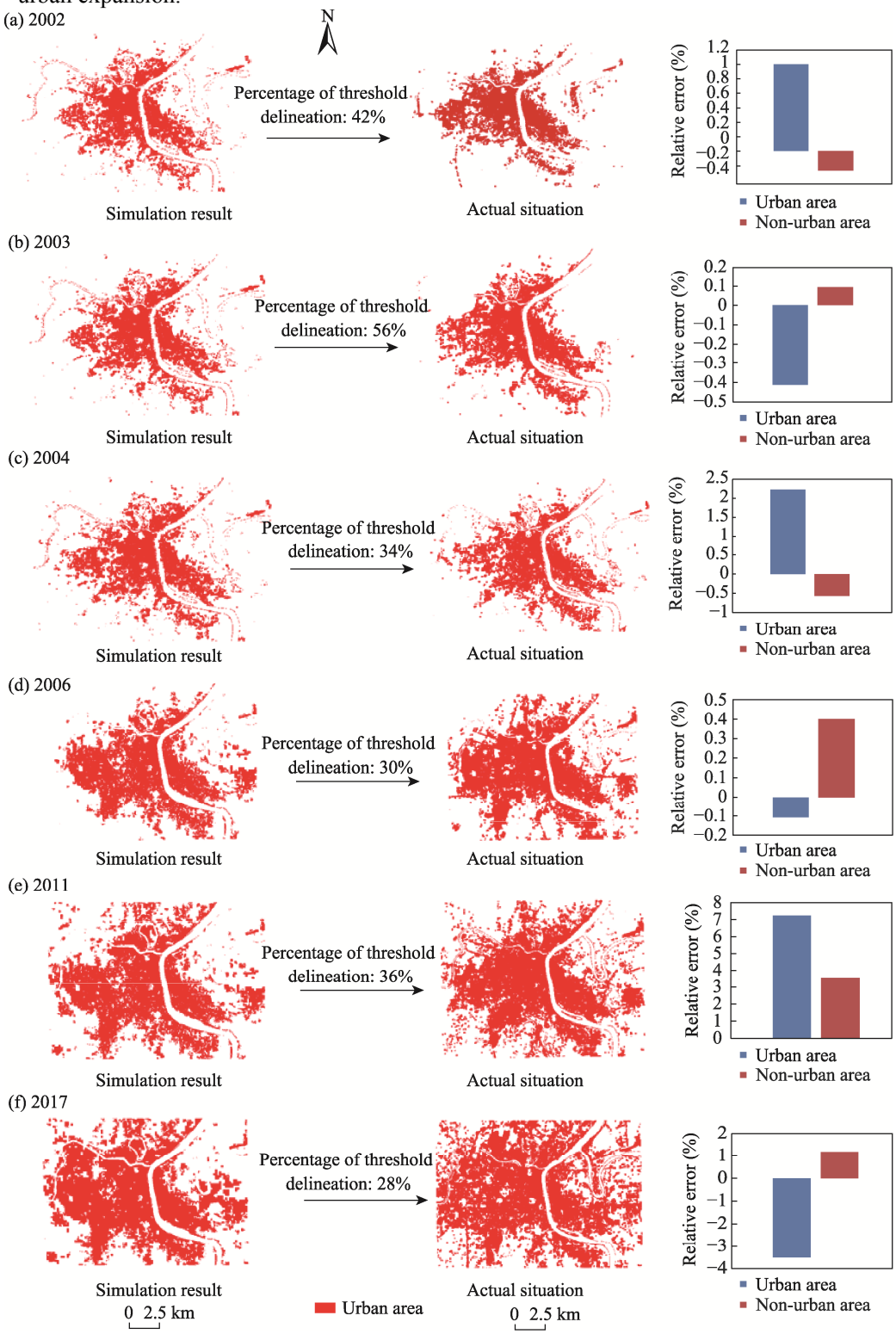

Figure 2 Comparison of the simulation results

According to the computation results of UDEI (Figure 5), the following features are observed. Firstly, from 2004 to 2005, the UDEI value of Hengyang city reaches the peak and the corresponding expansion area are the largest. After that, the UDEI value drops sharply. Secondly, from 2008 to 2009, Hengyang city resumes its rapid urban expansion. Since then, the UDEI value has involved in decreasing slowly or increasing gradually.

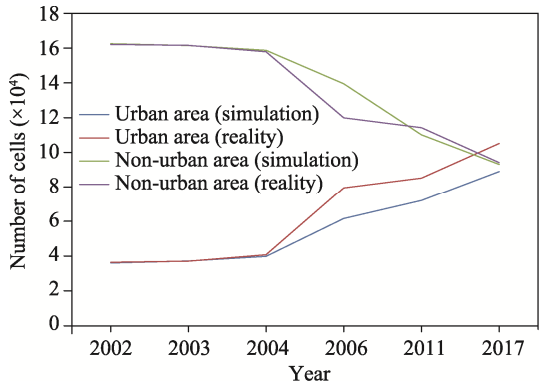

Figure 3 Comparison of the number of simulation and real cells

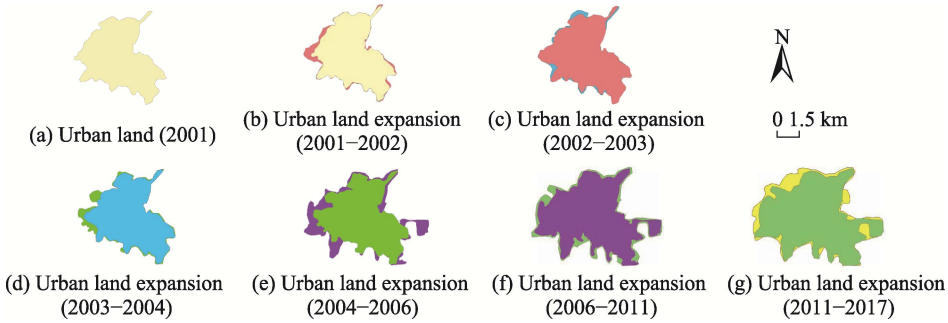

Figure 4 Maps of the expansion process of Hengyang city from 2001 to 2017

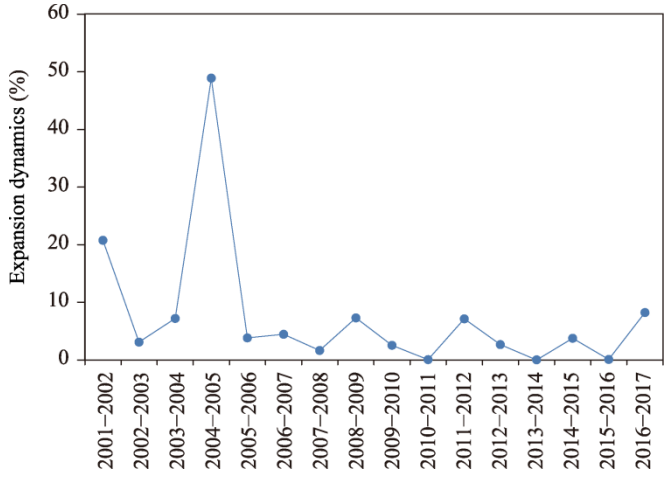

Figure 5 Annual dynamic rate of UDEI value of Hengyang city

4.3 Data Validation

In this work, the confusion matrix to verify the results of MCES-CA was used. For the confusion matrix, the simulation results of urban expansion and actual land use in Hengyang city were extracted from the remote sensing images of the corresponding year. Here, the detail simulation results of 2002, 2003, and 2004 were validated. In 2002, the overall accuracy is 89.24% and the related Kappa is 0.64. In 2003, the whole accuracy is 92.27% and the re-

levant Kappa is 0.75. In 2004, the accuracy of the MCES-CA model reaches 89.87% and the corresponding Kappa is 0.69. The value of Kappa is 0.6 to 0.8 from 2002 to 2004. The results strongly suggest that the MCES-CA model owns good performances while simulating urban expansion.

5 Discussions and Conclusions

This dataset was developed by using ArcGIS software to establish the MCES-CA model, which simulates urban expansion by using a series of remote sensing images as raw materials. At the same time, the simulation results of urban expansion of Hengyang city were obtained.

As the conclusion, the simulation accuracy of CA model is worth exploring for a long time in the future. In this study, in order to determine the performance of the MCES-CA model, we test it by comparing the simulation results with the in situ states. The test results show that the precision is less than 5%. In fact, the Kappa values of this dataset hint that the MCES-CA model is very potential in application.

Author Contributions

Hu, Z. is charged for dataset preparations and results optimal. Wang, H. establishes MCES-CA model and finishes the simulation. Zhao, S. analyzes the dataset and prepares this paper.

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