



生命游戏模型和多尺度城市动态模拟

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主要内容



- 1 生命游戏模型
- 2 地理元胞自动机
- 3 城市发展动态模拟模型
- 4 回答 “总理之问”
- 5 微观尺度城市发展模拟

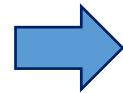
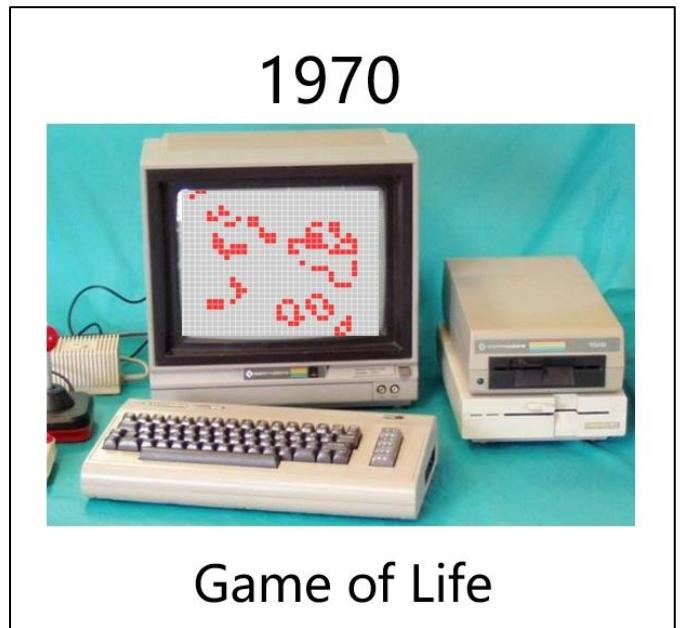


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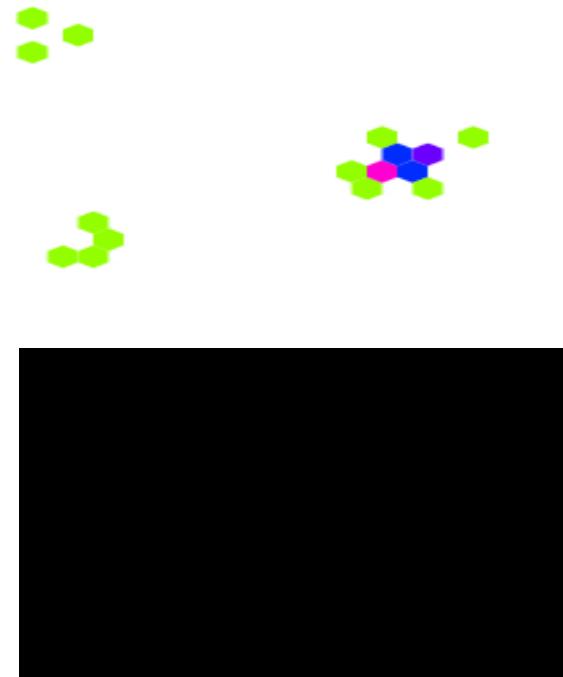


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生命游戏(Conway's Game of Life)——最简单的逻辑规则能产生复杂有趣的活动



“Life Game” of Cellular Automaton



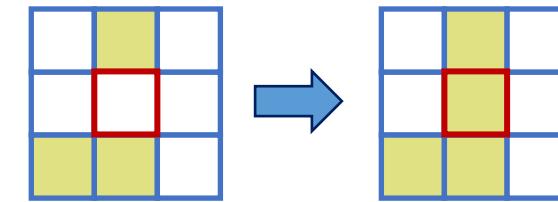
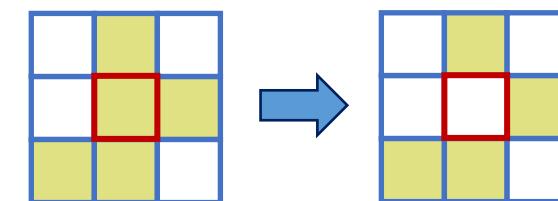
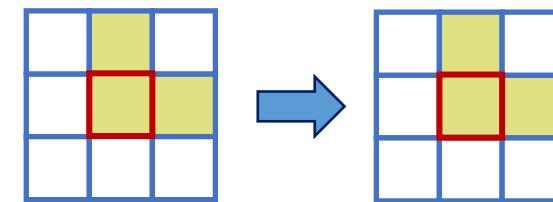
在一个二维矩形世界，每个方格居住着一个元胞，元胞在下一时刻的状态取决于其相邻八个方格中元胞的状态。

□ **生存规则**，周围有2个或者3个活着的邻居细胞，该活着的细胞将在下一时刻继续生存；

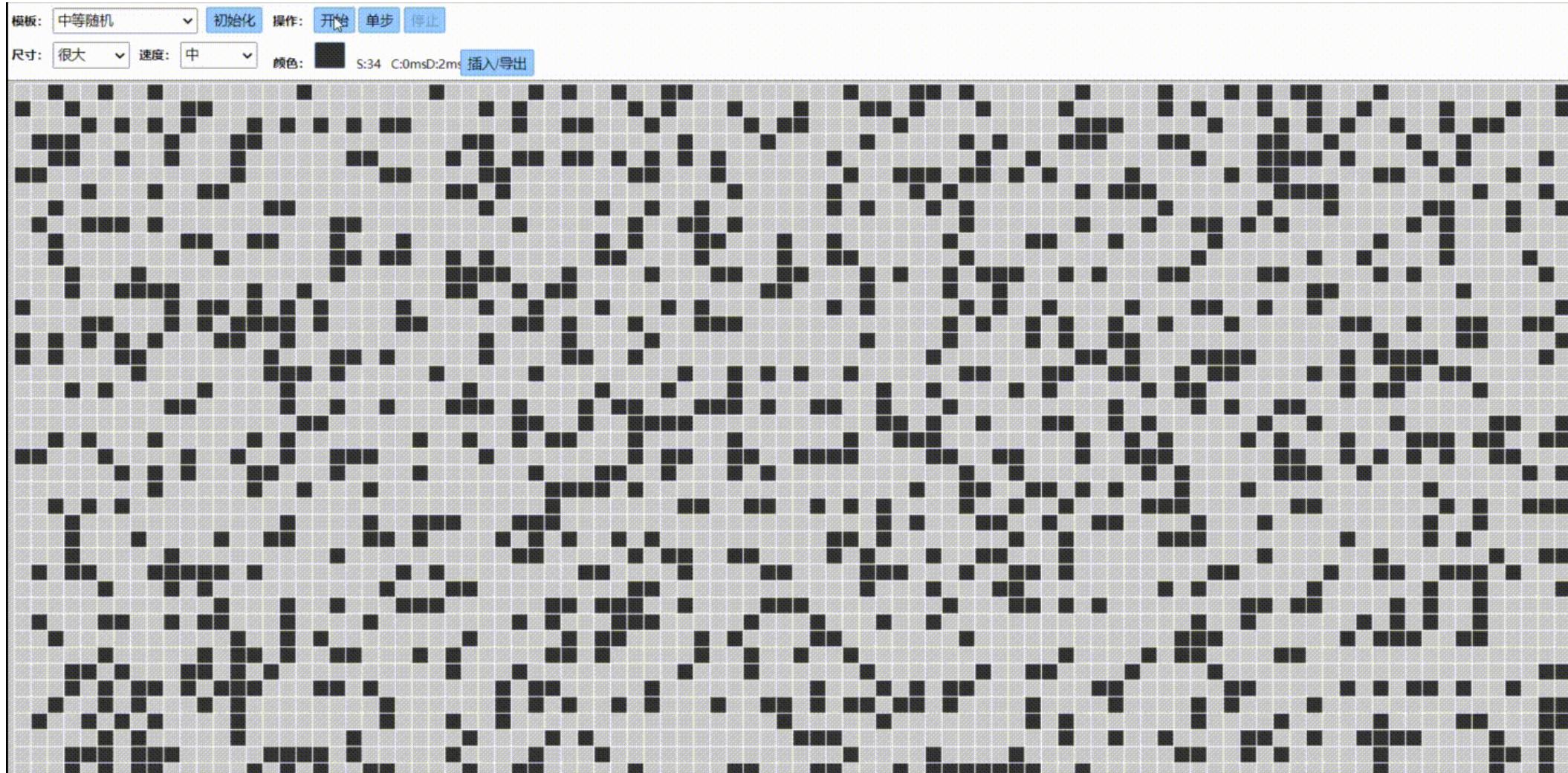
□ **死亡规则**，周围活着的细胞有3个以上，或者少于2个，该活着的细胞将在下一时刻死亡；

□ **繁殖规则**，周围存活邻居数达到3个，该死亡细胞在下一时刻被激活过来。

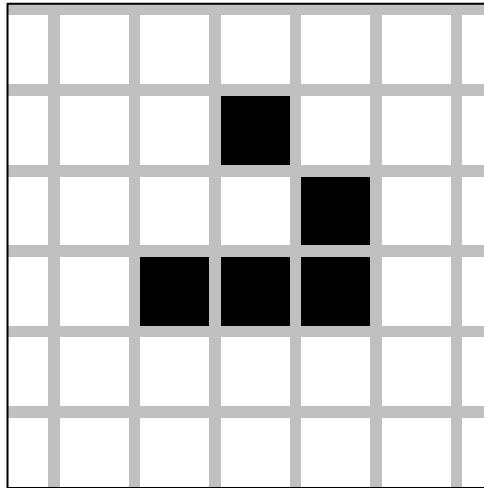
t时刻 t+1时刻



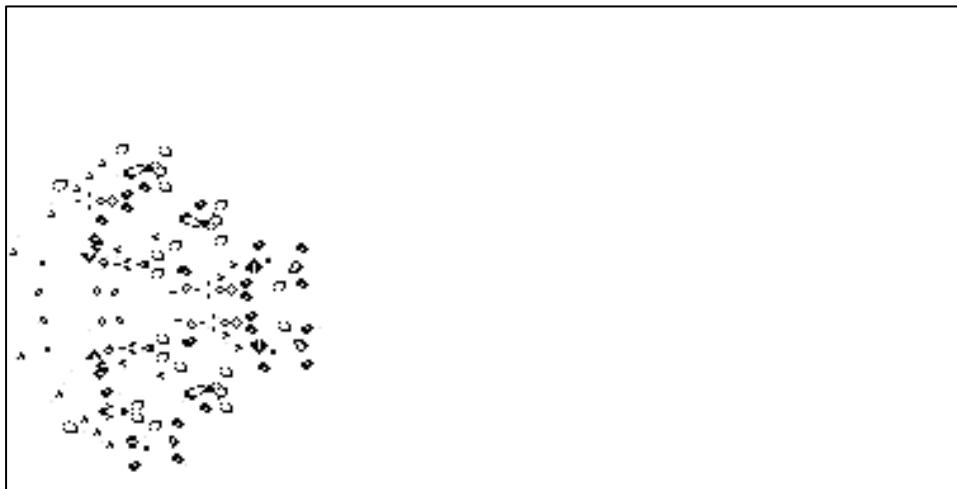
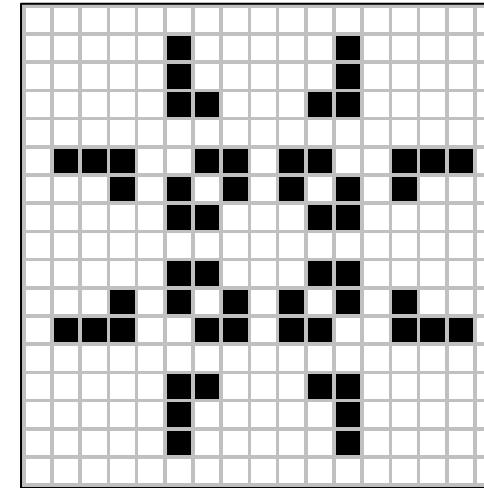
Game of life (funnyjs.com)



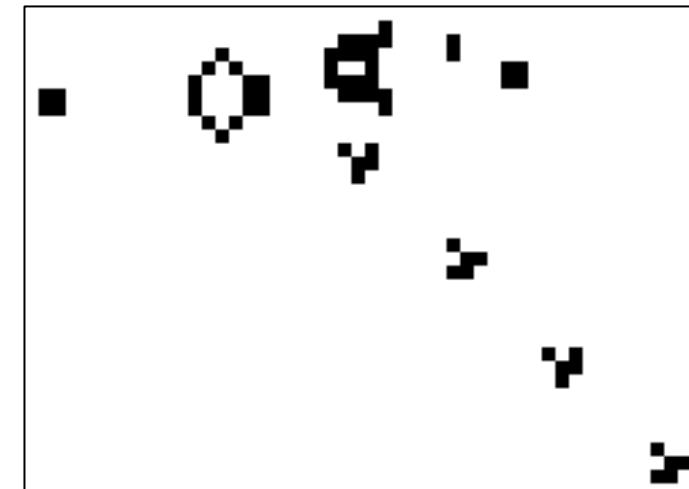
平移



脉冲星



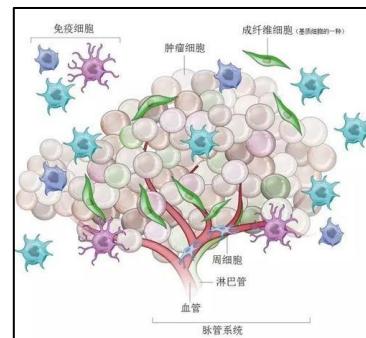
繁殖者



滑翔者

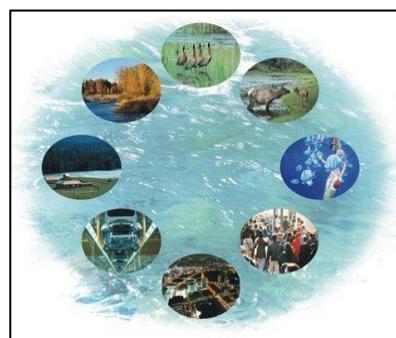
生命游戏模型是一种经典的元胞自动机模型（Cellular Automata, CA）

CA模型的应用



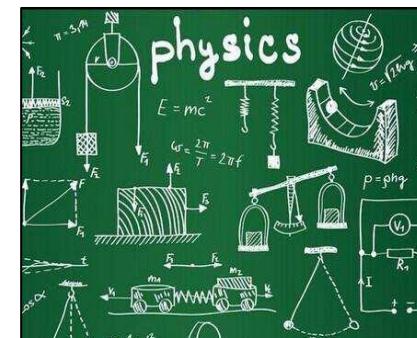
生物学

肿瘤细胞的增长机理和过程模拟等



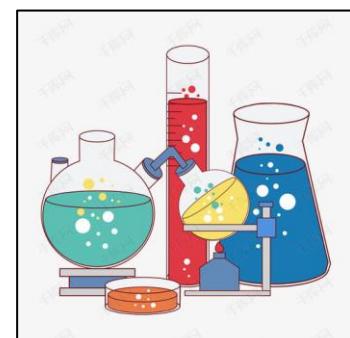
生态学

生物群落的扩散模拟等



物理学

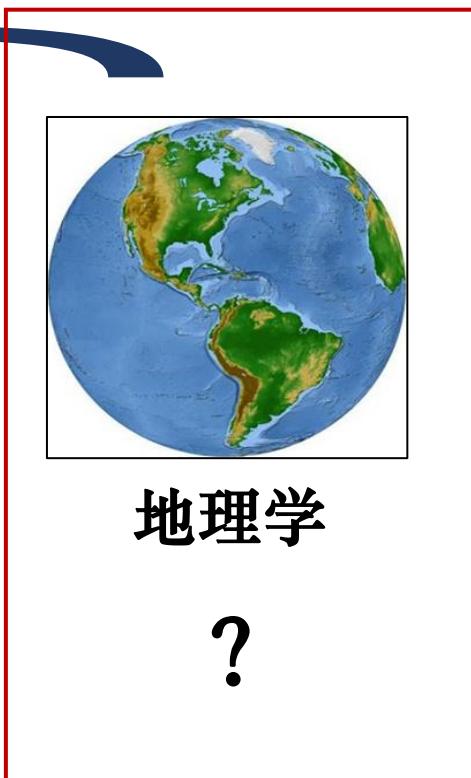
用于磁场、电场等场、热扩散、热传导等的模拟



化学

油污扩散、工厂周围废水、废气的扩散等过程的模拟

...



地理学

?



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2.1 地理元胞自动机

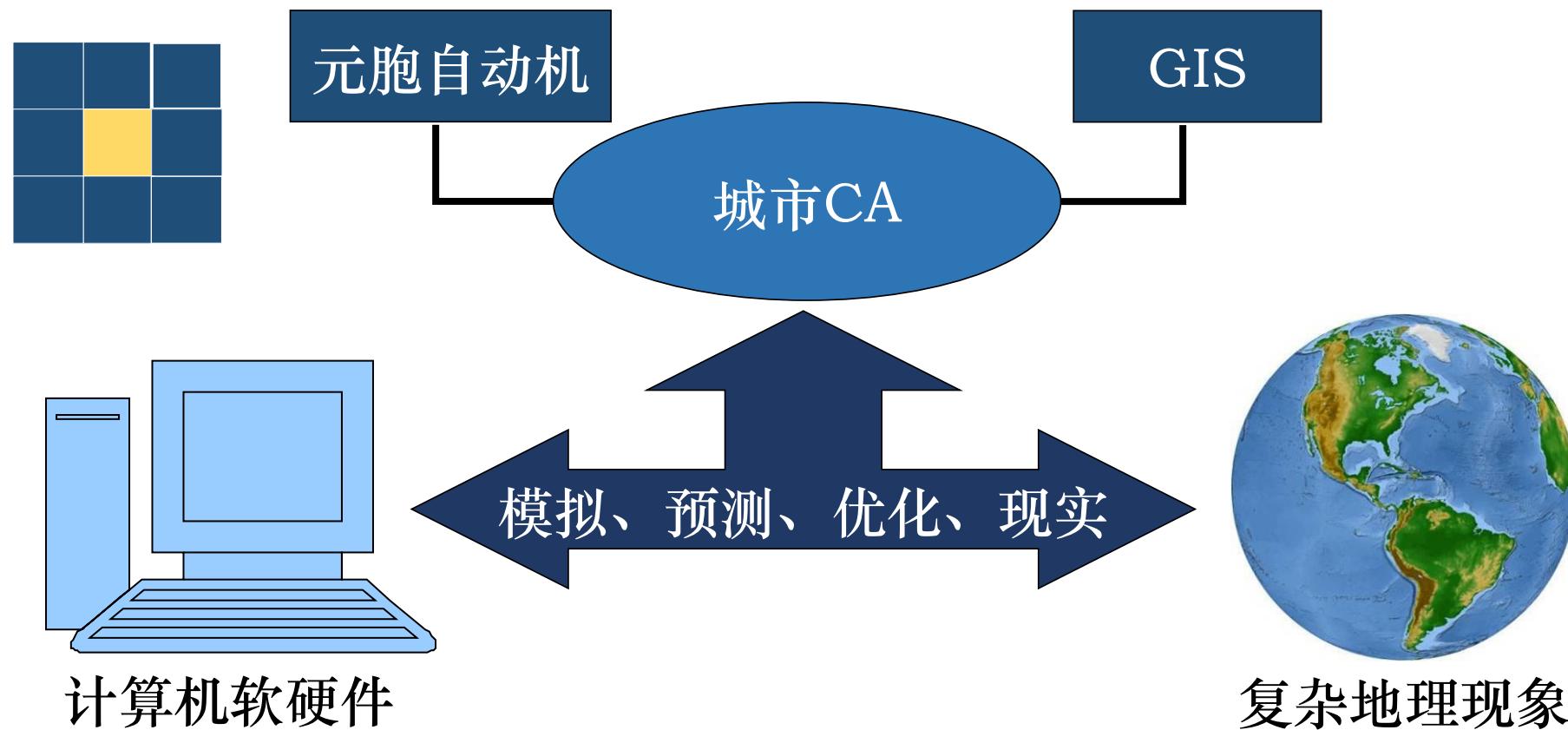


- 元胞自动机 (Cellular Automata, CA) 是一种时间、空间、状态都离散的模型，具有强大的空间建模和计算能力，能够模拟具有时空特征的复杂动态系统；
- 许多地理现象属于典型的动态复杂系统，具有开放性、动态性、自组织性、非平衡性等耗散结构特征。例如，城市系统的发展受到自然、社会、经济、文化、政治等多种因素的影响，因而其行为过程具有高度的复杂性。

2.1 地理元胞自动机

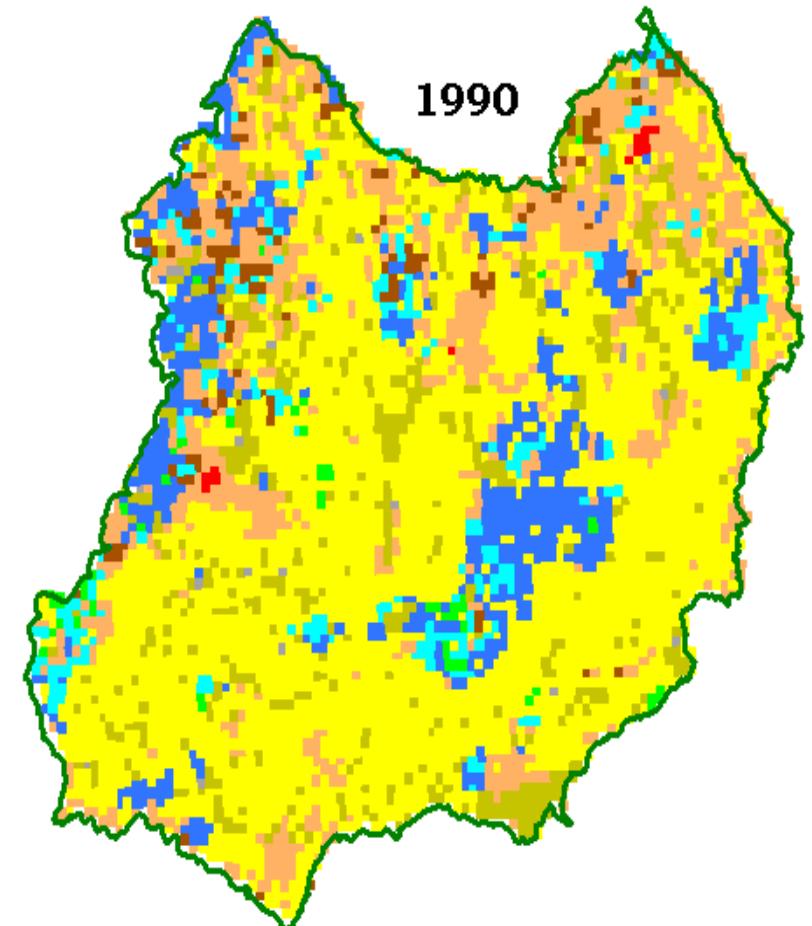


许多学者将元胞自动机引入地学研究中，以解决复杂**地理学**问题，如城市发展演变、土地利用变化等，取得了丰硕的研究成果。



□ 元胞自动机在地理学中的意义

- ✓ 模拟和认识复杂资源环境系统行为的强有力方法
- ✓ 发现规律，验证现有理论
- ✓ 寻找更有效利用土地资源的途径
- ✓ 与其它模型耦合
- ✓ 促进GIS理论和方法的发展



2.1 地理元胞自动机

口 基于地理CA的城市模拟流程

- ✓ 数据预处理
- ✓ 制定转换规则
- ✓ 获得模拟结果

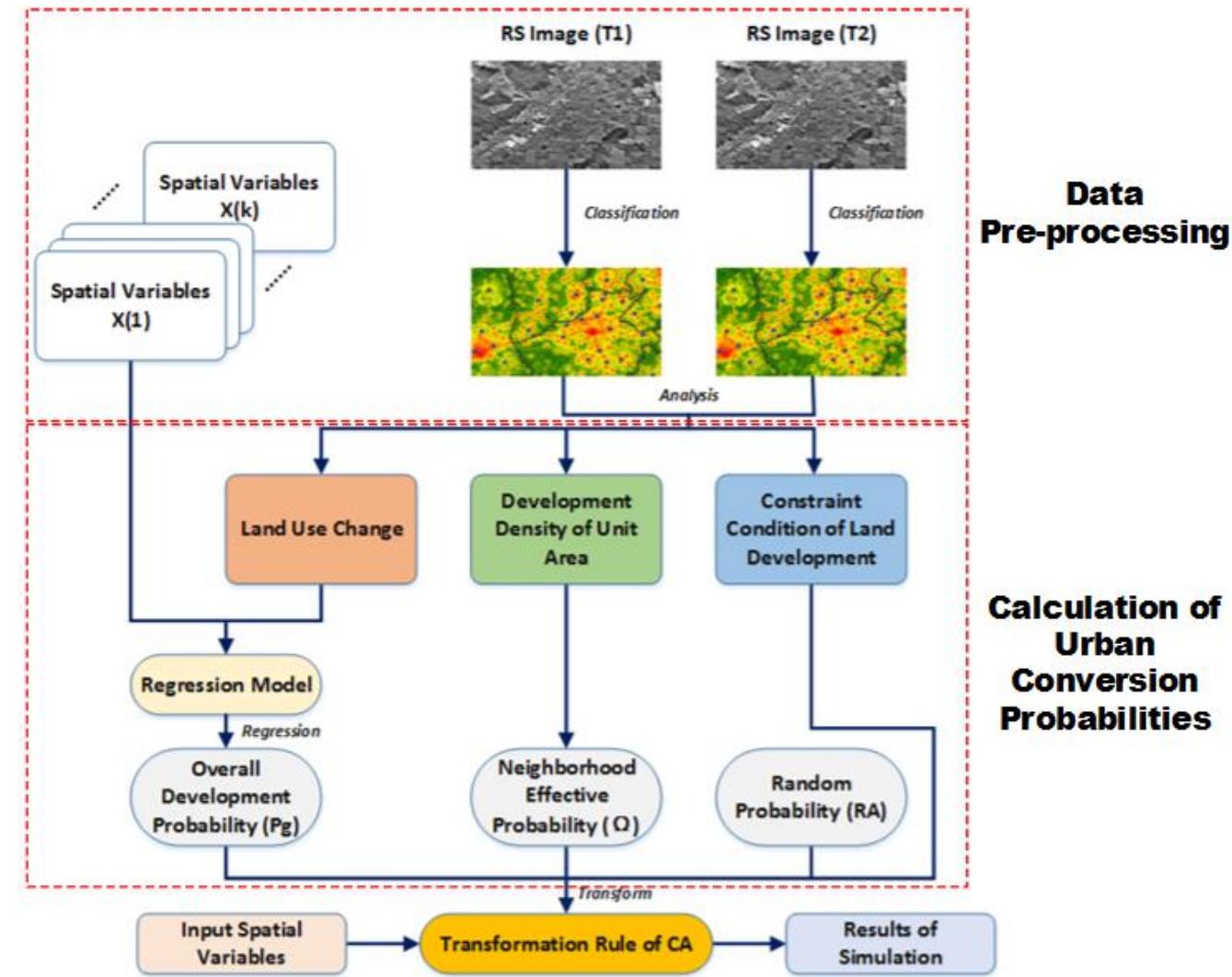
城市增长概率

$$P_{ij}^t = r \times pg_{ij} \times \Omega_{ij}^t \times \text{con}(S_{ij}^t)$$

随机因素
训练概率
邻域影响
限制因素

状态更新方式

$$S^{t+1} = \begin{cases} undevelop & \text{if } P_{ij}^t < \text{Threshold} \\ develop & \text{if } P_{ij}^t > \text{Threshold} \end{cases}$$



2.1 地理元胞自动机

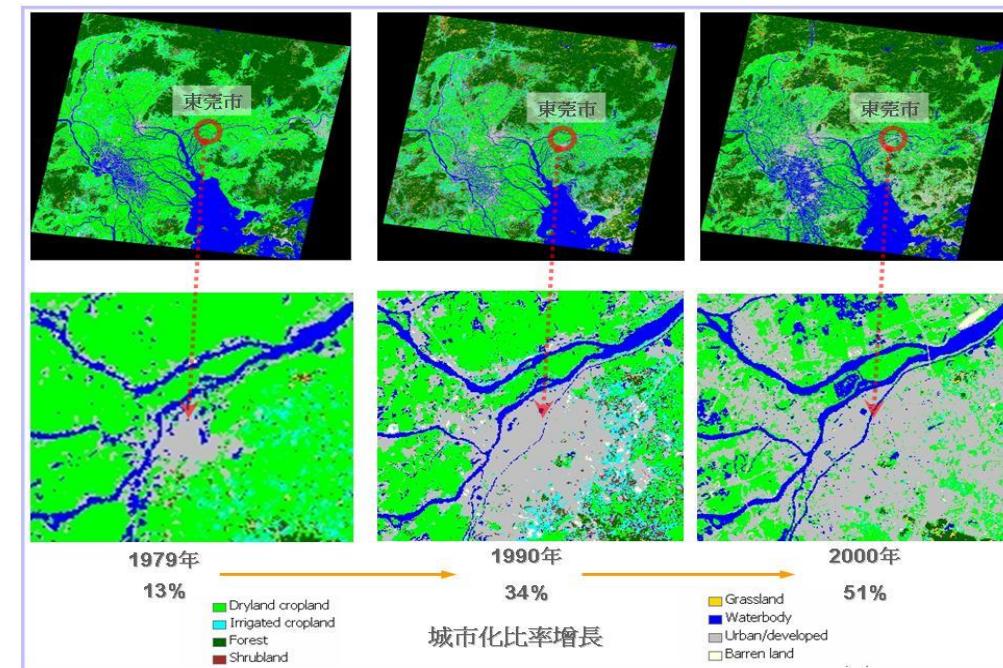
□ 城市受哪些要素驱动而变化?

仅仅依靠邻域相互作用的CA并不能较好的模拟真实地理过程，如城市增长。因此，城市CA建模需要给予模型以合适的地理知识与规则。

空间驱动变量

地形?
交通?
热点?
水文?
地质?
.....

因果关系



2.1 地理元胞自动机



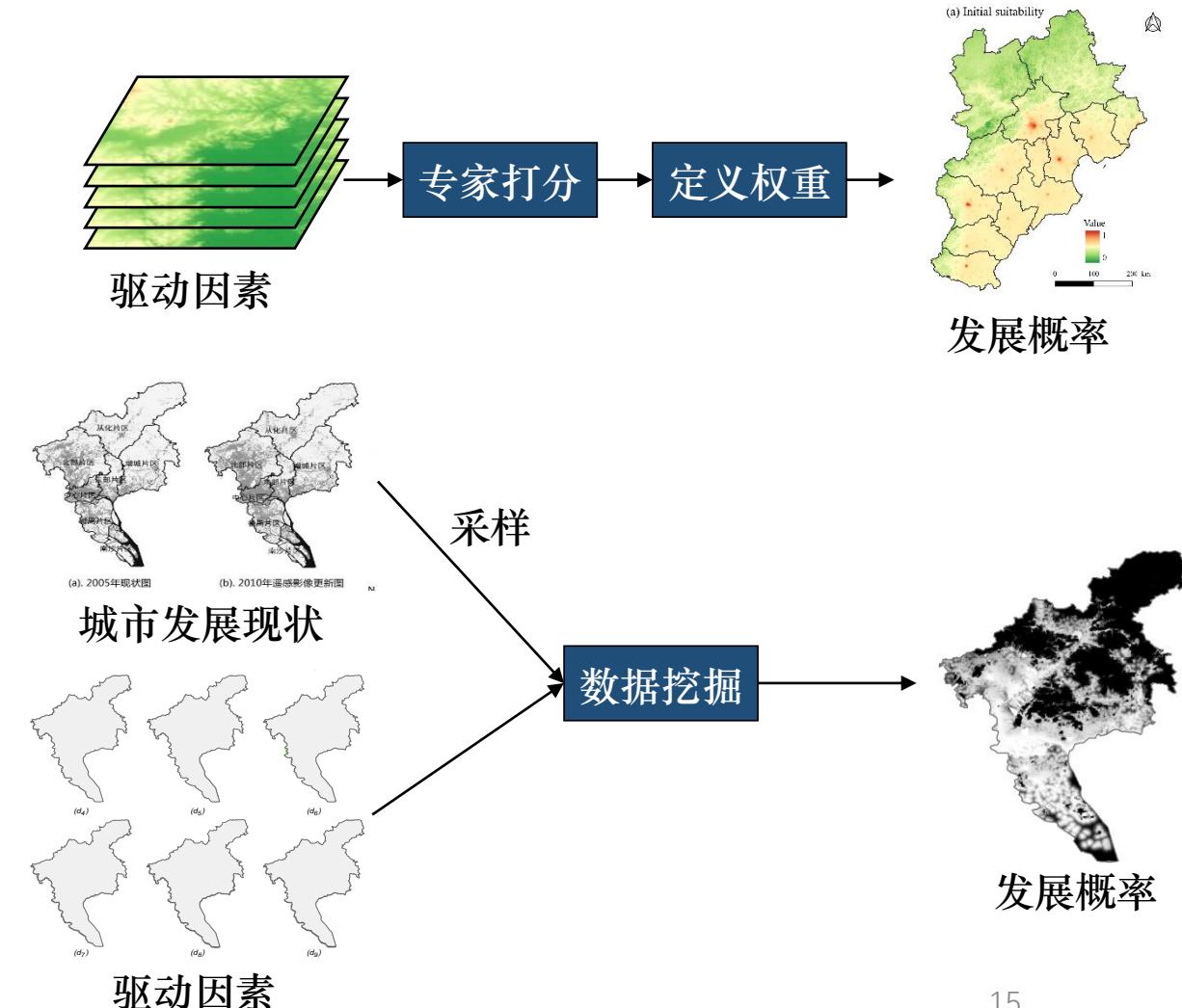
口 如何挖掘转换规则?

✓ 方式一：专家定义法

专家根据城市发展特点，**定义每个空间要素的作用力大小**（如AHP），并确定增长方式，进而利用CA自组织过程完成模拟。

✓ 方式二：数据训练法

利用一段**历史变化**，通过抽样，利用**数据挖掘**的方法训练转换规则，挖掘的方法有很多种。

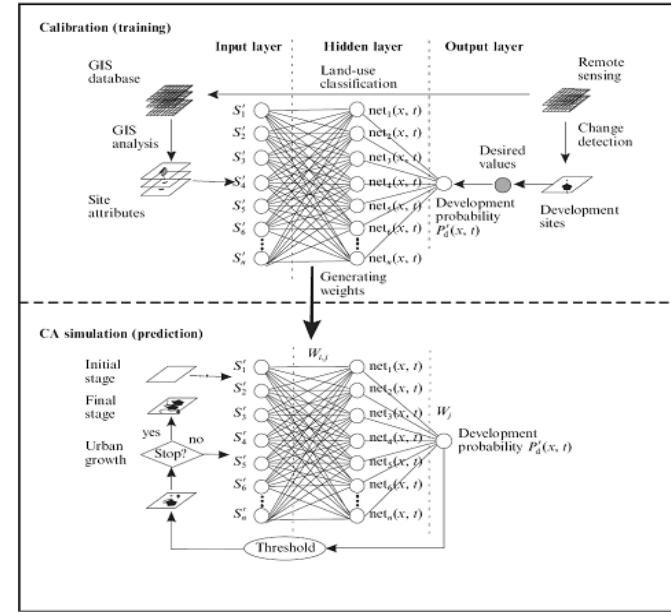


2.1 地理元胞自动机

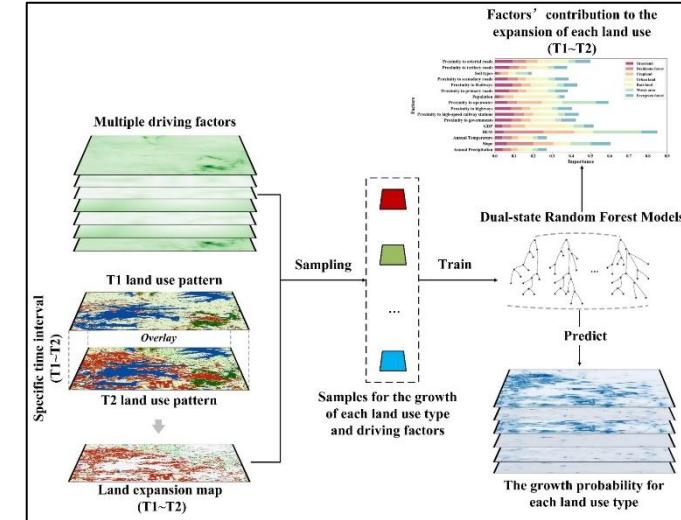


口 如何挖掘转换规则?

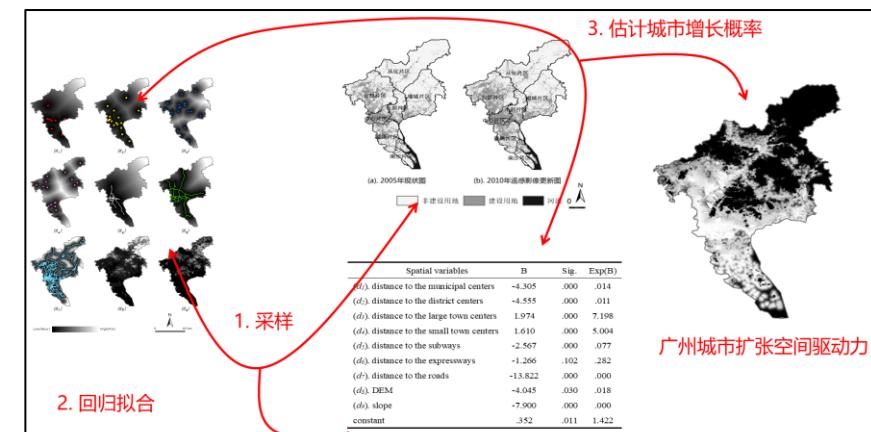
- ✓ 基于逻辑回归的CA模型
- ✓ 基于神经网络的CA模型
- ✓ 基于随机森林的CA模型
- ✓ 基于遗传算法的CA模型
- ✓ 基于蚁群智能的CA模型
- ✓ 基于核学习机的CA模型
- ✓ 基于案例推理的CA模型



神经网络CA



随机森林CA

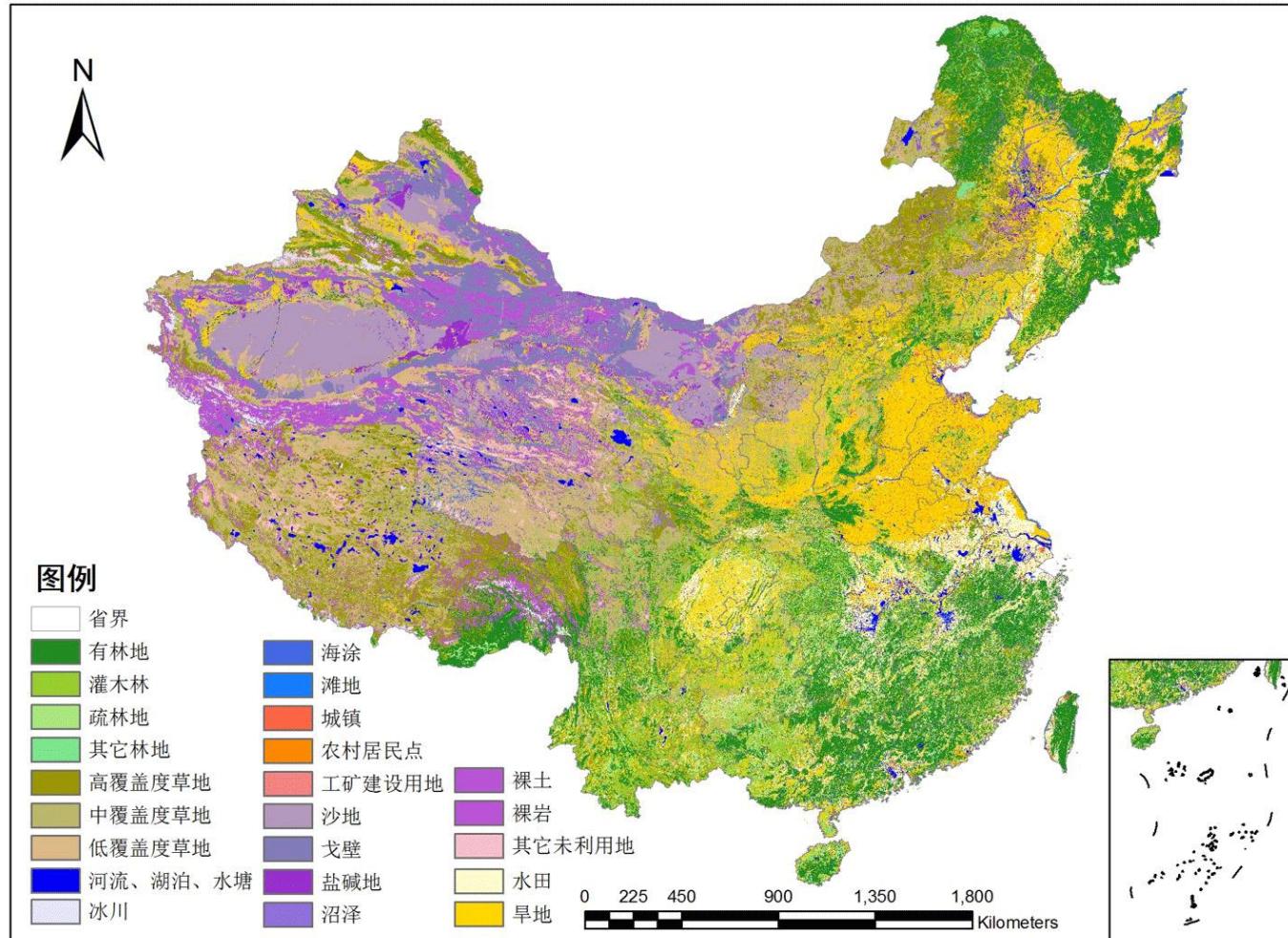


逻辑回归CA

2.2 | 地理模拟时空数据 – 多类型土地利用数据



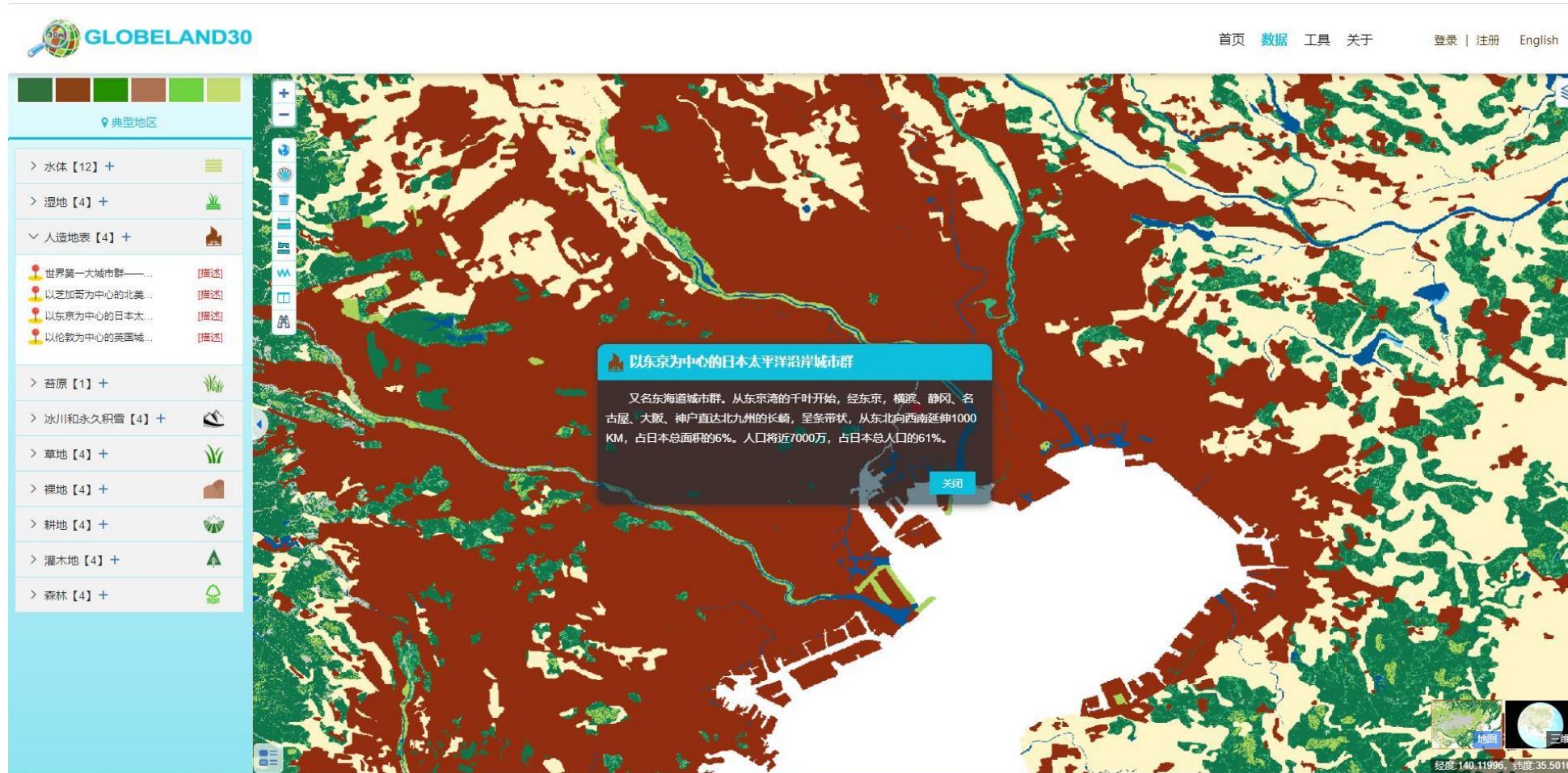
□ 全国多期土地利用现状遥感监测数据 (空间分辨率: 1公里) 1980年中国土地利用类型空间分布图



2.2 地理模拟时空数据 – 多类型土地利用数据

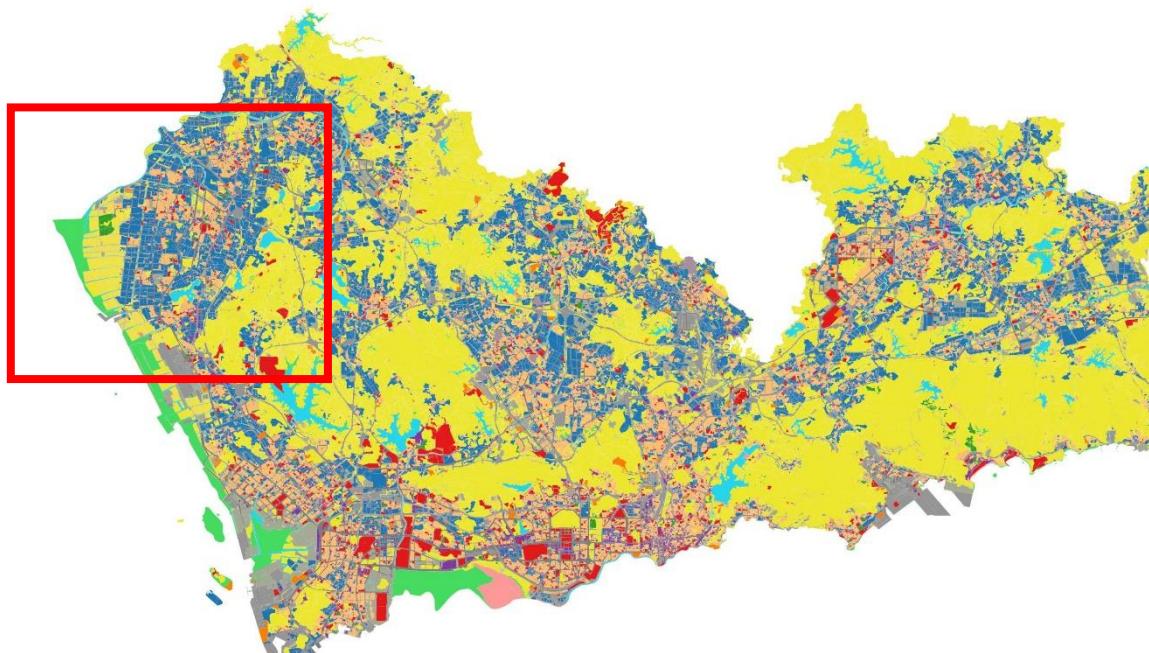


□ 全球30米地表覆盖产品 (GlobalLand30)



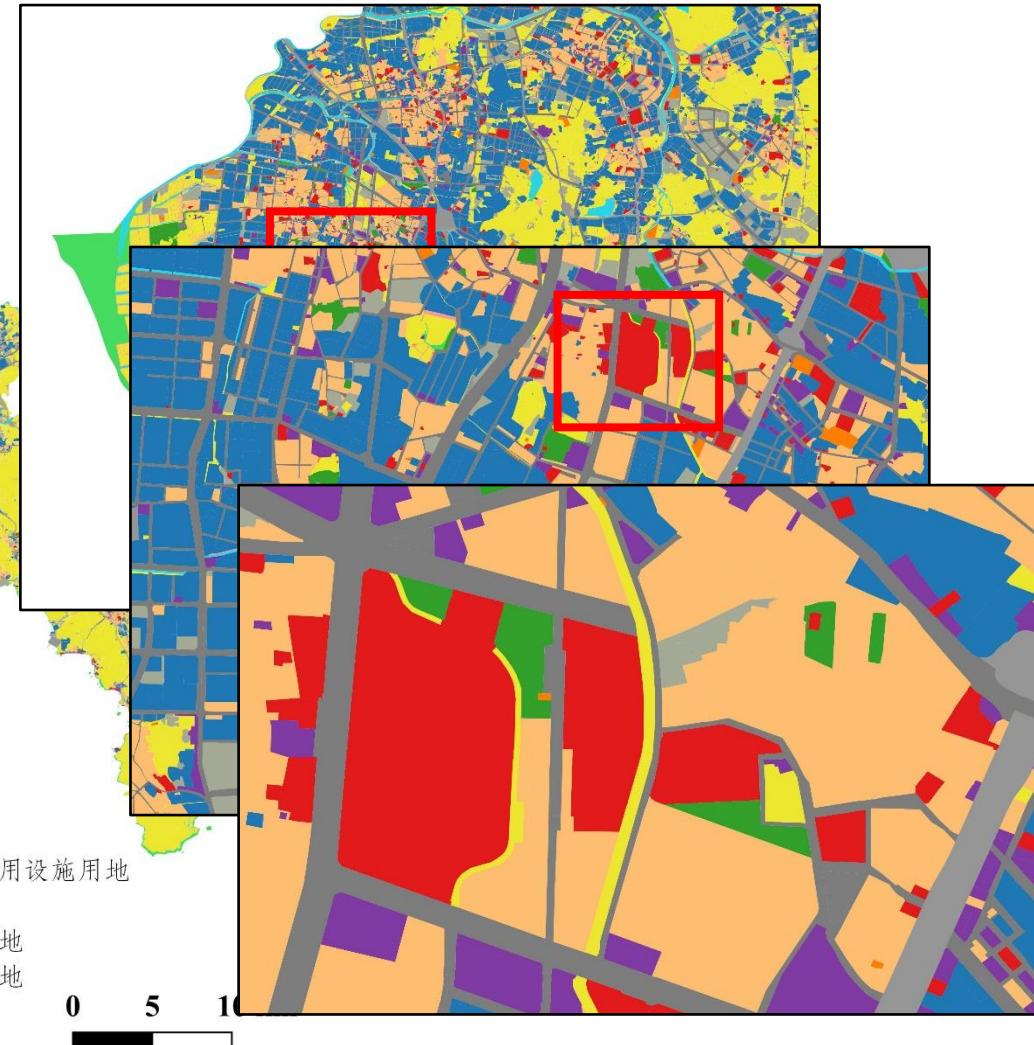
GlobalLand30: <http://www.globallandcover.com/>

□ 土地利用矢量地块数据 (深圳市)



图例

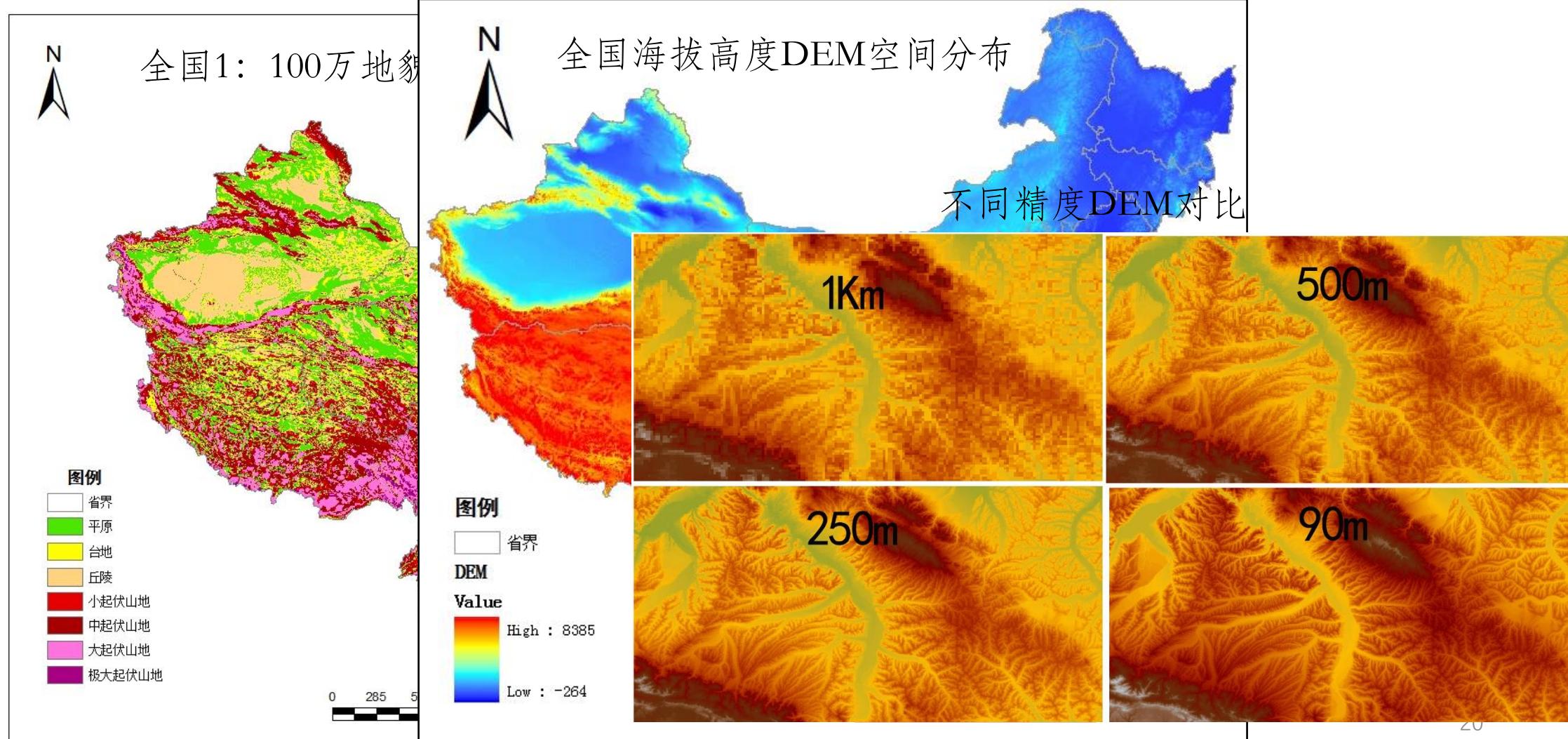
保护区	道路交通用地
道路	居住用地
工业用地	绿地
公共管理与公共服务用地	农用地
公用设施用地	商业用地



2.3 地理模拟时空数据 – 相关驱动因素数据



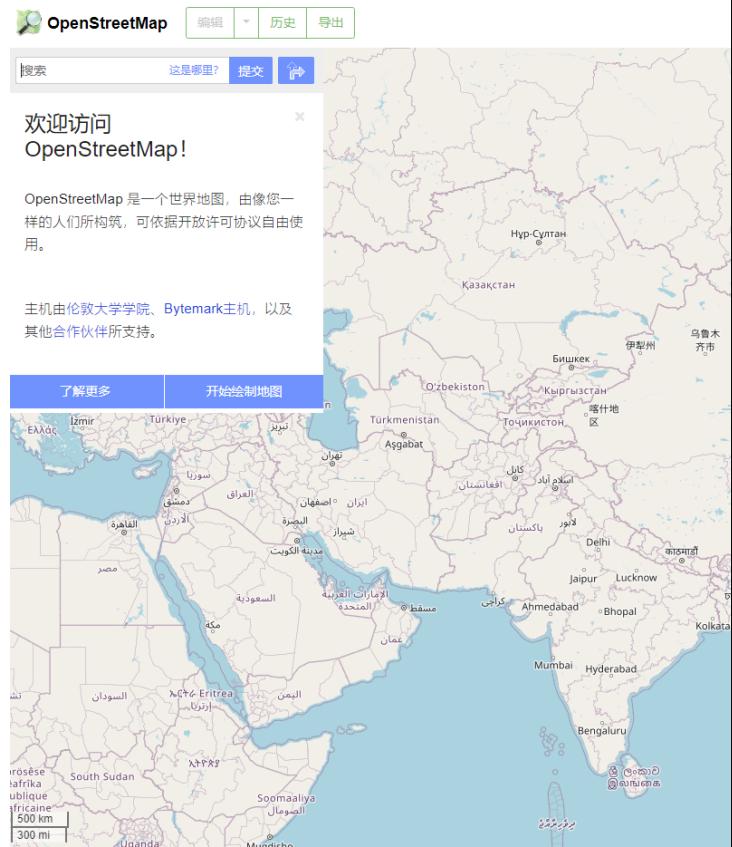
□ 地形地貌数据



2.3 地理模拟时空数据 – 相关驱动因素数据

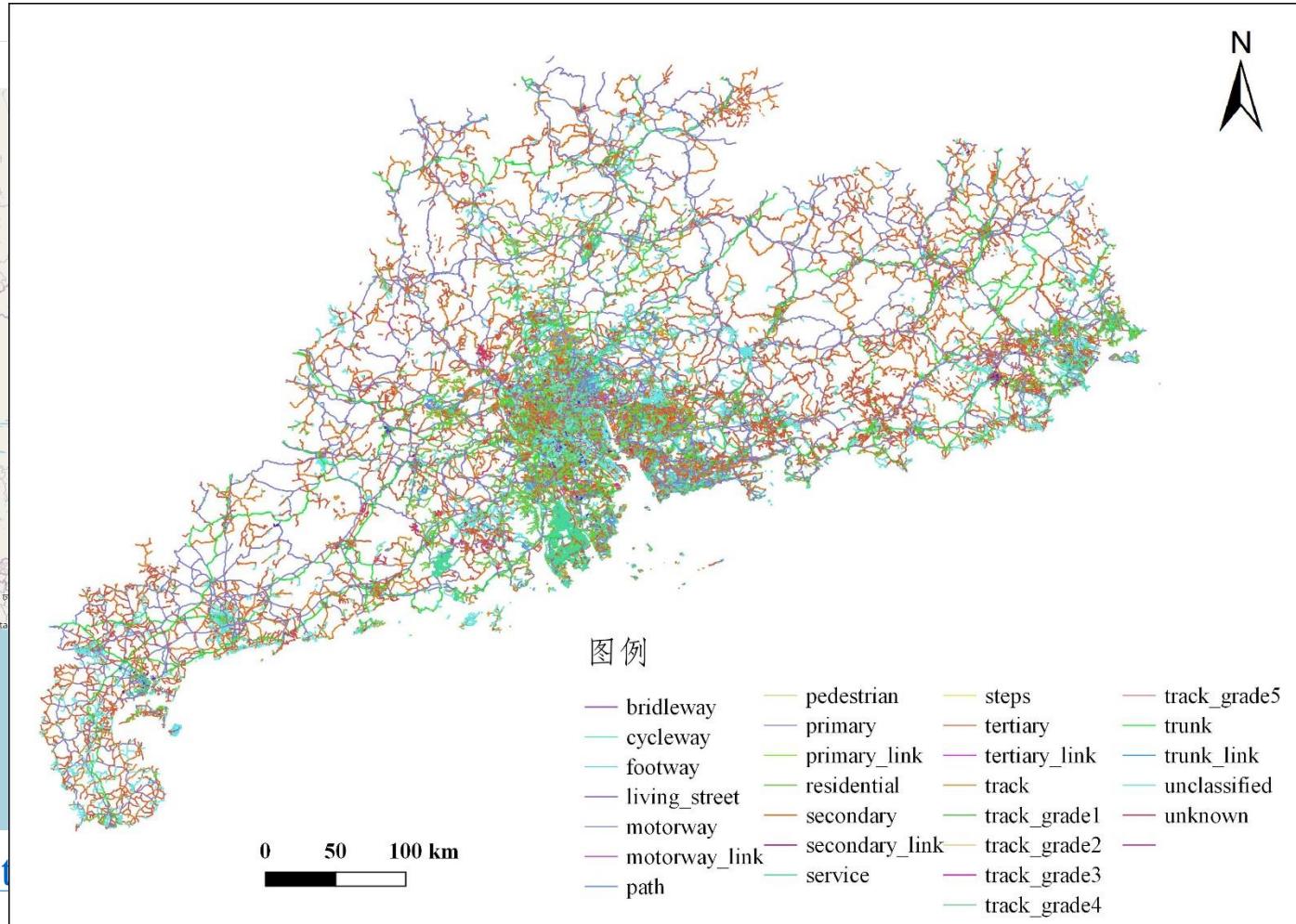


□ 交通路网数据



OSM路网 <https://www.openstreetmap.org>

广东省OSM路网空间分布



2.3 地理模拟时空数据 – 相关驱动因素数据



□ 社会经济数据——POI数据

□ 来源：高德APP

□ 包括：汽车服务、汽车销售、汽车维修、摩托车服务、餐饮服务、购物服务、生活服务、体育休闲服务、医疗保健服务、住宿服务、风景名胜、商务住宅、政府机构及社会团体、科教文化服务、交通设施服务、金融保险服务、公司企业、道路附件设施、地名地址信息、公共设施，**共20个大类。**

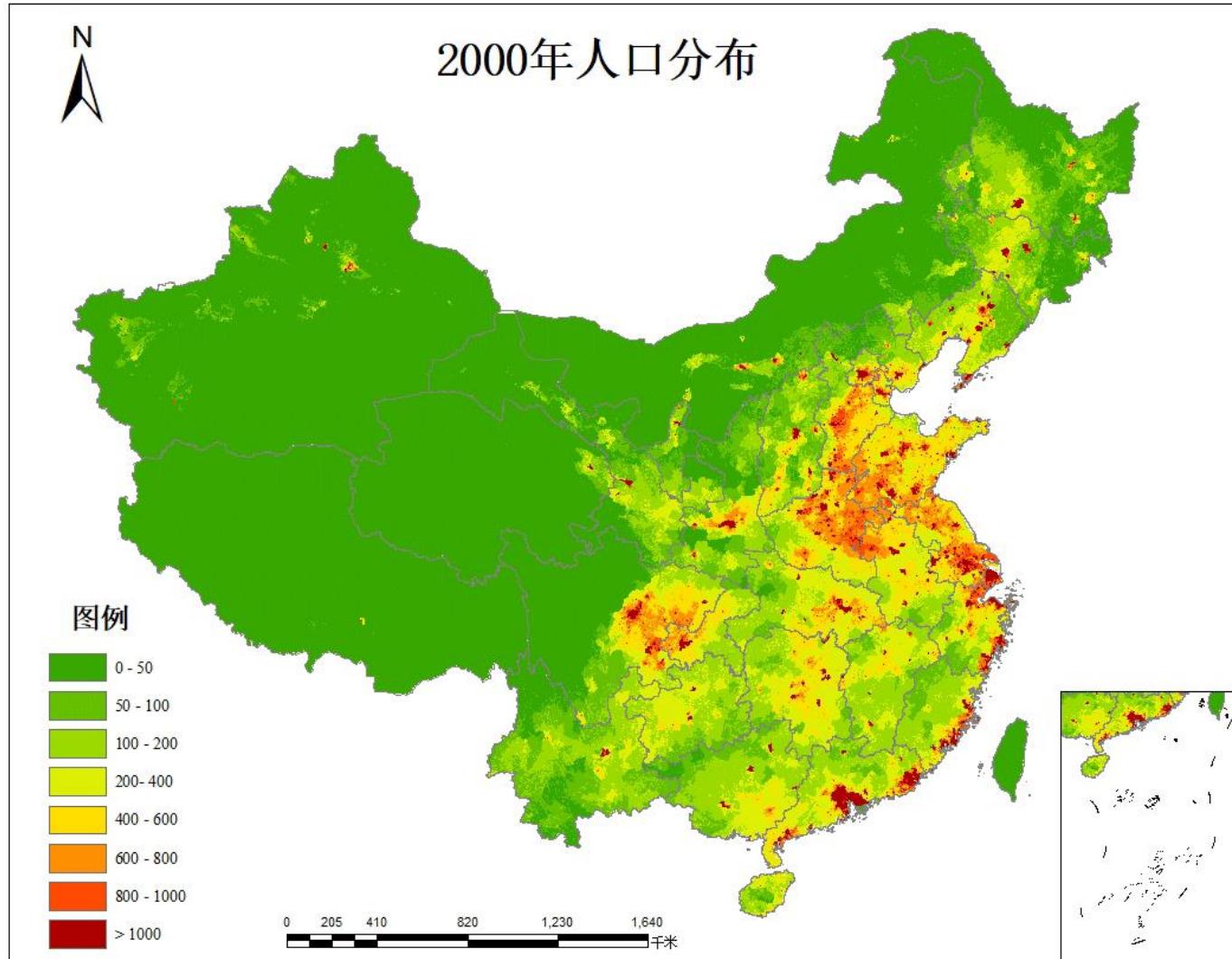
广东省POI共计 734,6810条数据

name	type	city	district	gpsx	gpsy↓
阳江市豫丰投资有限公司	公司企业;公司;公司 金融保险服务;金融保险服务机构;金融保险机构	阳江市	江城区	111.961108049043	21.878326305384↓
阳江市嘉润投资发展有限公司	公司企业;公司;公司 金融保险服务;金融保险服务机构;金融保险机构	阳江市	江城区	111.96207839298401	21.8804297805103↓
官寨岭	地名地址信息;自然地名;山	潮州市	饶平县	116.968987395778	23.984083639735104↓
野湖顶	地名地址信息;自然地名;山	梅州市	蕉岭县	116.24370106504	24.823625947718202↓
老赵轮胎	汽车服务;汽车配件销售;汽车配件销售	韶关市	南雄市	114.71838478418199	25.300483251672897↓
白叶峰	地名地址信息;自然地名;山	梅州市	兴宁市	115.560464847738	24.6383975961982↓
342省道	地名地址信息;交通地名;道路名	韶关市	南雄市	114.71841076109101	25.300423222434603↓
车海洋6元自助洗车	汽车服务;洗车场;洗车场	佛山市	顺德区	113.19203637419201	22.9026281246295↓
老罗油站	沙县小吃(科技中路)	东莞市	0	113.779824280196	23.09335074288602↓
下郭加油站	国芳照相馆(科技东路)	东莞市	0	113.784775149912	23.0948914633889↓
广祥加油站	停车场	东莞市	0	113.77141242504801	23.0897011184509↓
金贵加油站	停车场(华瑜百货东南)	东莞市	0	113.77259837242599	23.090180073558503↓
中国石油加	五洲电子科技有限公司	东莞市	0	113.7743142428	23.0914173074619↓
中国石化加	东莞市五株电子科技有限公司(旁通行设施;临街院门;临街院门)	东莞市	0	113.774905289508	23.091329969436497↓
中国石油加	东莞市五株电子科技有限公司(旁通行设施;临街院门;临街院门)	东莞市	0	113.77276164778499	23.0901962295125↓
洗车超人安	东莞群发公寓	东莞市	0	113.76895852808201	23.0891680968284↓
中国石油加	恒发批发部	东莞市	0	113.777236472387	23.091935287976398↓
中国石油加	上海灌汤包(石碣专卖店)	东莞市	0	113.777123240243	23.09225206494304↓
二运加油站	品翔电子塑胶制品东莞有限公司(旁通行设施;临街院门;临街院正门)	东莞市	0	113.77372026293999	23.0906030315275↓
街边油站	怡毅便利店	东莞市	0	113.77409390228998	23.0907463584622↓
茂化福兴油站	邑兴激光补焊	东莞市	0	113.765525514827	23.0875029957758↓
电脑洗车	鸿盛生活超市	东莞市	0	113.772849770229	23.090606145735503↓
中石油碧辟博	悦湘居菜馆	东莞市	0	113.768913488328	23.0887102497766↓
中国石油大安	卡地尔·水箱专家	东莞市	0	113.773672181327	23.0905799917061↓
	振宏大水磨加工	东莞市	0	113.778422629629	23.0928722677966↓
	鸿发日用品店	东莞市	0	113.76606127912201	23.0875903694906↓
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	停车场	东莞市	0	113.77867795320499	23.0952945554601↓
	锋腾	东莞市	0	113.77978119322701	23.0934046679595↓
	科怡环保设备科技有限公司	东莞市	0	113.767081718864	23.088455814934804↓
	中城	东莞市	0	113.76349875313801	23.0867318579646↓
	东莞市石碣宏溢丝印器材商店	东莞市	0	113.77463083052	23.0909388416654↓
	康城五金模具配件	东莞市	0		

2.3 | 地理模拟时空数据 – 相关驱动因素数据



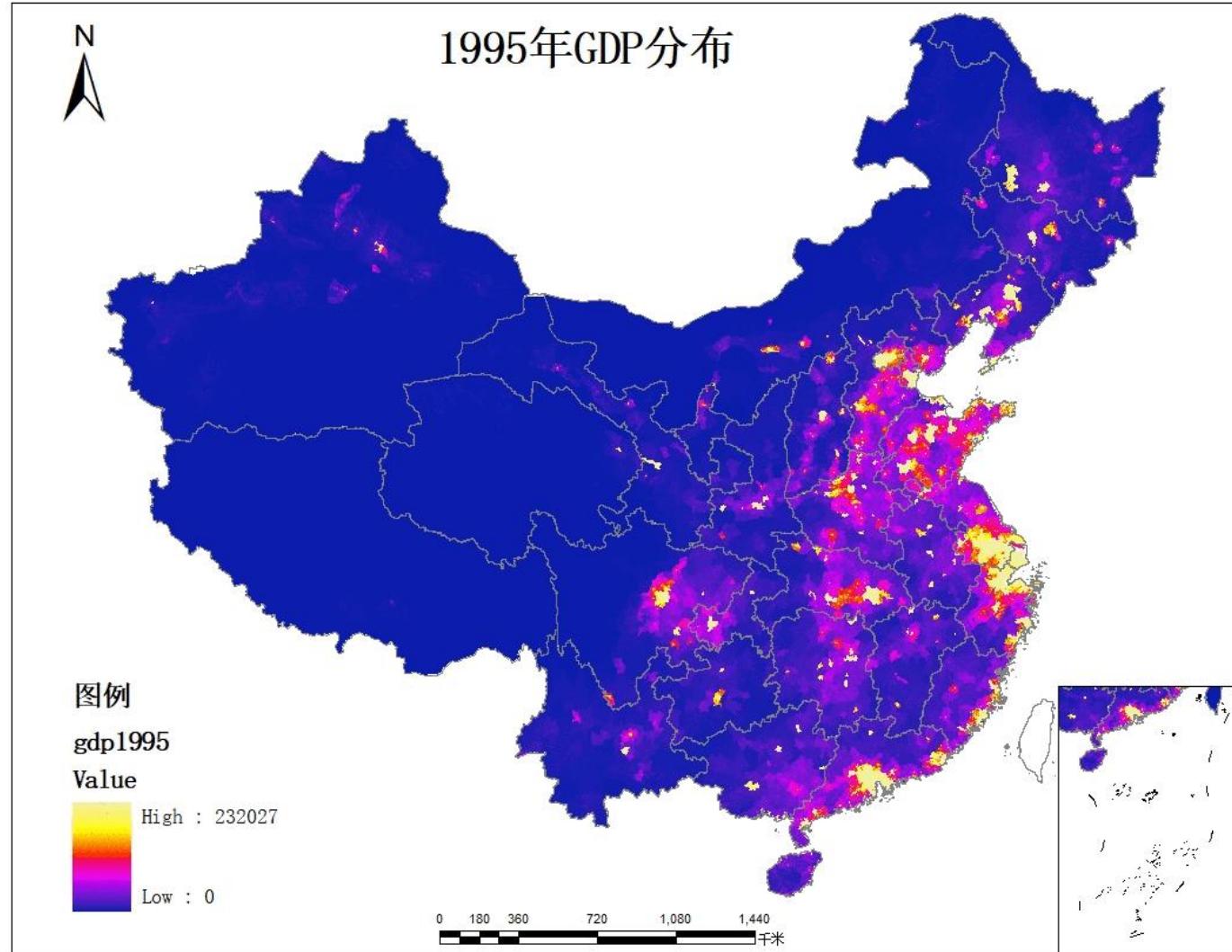
□ 社会经济数据——1km网格人口分布数据



2.3 | 地理模拟时空数据 – 相关驱动因素数据



□ 社会经济数据——1km网格GDP空间分布数据



2.3 | 地理模拟时空数据 – 相关驱动因素数据



□ 社会经济数据——夜间灯光影像数据



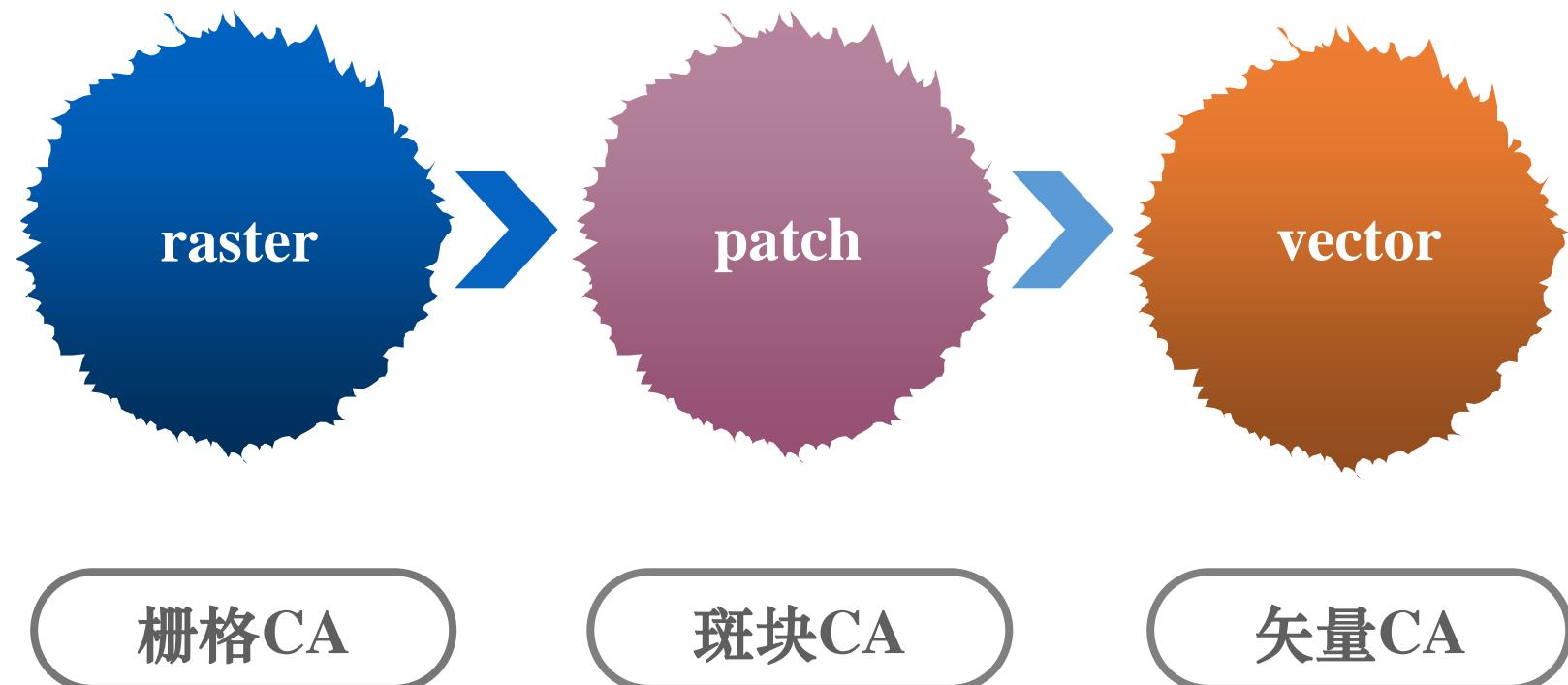


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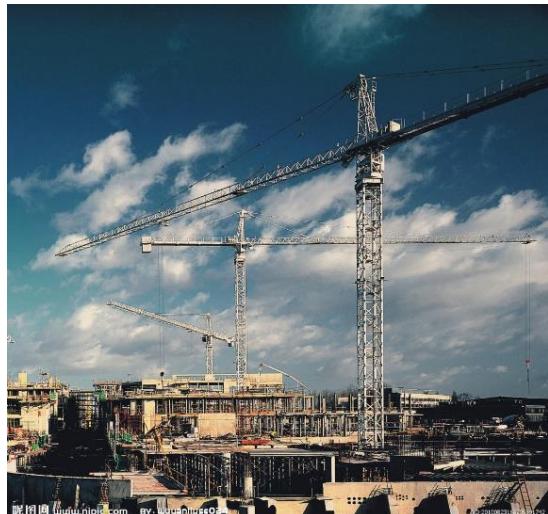
根据cell的不同，CA模型经历了以下三个发展阶段：



3.1 | 棚格级未来土地利用模拟模型 (FLUS)



- 在“人口-资源-环境-发展”复合系统中，处于基础性地位的是土地资源。随着土地资源的日益紧张、人地矛盾的迅速加剧，土地利用变化研究逐渐成为了保护环境、维持可持续发展等方面不可忽视的重要课题(刘纪远等 2009; 摆万奇等 1997; Lambin等 2006)。
- 采用地理模拟方法研究未来土地利用变化可以为国家制定长远的土地政策和土地战略提供有效的信息 (Huang Q 2014) 。也可以为城市规划部门提供有效的决策支持 (Xiang W, Clarke K C 2016) ，其中元胞自动机 (CA) 是地理模拟的有效工具。



3.1 FLUS模型 - 概念

- 耦合模型

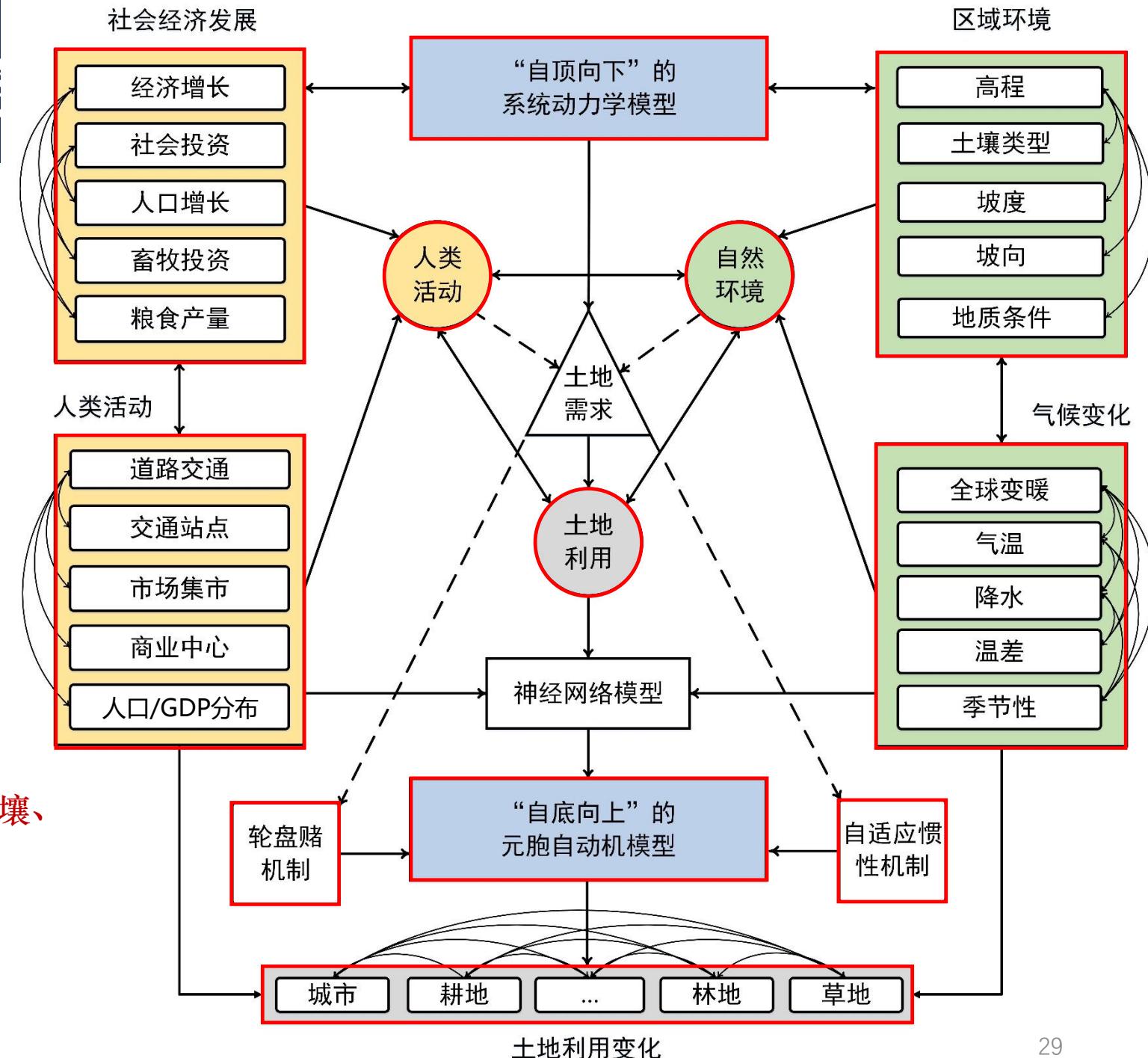
- FLUS模型采用耦合“自顶向下”系统动力学（SD）和“自底向上”改进的元胞自动机的框架。

- 系统动力学

- 考虑了宏观气候变化（气温、降水）以及社会经济变化（人口、投资）

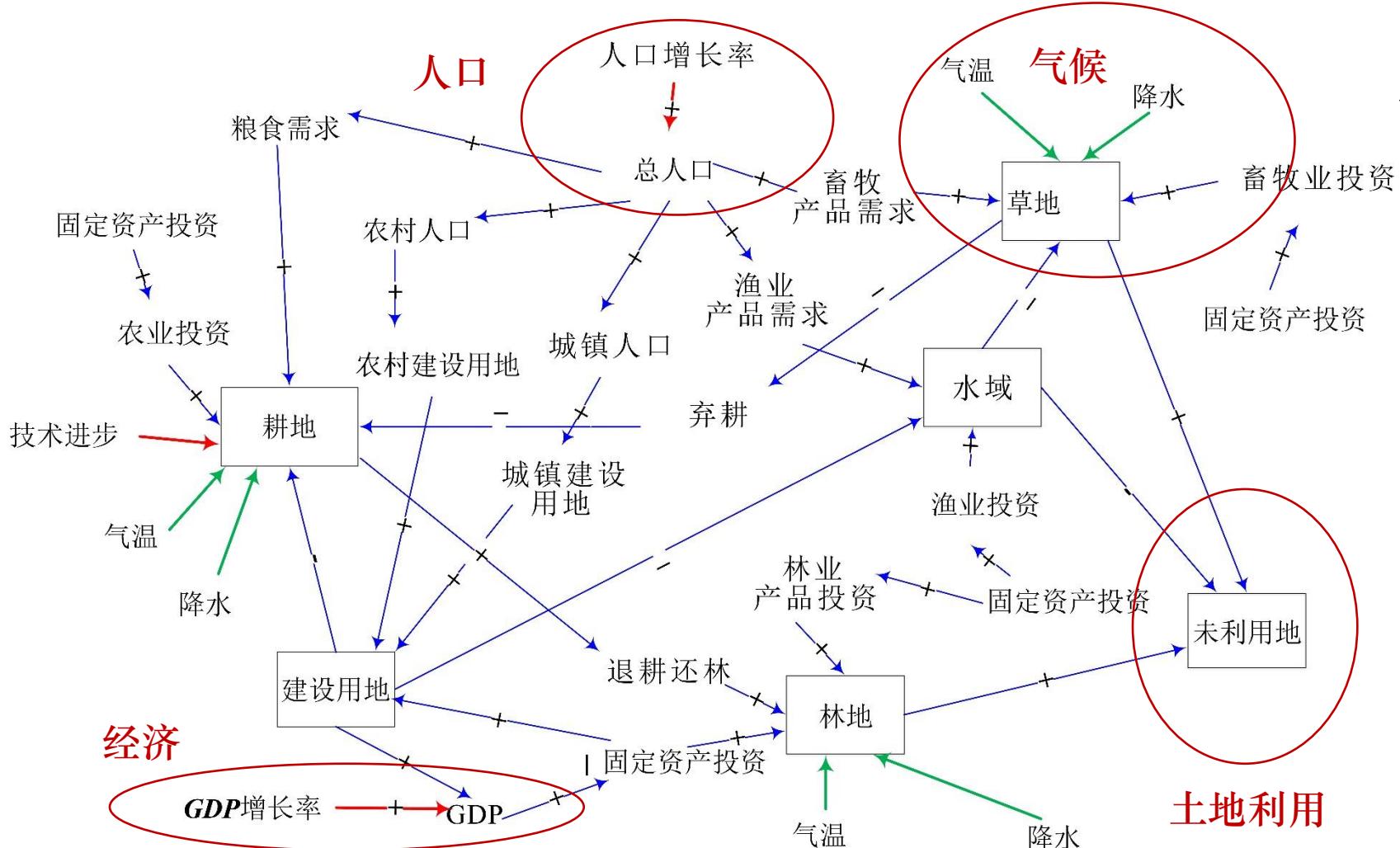
- 改进的元胞自动机

- 考虑了微观气候变化（气温、降水、土壤、温差）、社会经济变化（交通、区位）
- 自适应惯性机制
- 轮盘赌竞争



3.1 | FLUS模型 – 系统动力学模型

系统动力学 (System Dynamics, SD) 模型是建立在控制论、系统论和信息论基础上研究反馈系统结构、功能和动态行为的一类模型，其通过不同模块和变量之间的交流与回馈从而模拟复杂系统的行为。



系统动力学结构

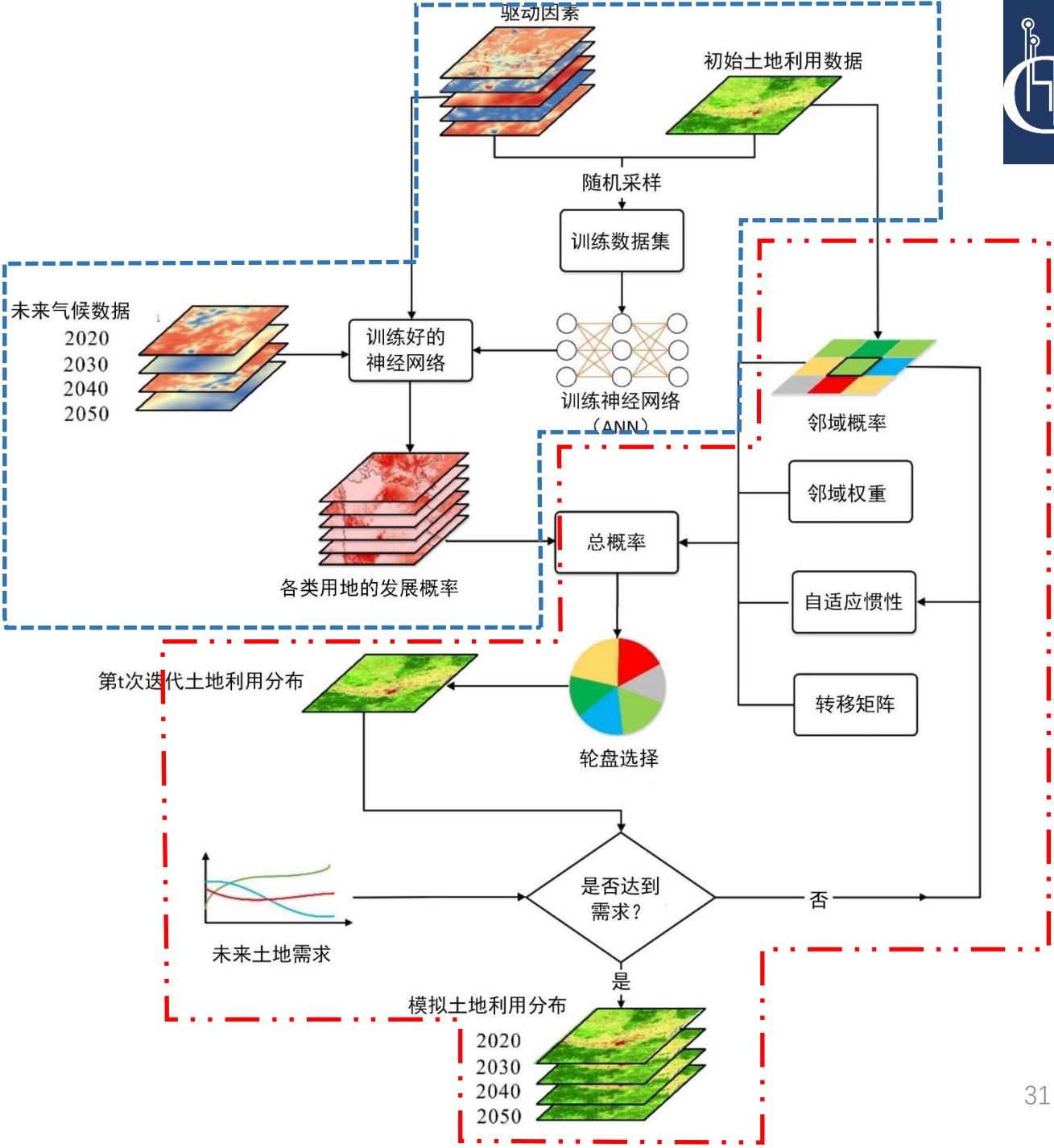
- 4个模块相互作用

❖ 该模型能考虑人类活动和自然生态效应来预测不同情景下的多种土地利用需求。

3.1 | FLUS模型 – 模拟



□ 基于神经网络的用地发展概率计算



□ 基于自适应惯性竞争机制的元胞自动机



3.1 | FLUS模型 – 模拟结果

□ 精度评价

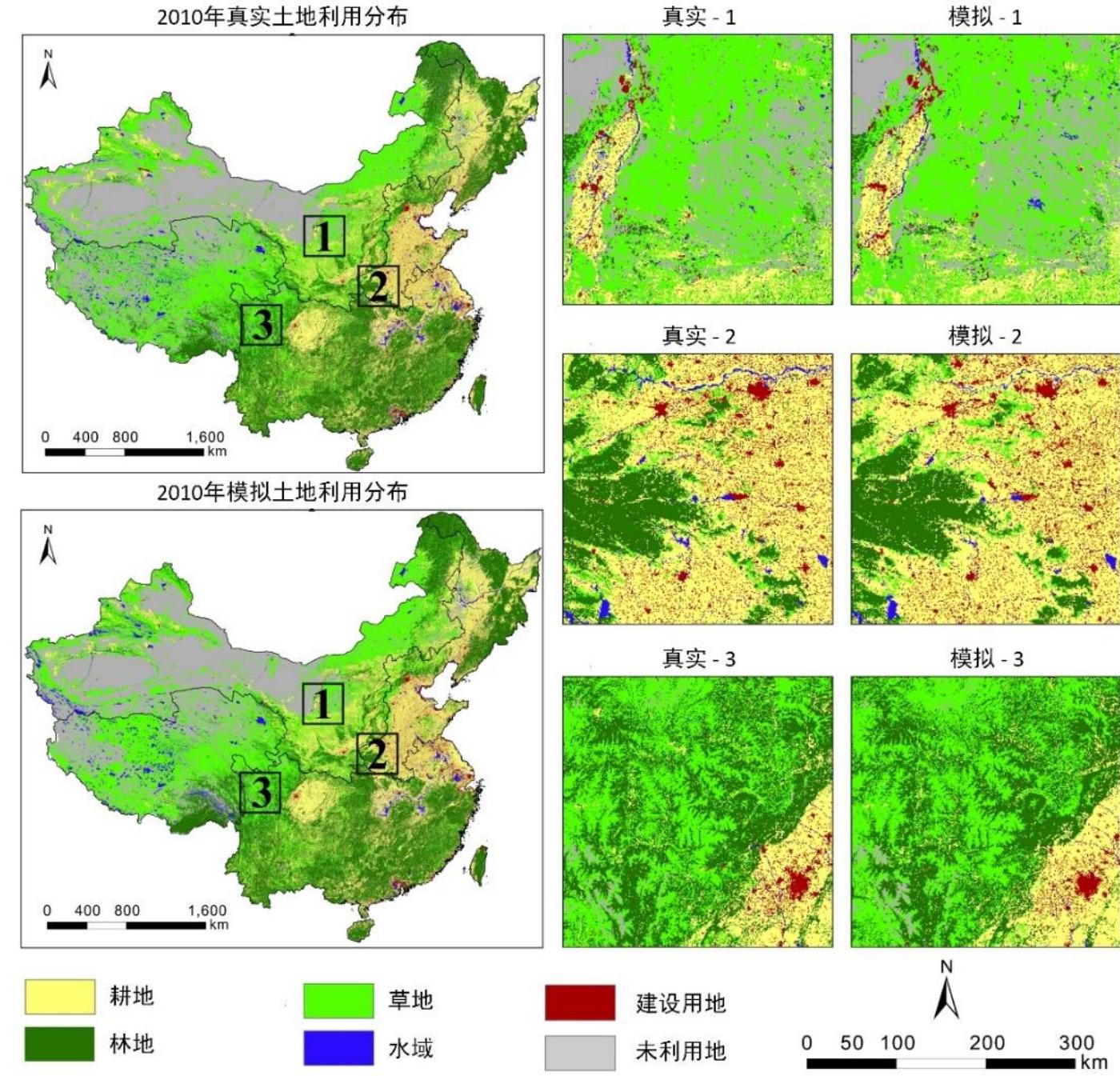
中国大陆1000m分辨率

模拟的总体分布与现实分布的一致性较高

总体精度（正确率）：0.75

Kappa系数：0.67

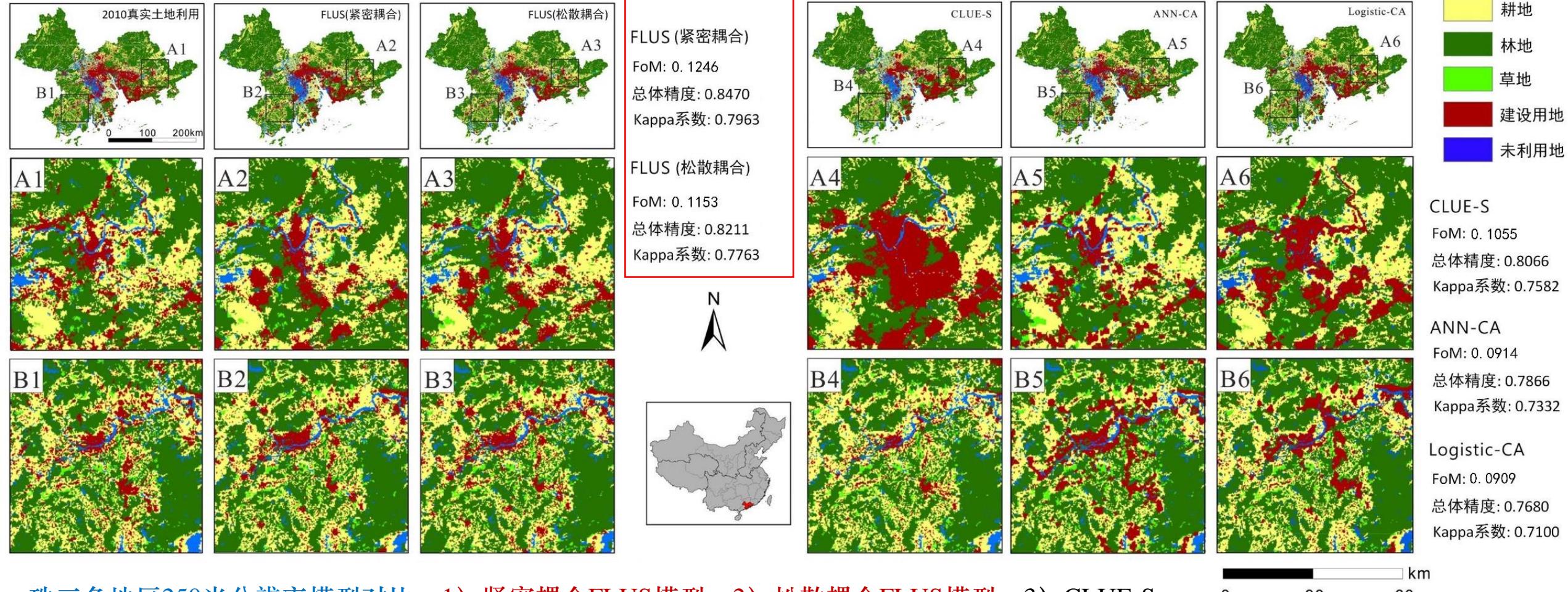
FoM：0.1962



3.1 | FLUS模型 – 模拟结果及验证



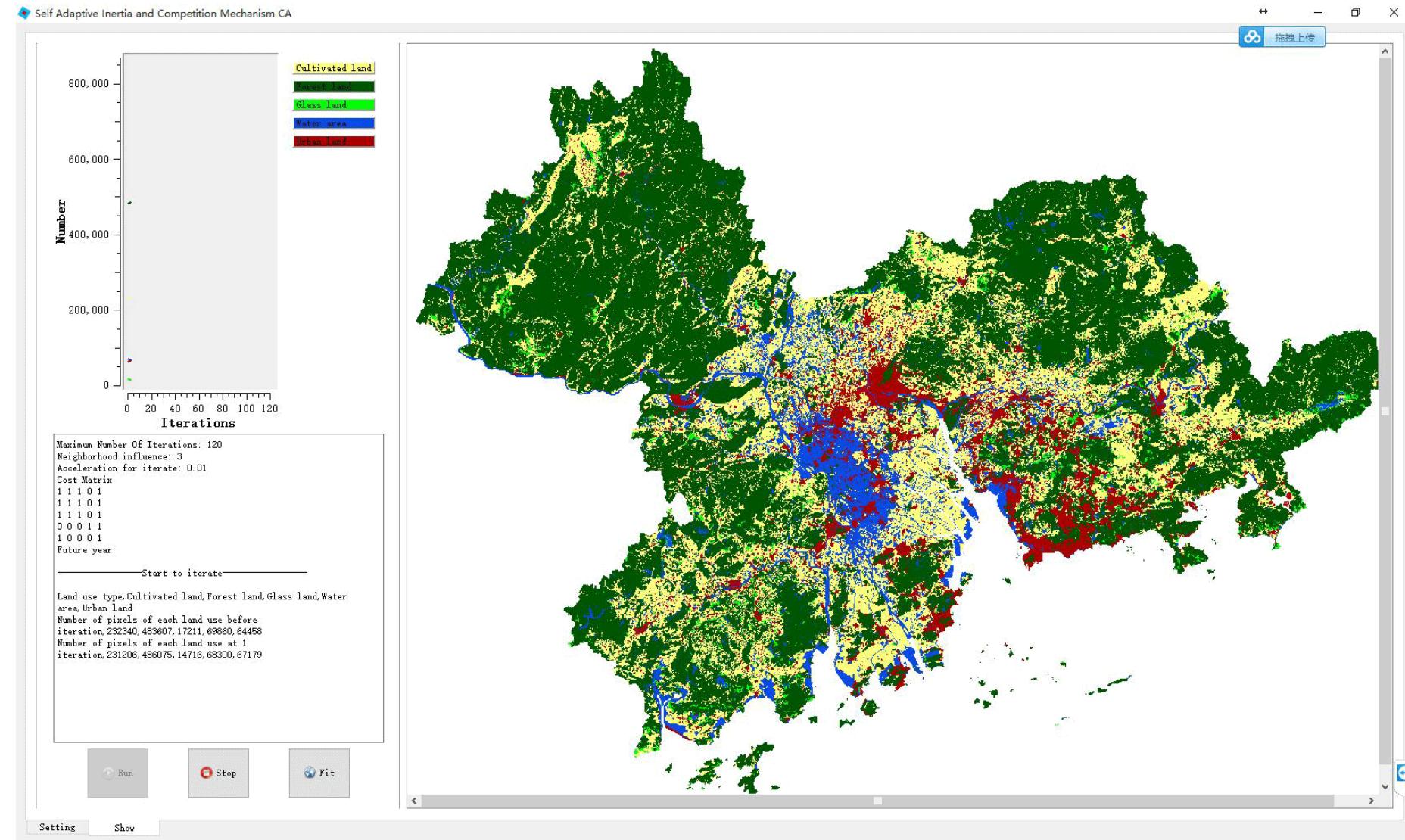
模型精度对比



珠三角地区250米分辨率模型对比: 1) 紧密耦合FLUS模型, 2) 松散耦合FLUS模型, 3) CLUE-S
模型, 4) ANN-CA模型和5) Logistic-CA模型

3.1

FLUS模型 – 运行界面及下载地址



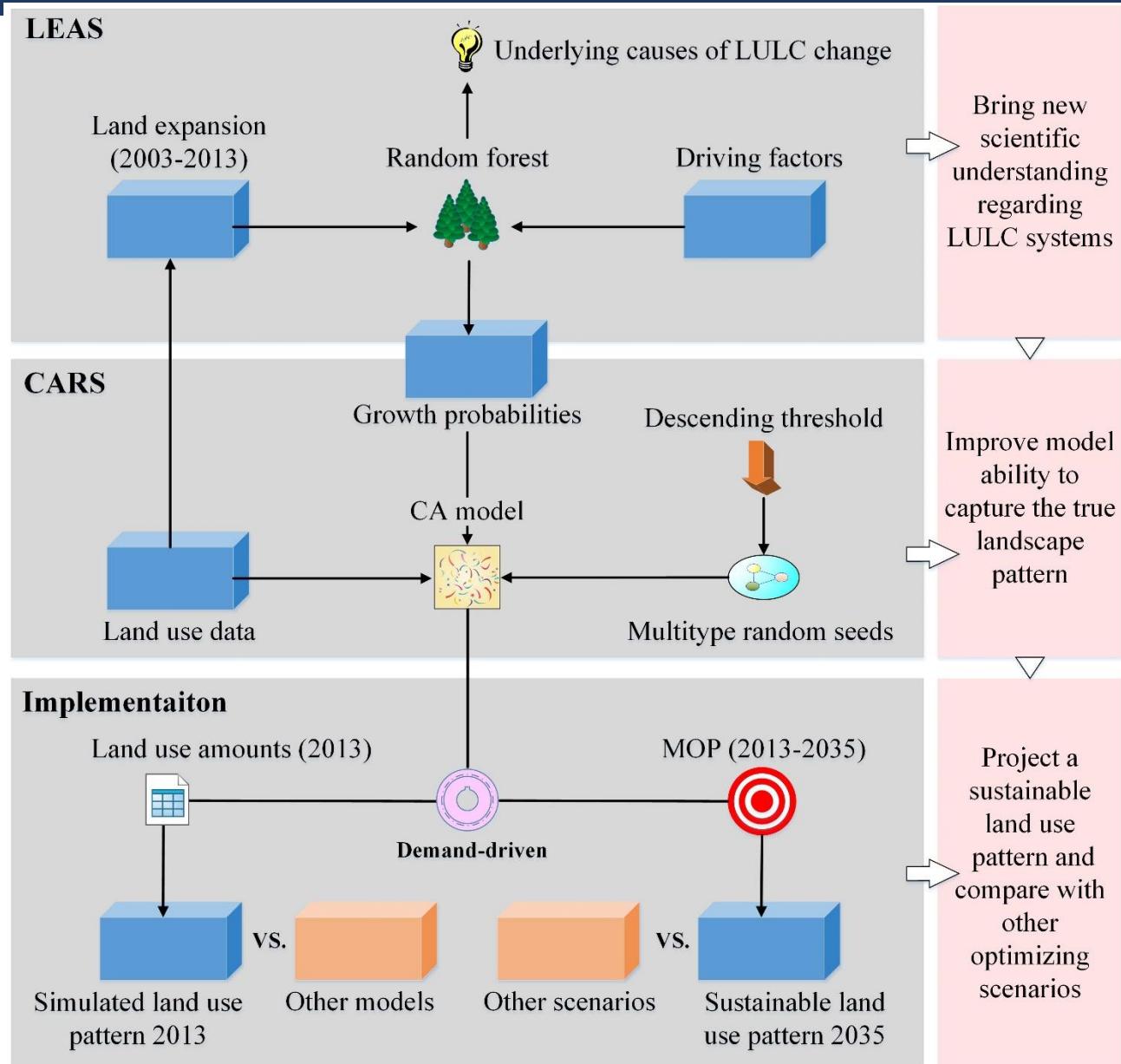
FLUS免费软件: <http://www.geosimulation.cn/flus.html>

3.2 | 斑块级土地利用变化模拟模型 (PLUS)



本研究基于栅格数据，提出一种斑块级别土地利用变化模拟模型 (patch-level land use simulation, PLUS)，该模型：

- 1) 应用一种新的分析策略，可以更好地挖掘各类土地利用变化的诱因。
- 2) 包含一种心的多类种子生长机制，可以更好地模拟多类土地利用斑块级的变化。
- 3) 与多目标优化算法耦合，模拟结果可以更好地支持规划政策以实现可持续发展。



目
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Function	Formula	Description	Subject to
经济效益函数	$f_1(x) = \max \sum_{i=1}^7 ec_i \cdot x_i$ $= \max\{198.04x_1 + 1.88x_2 + 6.70x_3 + 1831.26x_4 + 0x_5 + 1.69x_6 + 1.88x_7\}$	The coefficient ec_i is the economic benefits of each land use type (unit: 10^4 CNY/ha), CNY = Chinese Yuan.	$\sum_{i=1}^7 x_i = 479285.19 \text{ (ha)}$
生态服务函数	$f_2(x) = \max \sum_{i=1}^7 esv_i \cdot x_i$ $= \max\{8.56x_1 + 20.63x_2 + 5.80x_3 + 0x_4 + 1.02x_5 + 33.27x_6 + 20.63x_7\}$	The coefficient esv_i is the ecological service values of each land use type (unit: 10^4 CNY/ha)	$0.55 * (x_1 + x_2 + x_3 + x_7) + 48.93x_4 \leq 14200000$
生态承载力函数	$f_3(x) = \max \sum_{i=1}^7 ec_i \cdot x_i$ $= \max\{0.08x_1 + 1.76x_2 + 5.00x_3 + 2.5x_4 + 0x_5 + 9.42x_6 + 1.76x_7\}$	The coefficient ec_i is the ecological capacity of each land use type.	$\frac{x_5 + x_1}{479285.19} \geq 2.5\%$
经济发展 (ED) 情景: 经济发展目标最大	$\max\{f_1(x)\}$	$x_1 \sim x_7$ represent the area (ha) of grassland (x_1), deciduous forest (x_2), cropland (x_3), urban land (x_4), bare land (x_5), water area (x_6), and evergreen forest (x_7). The three optimization objectives share the same constraint conditions.	$\frac{0.49x_1 + x_2 + 0.46x_3 + x_7}{479285.19} \geq 22\%$
环境保护 (EP) 情景: 最大化生态服务价值和 承载力	$\max\{f_2(x), f_3(x)\}$		$x_3 \times 6312 \times 0.4072 \times 2.85 \geq 14200000 \times 209.30 \times 0.187$
可持续发展 (SD) 情景: 最大化经济、生态服务 价值和承载力	$\max\{f_1(x), f_2(x), f_3(x)\}$		$0.0066 \leq \frac{x_1}{479285.19} \leq 0.0112$
			$0.2349 \leq \frac{x_4}{479285.19} \leq 0.3523$
			$0.2502 \leq \frac{x_6}{479285.19} \leq 0.373$
			$0.0136 \leq \frac{x_7}{479285.19} \leq 0.0355$
			$0.325 \leq \frac{x_7}{x_2} \leq 0.65$

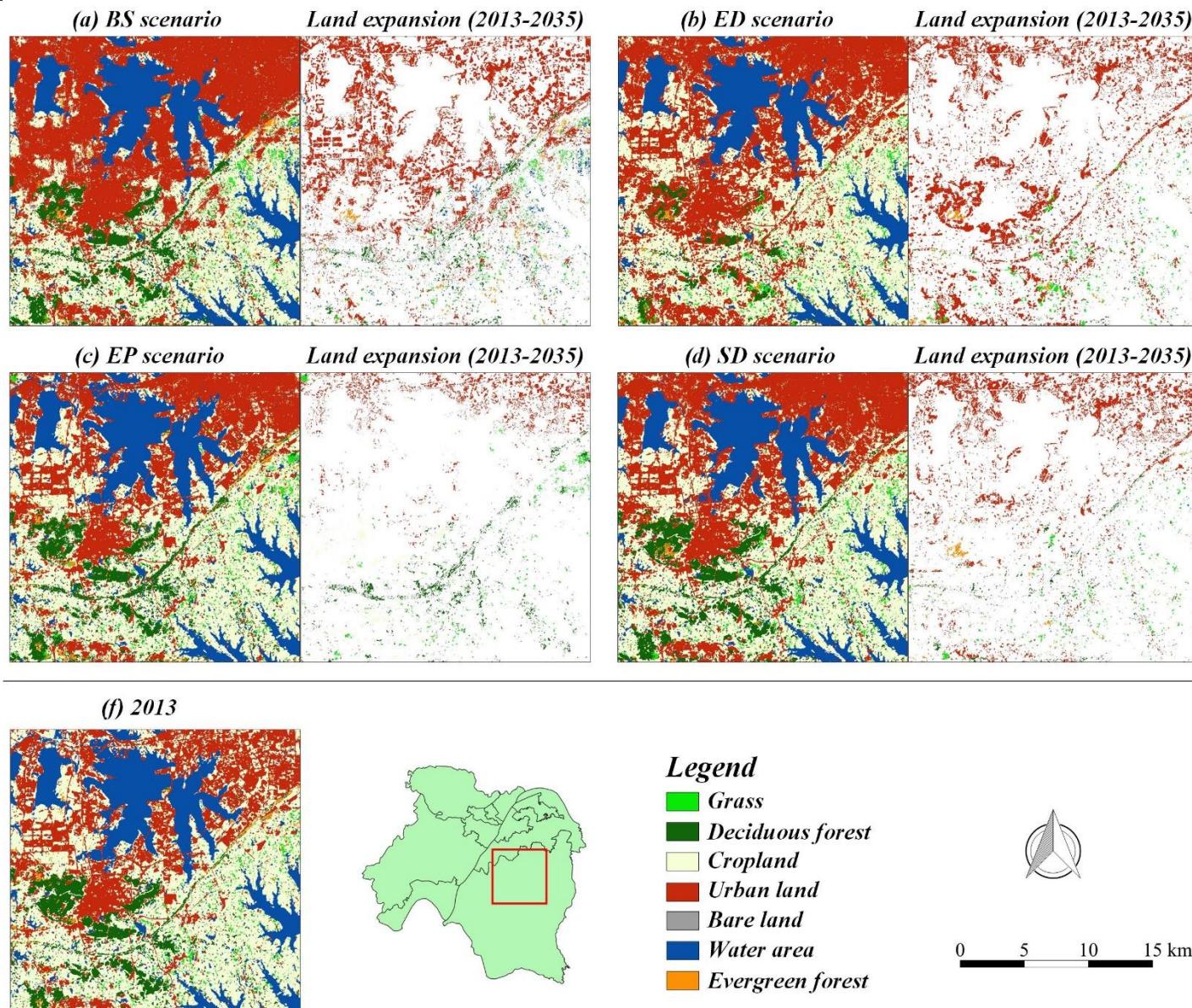
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3.2 | PLUS模型 – 未来多情景模拟



在靠近武汉市汤逊湖附近的一个区域：

- 1) BS情景下的城市增长将会扩大并侵占很多农田，但最大的落叶林斑块将会得到很好的保护。落叶林廊道会变得更连续。
- 2) 尽管ED方案下的城市增长更加紧凑，但它保留了更多的耕地，从而可以创造更多的经济利益，代价是侵占更多的落叶林。因此，在ED情景下，落叶林斑块变小，落叶林廊道几乎消失。
- 3) 与ED方案相比，EP方案对林地的需求最大，落叶林斑块保存最完好。EP情景下落叶林廊道的生长最为明显。
- 4) 在SD情景下，城市生长得到控制，减少对落叶林的影响。落叶林的分布格局与2013年基本相同。



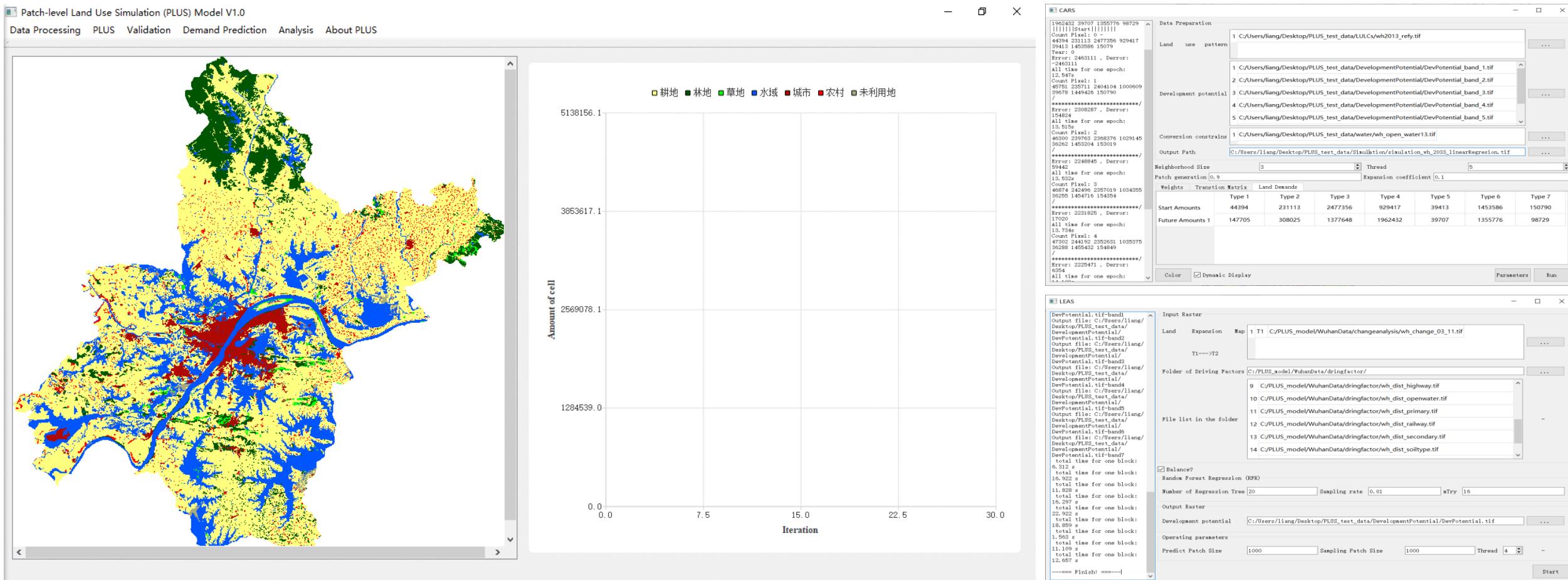
3.2 | PLUS模型 – 运行界面及下载地址



HPSCIL实验室已经发布了PLUS模型的软件，包括完整用户手册和测试数据，供全球研究者免费下载。

下载链接为：<http://www.urbancomp.net/2020/07/25/plus/>

https://github.com/HPSCIL/Patch-level_Land_Use_Simulation_Model



3.2

栅格CA城市模拟套件工具包 (GeoCA)



GeoCA V2.4 by HPSCIL@CUG

Geographical Simulation App via Cellular Automata (GeoCA)
Version 2.4
Copyright by HPSCIL@CUG
Website: <http://www.urbancomp.net>

GeoCA is a free software for the simulation and prediction of a large-scale pixel-based urban development process. GeoCA has been well applied in the fields of urban development process analysis, urban ecological environment analysis and urban planning. GeoCA supports multi-rule mining models, multi-spatial variable processing, geographic location alignment and automatic memory control for large-scale urban development simulation.

GeoCA was developed by the following laboratory:
High-Performance Spatial Computational Intelligence Laboratory,
School of Geography and Information Engineering,
China University of Geosciences, Wuhan, China.
<http://www.urbancomp.net>

Urban simulation algorithm developers:
Yao Yao, China University of Geosciences, Wuhan, China.
Guangzhao Chen, Sun Yat-sen University, Guangzhou, China.
Jinba Zhang, Sun Yat-sen University, Guangzhou, China.
Xun Liang, China University of Geosciences, Wuhan, China.
Dongsheng Chen, Wuhan University, Wuhan, China.
Dachuan Zhang, Sun Yat-sen University, Guangzhou, China.
Hongchi Cui, Chinese Academy of Sciences, Beijing, China.

High-performance computing platform developers:
Qingming Guan, China University of Geosciences, Wuhan, China.
Xiang Liu, China Aerospace Science and Technology Corporation, Beijing.
Yao Yao, China University of Geosciences, Wuhan, China.
Jinba Zhang, Wuhan University, Wuhan, China.
Penghua Liu, Alibaba Group, Hangzhou, China.
Zhewei Liang, China University of Geosciences, Wuhan, China.

User interface developers:

Load Params Export Params Run

Auxiliary Files

nFID	File Name	Minimum Value	Maximum Value	Mean Value	Better (1=Yes, 0 = No)	Comment
1 0	WUHAN_capit...	0.000000	130032.000000	60000.000000	1	WUHAN_capit...
2 1	WUHAN_chin...	0.000000	69483.000000	102.860000	1	WUHAN_chin...
3 2	WUHAN_Chin...	0.000000	27.394400	1.000000	1	WUHAN_Chin...
4 3	WUHAN_city.tif	0.000000	69498.600000	30000.000000	1	WUHAN_DIST...

NOTE: The maximum, minimum and average values of each spatial auxiliary variable must be entered manually!

Additional Probability File
 Do you use additional probability data multiplied by Pg? If yes, put it in Aux_Filepath if use. (DATATYPE=FLOAT32)
 Additional Probability File

@CUG

Output Settings Simulation Settings Rule-Mining Settings Validation Settings Land Erosion Mapping Process Log About

Set files of the program to change the default file name. All automatically add the file extension like filename_IterNo_X.tif
 PUT_FILEPATH

(Start Year) File Name: UrbanChangeFile.tif
 (End Year) File Name: UrbanClassificationFile.tif
 (Year) File Name: LandDevelopmentSuitableIndexFile.tif
 Session File Name: RegressionAnalysisPointsFile.txt
 Probability (N-U) File Name: PROB.tif
 file extension required: UrbanDevelopmentIterationsResult
 nine-band probability file: 9B_PROB_E01.tif

/ 9-Band Probability (BAND):

GeoCA V2.4 by HPSCIL@CUG

Simulation Data Output Settings Simulation Settings Rule-Mining Settings Validation Settings

Execute Land Erosion Mapping Process

Parameters

LULC Data File Name: \WUHAN_DATA\WUHAN_LANDUSE\WUHAN_GLC30_2000.tif
 LULC-Codes (The Codes of Erosion Land-use, Separated by commas): 10
 CA Iteration Results (without suffix): \WUHAN_DATA\WUHAN_OUTPUT\5UrbanDevelopmentIterationsResults
 Land Erosion Mapping Results (without suffix): \WUHAN_DATA\WUHAN_OUTPUT\FAEMLAND_LOSS\7FarmLandAnalysis

This step supports the mapping and analysis of environmental erosion phenomena caused by urbanization. This step is optional.

LULC Data File:
 1 This is the original land use data. The test data of this software is for GLC_30.
 2 LULC codes of GLC_30:
 10, Cultivated Land
 20, Forest
 30, Grassland
 40, Shrubland
 50, Wetland
 60, Water bodies
 70, Tundra
 80, Artificial Surfaces
 90, Barren
 100, Permanent snow and ice
 255, Unknown Place
 Therefore, we choose 80 and 30 in "LULC-Codes" as the eroded analysis objects.

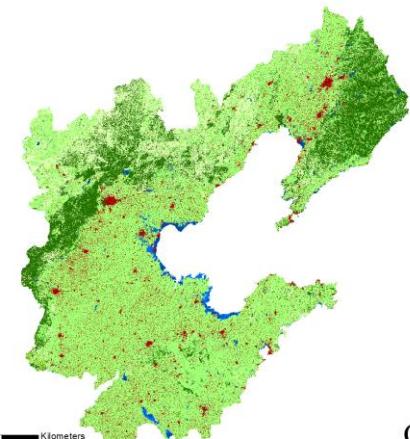
CA Iteration Results:
 1 This is the simulation file output by the model.
 2 The file name is similar to "UrbanDevelopmentIterationsResult_IterNo_*_tif". * Is the number of iterations.
 3 Only need to open any one of the iteration result files. If the program finds that the suffix ("_IterNo_*_tif") is read the file.
 4 The data contains four attributes (as Reclassification Code of LULC):
 ID = 0, RECLASS_UNKNOW
 ID = 1, RECLASS_CITY
 ID = 2, RECLASS_VICITY
 ID = 3, RECLASS_PROTECTIVE

Land Erosion Mapping Results:
 1 This is the land erosion mapping file to be output.
 2 The file extension is ".tif".
 3 When outputting map files, the suffix ("_IterNo_*_tif") will be automatically added after the filename, corresponding to the number of iterations corresponding to CA Iteration Results.

Load Params Export Params Run

Urban expansion simulation in Circum-Bahai Sea economic zone (2000-2026)

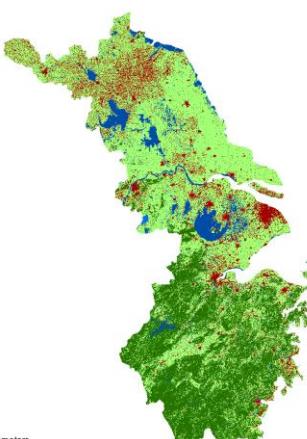
Year: 2000



GeoCA v1.0

Urban expansion simulation in Yangtze River delta economic zone (2000-2026)

Year: 2000



GeoCA v1.0

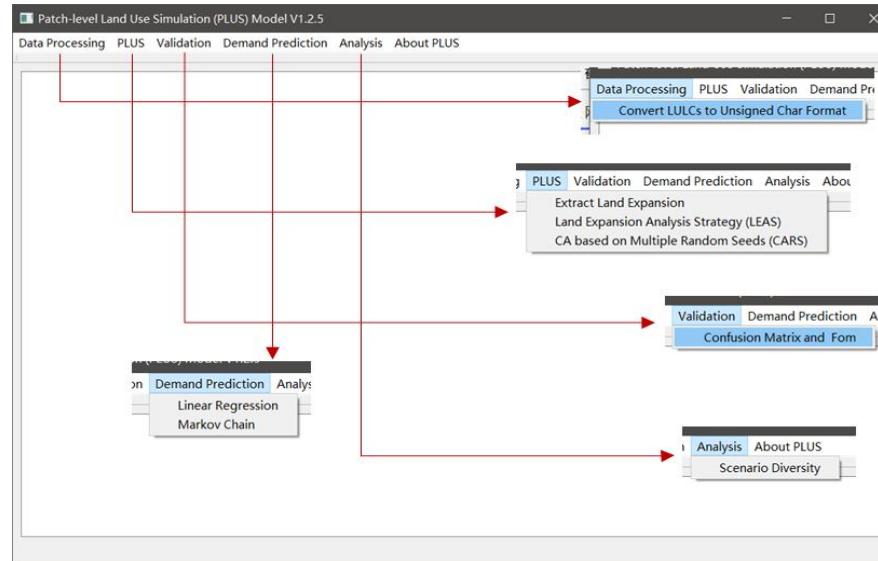
下载地址为: http://www.urbancomp.net/2020/10/18/geoca_v_2_4/

3.2

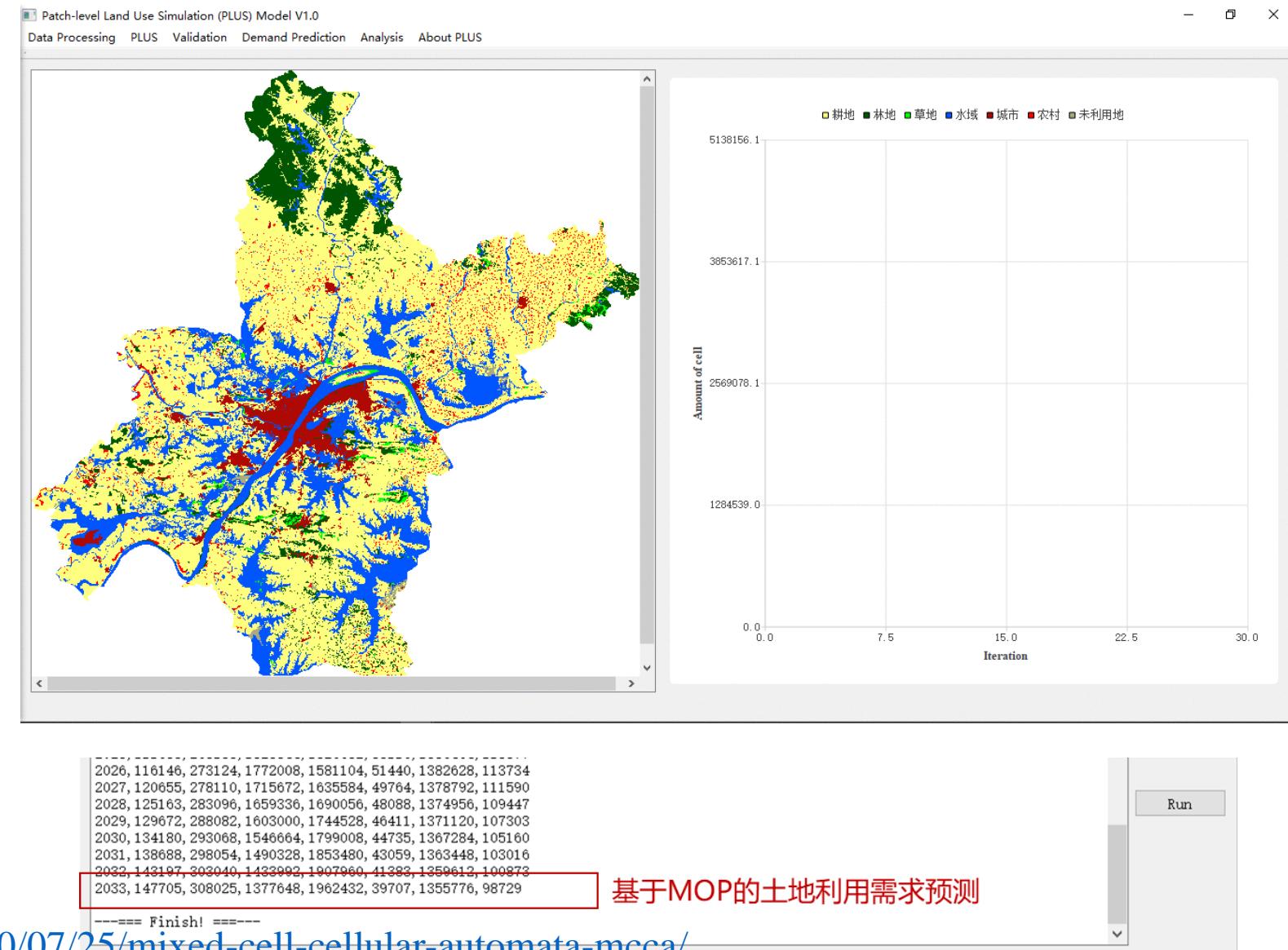
栅格CA城市模拟套件工具包 (PLUS)



斑块级土地利用模拟模型(PLUS)软件



```
1962432 39907 1355776 98729
|||||Start|||||
Count Pixel: 0
449413 1453586 1477256 929417
39413 1453586 15079
154624 2398287 . Derree:
-2463111
All time for one epoch:
12.322
Count Pixel: 1
45758 235711 2404104 1000609
39678 1449426 150790
/
*****
Error: 2398287 . Derree:
154624
All time for one epoch:
12.322
Count Pixel: 2
46306 239763 2368376 1029145
36262 1453204 153019
/
*****
Error: 2248845 . Derree:
154624
All time for one epoch:
13.352
Count Pixel: 3
46874 242496 2357019 1034355
36265 1454716 154354
/
*****
Error: 2231825 . Derree:
17029
All time for one epoch:
13.734
Count Pixel: 4
47302 244192 2352631 1035375
36268 1455432 154849
/
*****
```



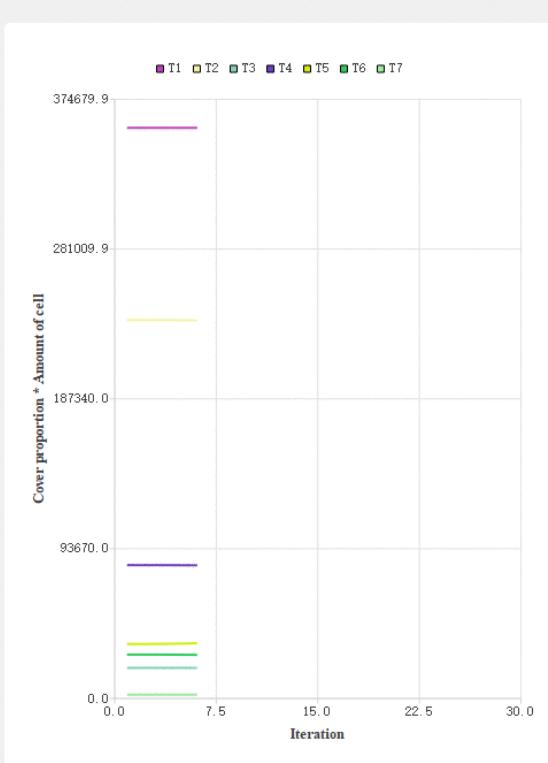
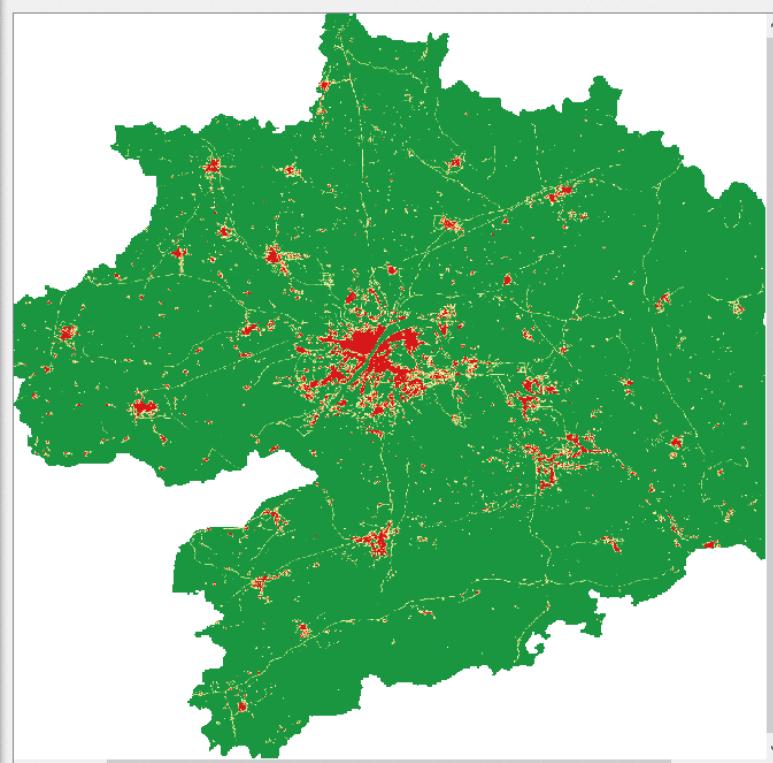
下载地址为：<http://www.urbancomp.net/2020/07/25/mixed-cell-cellular-automata-meca/>

栅格CA城市模拟套件工具包 (MCCA)



混合元胞CA模型软件

Mixed-Cell Cellular Automata(MCCA) V.1
 Data processing Mixed-Cell Cellular Automata Validation Demand Prediction Analysis About



Mining of quantitative transition rules

OS Error = 0.0202168
Run time: 0.922
Input Raster
Land use Structure
T1-->T2
7 71 C:/Users/Xun Liang/Desktop/MCCA V1.0/TestData/MixedLanduse/Xianning_2010_lenduse_7.tif
8 72 C:/Users/Xun Liang/Desktop/MCCA V1.0/TestData/MixedLanduse/Xianning_2015_lenduse_7.tif
9 72 C:/Users/Xun Liang/Desktop/MCCA V1.0/TestData/MixedLanduse/Xianning_2015_lenduse_2.tif
10 72 C:/Users/Xun Liang/Desktop/MCCA V1.0/TestData/MixedLanduse/Xianning_2015_lenduse_3.tif
11 72 C:/Users/Xun Liang/Desktop/MCCA V1.0/TestData/MixedLanduse/Xianning_2015_lenduse_4.tif
12 72 C:/Users/Xun Liang/Desktop/MCCA V1.0/TestData/MixedLanduse/Xianning_2015_lenduse_5.tif
13 72 C:/Users/Xun Liang/Desktop/MCCA V1.0/TestData/MixedLanduse/Xianning_2015_lenduse_6.tif
14 72 C:/Users/Xun Liang/Desktop/MCCA V1.0/TestData/MixedLanduse/Xianning_2015_lenduse_7.tif

Folder of Driving Factors
C:/Users/Xun Liang/Desktop/MCCA V1.0/TestData/DrivingFactors/
1 C:/Users/Xun Liang/Desktop/MCCA V1.0/TestData/DrivingFactor/DEM.tif
2 C:/Users/Xun Liang/Desktop/MCCA V1.0/TestData/DrivingFactor/annualprecipitation.tif
3 C:/Users/Xun Liang/Desktop/MCCA V1.0/TestData/DrivingFactor/annualtemperature.tif
4 C:/Users/Xun Liang/Desktop/MCCA V1.0/TestData/DrivingFactor/dst_arterialroad.tif
5 C:/Users/Xun Liang/Desktop/MCCA V1.0/TestData/DrivingFactor/dst_highspeedrailwaystation.tif
6 C:/Users/Xun Liang/Desktop/MCCA V1.0/TestData/DrivingFactor/dst_highway.tif
7 C:/Users/Xun Liang/Desktop/MCCA V1.0/TestData/DrivingFactor/dst_primaryroad.tif
8 C:/Users/Xun Liang/Desktop/MCCA V1.0/TestData/DrivingFactor/dst_secondaryroad.tif

Random Forest Regression (RFR)
Number of Regression Tree 20
Sampling rate 0.01
Start

Simulating dynamics of land-use structures

Start Pixel: 356383 236639 19109.2
83383.1 34013.2 27423.9
2395.46
Future Pixel: 31383 236639 18132.3
94423.1 0 28094.5
685.675
[[[[[[[[[|]]]]]]]]
Count Pixel: 0
356383 236639 19109.2
83383.1 34013.2 27423.9
2395.46
Year: 0
Iteration 0, Error: 83011
All time for one epoch: 1.781s
Count Pixel: 1
356383 236639 19108.9
83383.1 34007.2 27420.2
2395.26

Iteration 1, Error: 83469
All time for one epoch:
1.790s
Count Pixel: 2
356760 236639 19107.7
83398.9 34121.7 27406.5
2394.26

Iteration 2, Error: 83260
All time for one epoch:
1.81s
Count Pixel: 3
356917 236639 19102.5
83396.2 34324.2 27379.4
2390.82

Iteration 3, Error: 82960
All time for one epoch:
1.766s
Count Pixel: 4
356934 236639 19092.8
83405.2 34068.8 27332.1
2385.42
/

Land Use Structure
1 C:/MCCData/QGISgrid/whma_wgs84_2015_mirr02_lenduse_1.tif
2 C:/MCCData/QGISgrid/whma_wgs84_2015_mirr02_lenduse_2.tif
3 C:/MCCData/QGISgrid/whma_wgs84_2015_mirr02_lenduse_3.tif
4 C:/MCCData/QGISgrid/whma_wgs84_2015_mirr02_lenduse_4.tif
5 C:/MCCData/QGISgrid/whma_wgs84_2015_mirr02_lenduse_5.tif

Development potential
1 C:/MCCData/Revised/Po010_15/regressionProbRF_2010_2015_RASTER_band_1.tif
2 C:/MCCData/Revised/Po010_15/regressionProbRF_2010_2015_RASTER_band_2.tif
3 C:/MCCData/Revised/Po010_15/regressionProbRF_2010_2015_RASTER_band_3.tif
4 C:/MCCData/Revised/Po010_15/regressionProbRF_2010_2015_RASTER_band_4.tif
5 C:/MCCData/Revised/Po010_15/regressionProbRF_2010_2015_RASTER_band_5.tif

Conversion constraint
1 C:/MCCData/QGISgrid/whma_wgs84_2015_mirr02_lenduse_4.tif

Output Path
C:/MCCData/test0018/testtest.tif

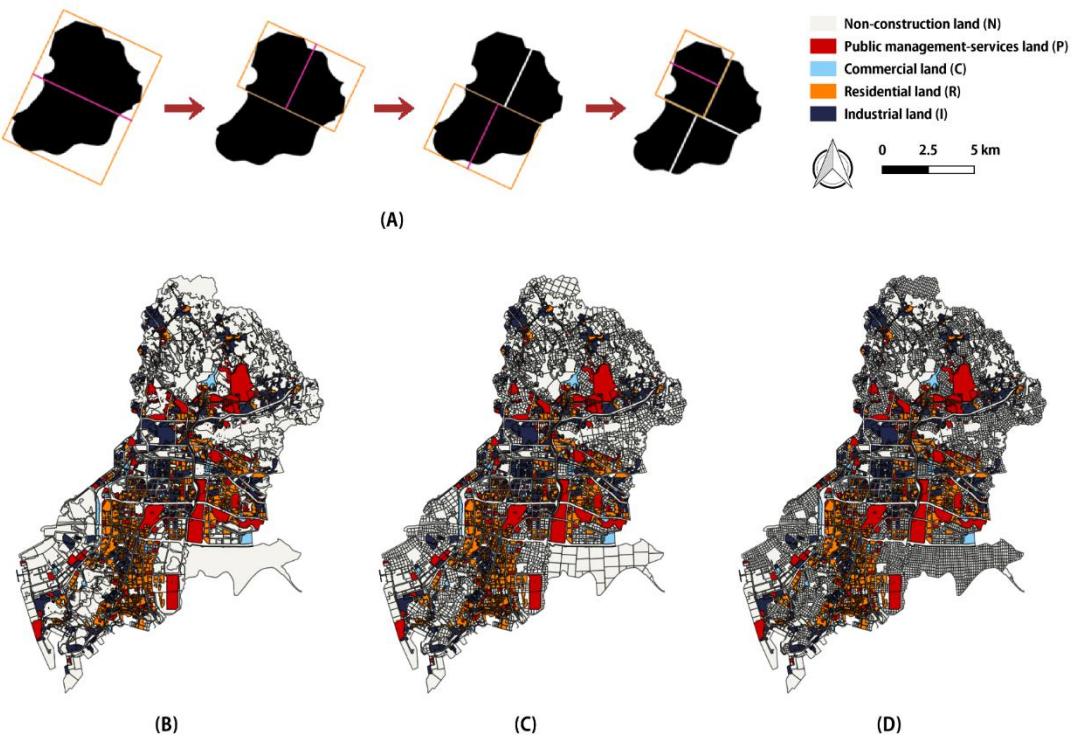
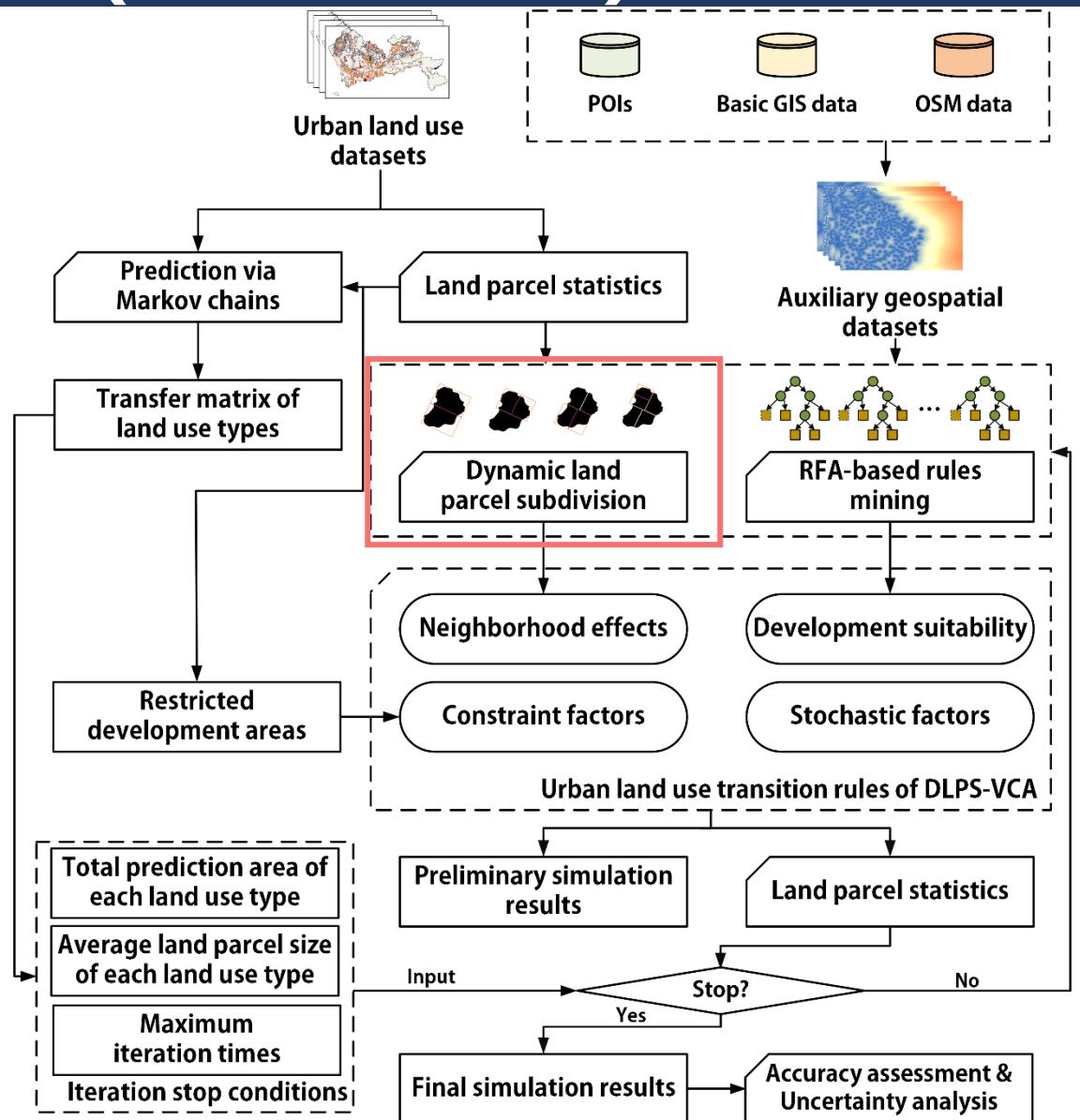
Step Size Transition Matrix Land Demands

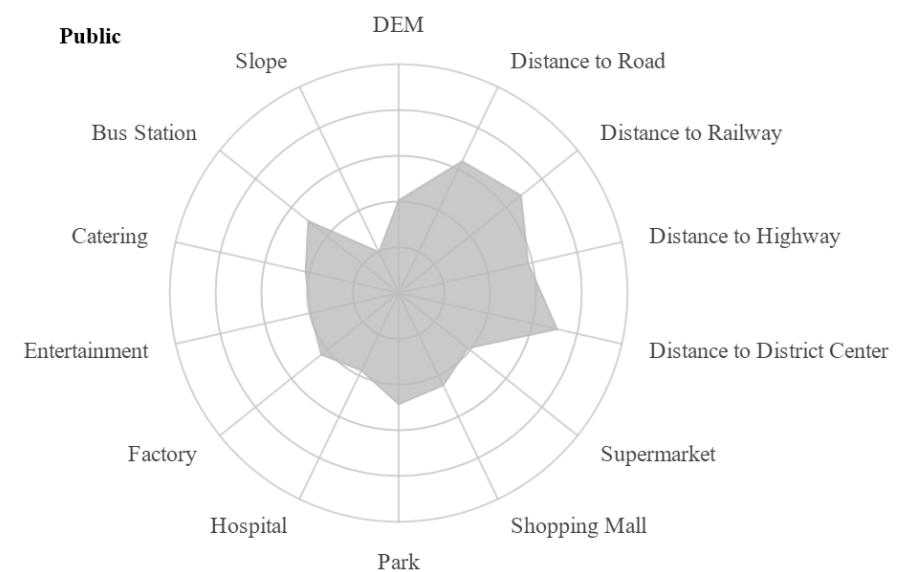
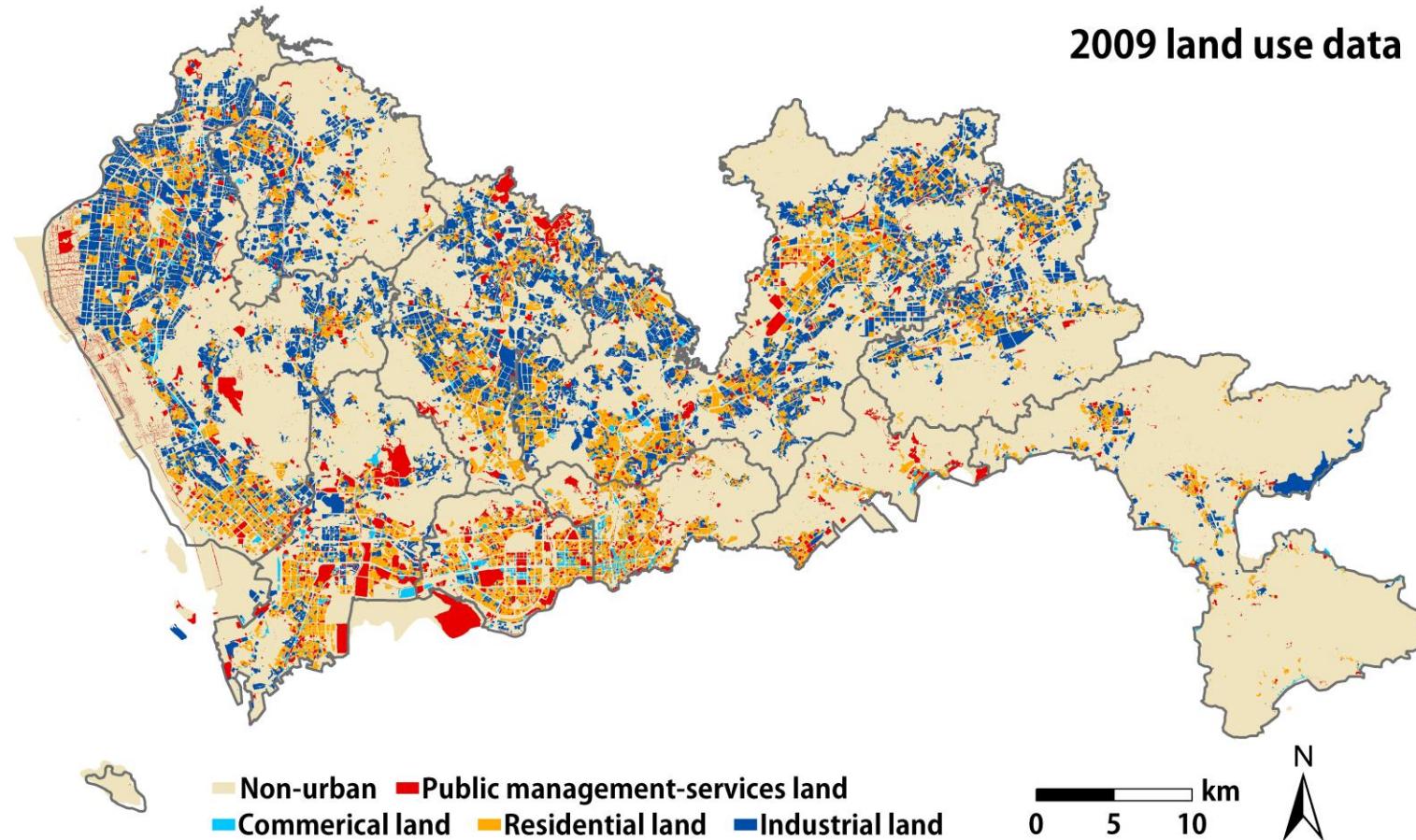
	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7
Type 1	1	1	1	1	1	1	0
Type 2	1	1	1	0	1	1	0
Type 3	1	1	0	1	1	1	0
Type 4	1	0	0	1	1	1	0

Parameters Run

3.3

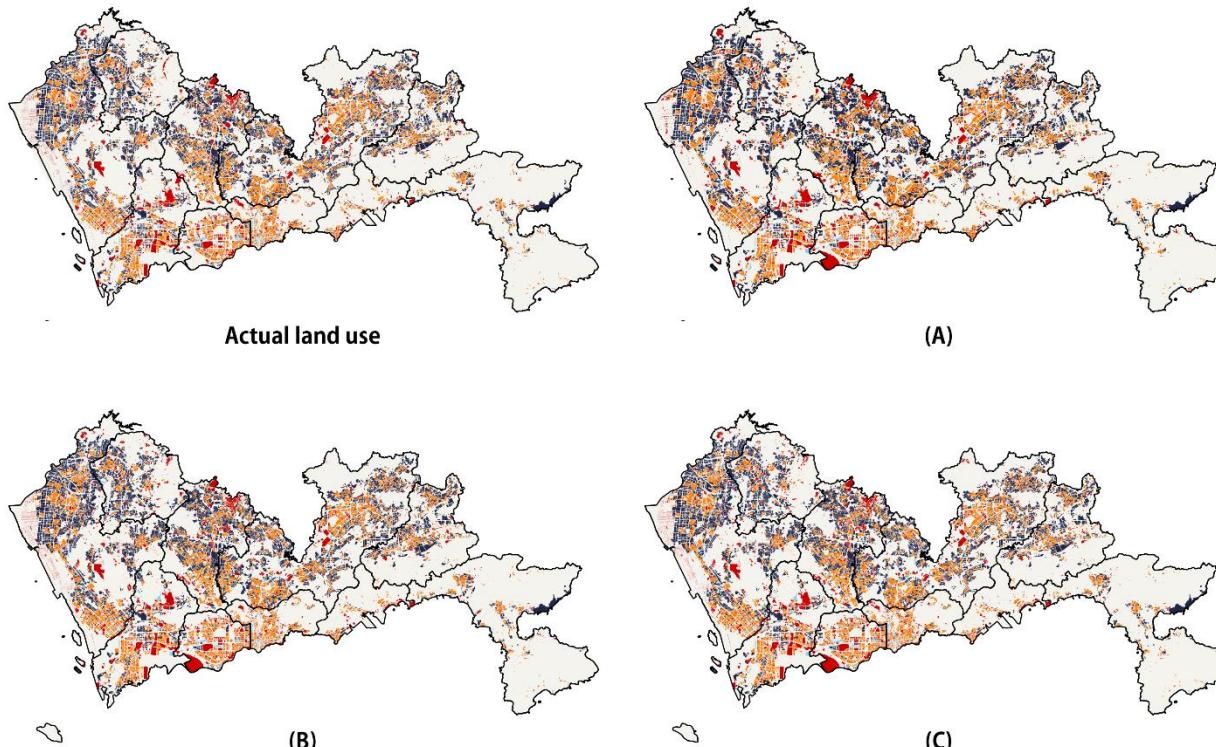
基于真实地块的城市土地利用变化模拟模型 (UrbanVCA)





3.3

UrbanVCA模型 – 模拟结果及精度评价

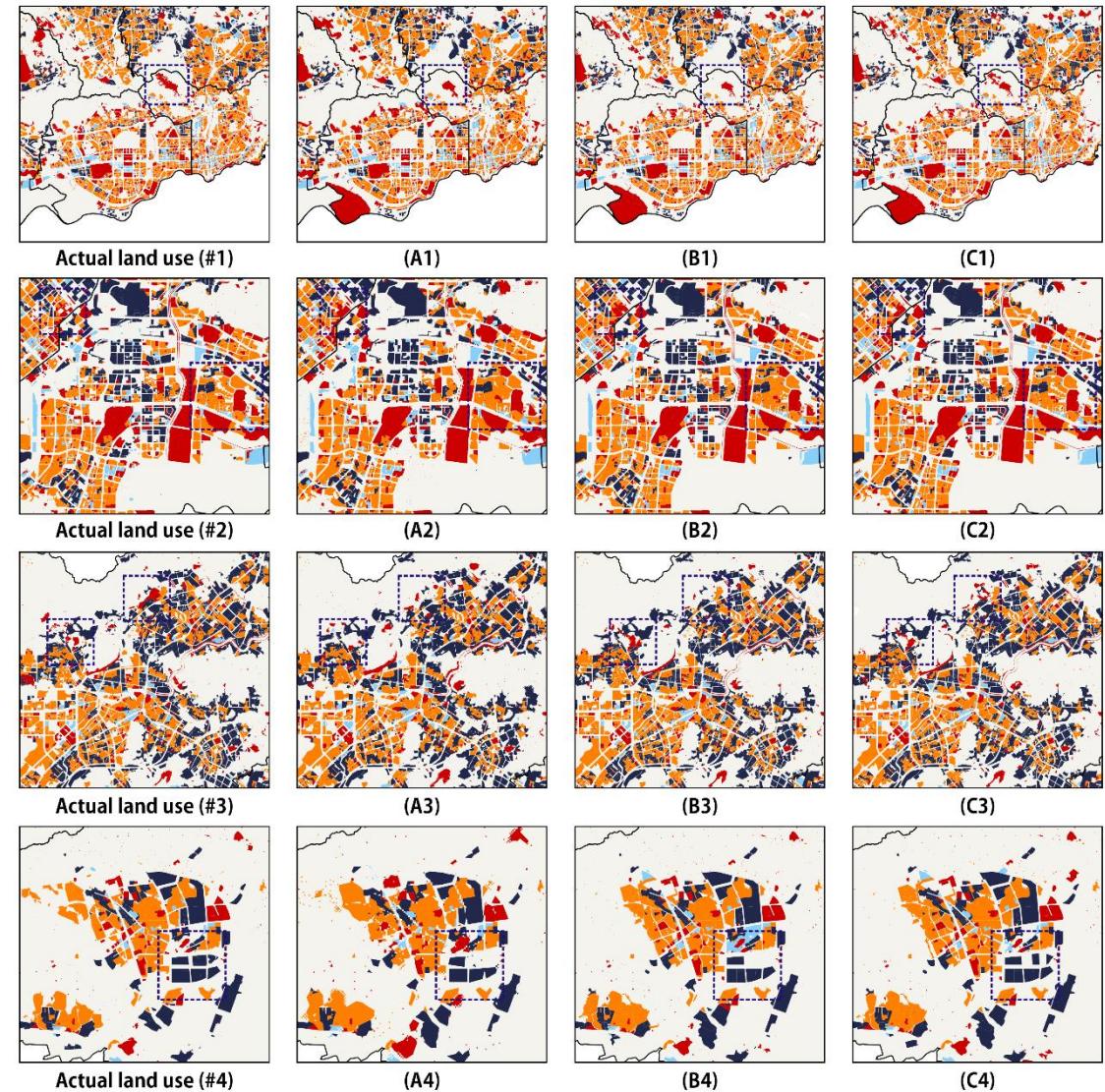


Non-construction land (N)
Public management-services land (P)

Commercial land (C)
Residential land (R)

Industrial land (I)
0 5 10 km
Compass rose

Actual and simulated urban land-use patterns in Shenzhen in 2014. Simulated urban land-use patterns in the study area via (a) Patch-CA, (b) RFA-VCA and (c) DLPS-VCA.



Non-construction land (N)
Public management-services land (P)

Commercial land (C)
Residential land (R)

Industrial land (I)

Compass rose

3.3 | UrbanVCA模型 – 模拟结果及精度评价

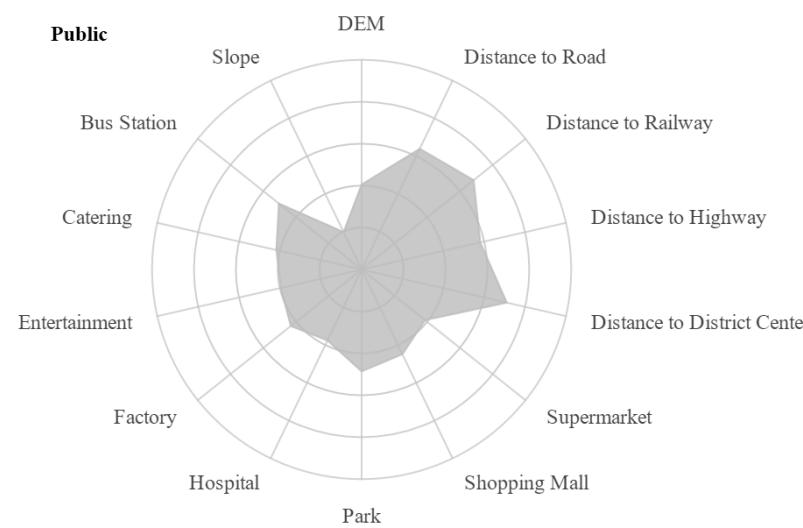


Results	PA	UA	FoM
Patch-CA	29.83%	29.05%	0.175
RFA-VCA	32.74%	31.91%	0.195
DLPS-VCA	37.45%	37.20%	0.232

Results	NP	LPI	ENN	PARA	Similarity
Actual Land Use	28550	67.673	124.799	906.634	-
Patch-CA	26826	66.793	121.022	923.85	87.63%
RFA-VCA	27961	67.001	121.589	911.377	90.95%
DLPS-VCA	27910	67.286	123.596	909.309	94.73%

Districts	Type	NP	LPI	ENN	PARA	Similarity
Futian	Actual	1368	59.22	113.124	746.733	79.21%
	Simulated	1366	57.566	112.871	750.805	
Luohu	Actual	1326	70.875	123.492	833.318	94.11%
	Simulated	1317	71.296	118.485	831.682	
Nanshan	Actual	2199	63.139	161.124	794.401	89.64%
	Simulated	2057	63.896	162.05	795.827	
Yantian	Actual	520	87.307	179.479	893.546	93.39%
	Simulated	498	87.701	163.327	895.857	
Baoan	Actual	8250	60.291	111.796	970.609	87.44%
	Simulated	8473	59.355	108.565	982.972	
Guangming	Actual	2168	69.718	140.569	936.472	71.70%
	Simulated	2071	67.562	132.773	944.271	
Longgang	Actual	6230	59.392	119.576	893.631	95.27%
	Simulated	5907	59.711	119.415	887.44	
Longhua	Actual	3531	50.376	117.156	936.245	79.91%
	simulated	3451	48.844	111.98	944.451	
Pingshan	Actual	1995	73.881	131.569	883.653	96.25%
	Simulated	1924	73.641	128.66	885.43	
Dapeng	Actual	1242	92.088	205.705	913.509	97.36%
	Simulated	1237	91.919	199.651	921.619	
Shenzhen	Actual	28550	67.673	124.799	906.634	94.73%
	Simulated	27910	67.286	123.596	909.309	

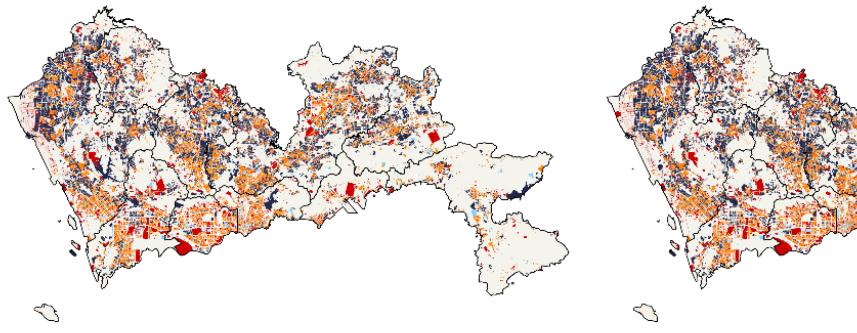
3.3 | UrbanVCA模型 – 驱动因素权重分析



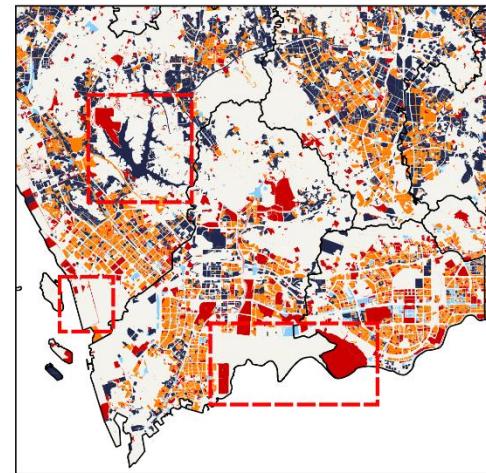
Spatial variables	P	R	C	I
DEM	6.08%	3.00%	5.59%	5.95%
Slope	2.98%	6.95%	3.75%	3.82%
Distance to district centers	10.66%	9.41%	9.05%	10.48%
Distance to railways	10.26%	6.12%	6.76%	13.84%
Distance to highways	8.71%	8.51%	7.14%	7.11%
Distance to roads	9.59%	8.35%	8.31%	8.01%
Density of bus stations	7.58%	9.28%	7.29%	7.12%
Distance to medical facilities	5.64%	8.62%	7.02%	5.30%
Distance to entertainment facil.	5.93%	6.27%	7.15%	5.61%
Density of shopping malls	6.73%	6.53%	7.36%	5.59%
Density of restaurants	6.26%	6.88%	8.77%	6.40%
Density of parks	7.29%	7.41%	6.63%	5.20%
Density of factories	6.49%	5.68%	6.76%	9.63%
Density of whole markets	5.81%	6.99%	8.42%	5.95%

3.3

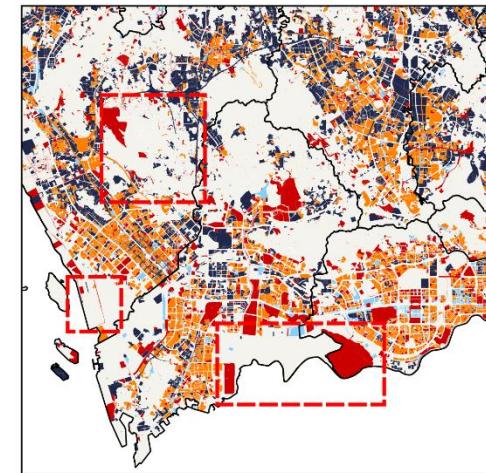
UrbanVCA模型 – 未来多情景模拟



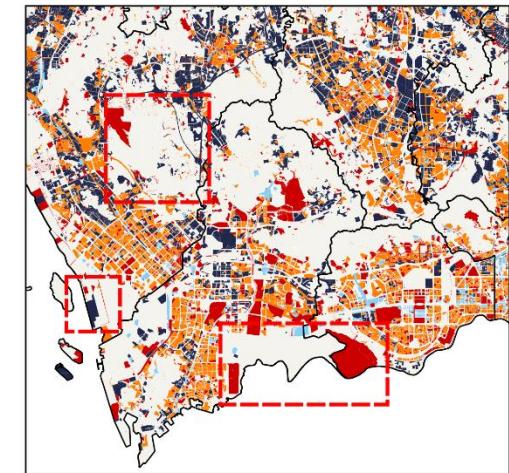
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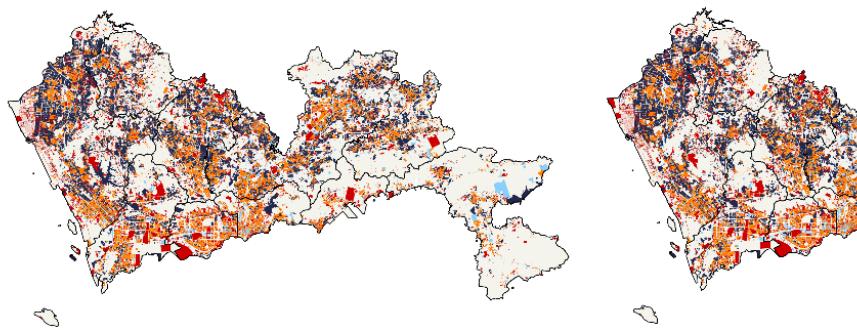
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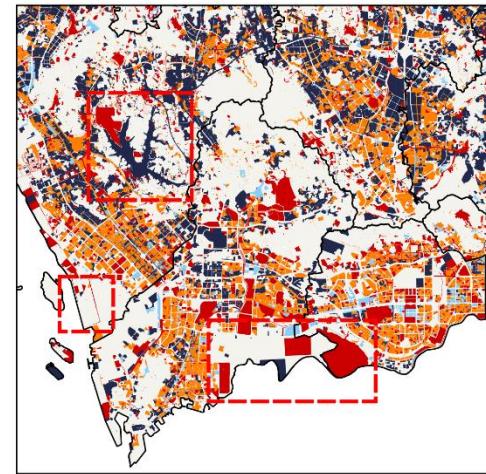
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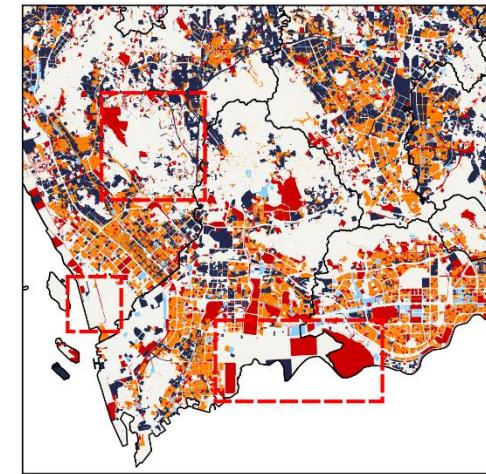
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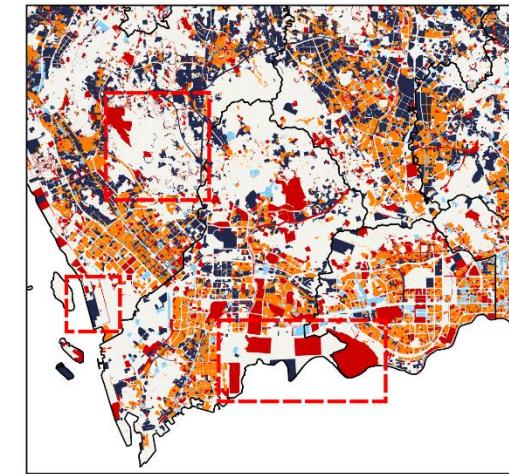
(B1)



(B1)



(B2)



(B3)

Non-construction land (N) Commercial land (C)
Public management-services land (P) Residential land (R)

In

Non-construction land (N) Commercial land (C)
Public management-services land (P) Residential land (R)

Industrial land (I)

0 5 10 km

3.3 | UrbanVCA模型 – 运行界面及下载地址



About Us

UrbanVCA: Land-parcel based Version 1.0.0 Copyright by HPSCIL@CUG Website: <http://www.urbancomp.net>.

UrbanVCA is a GeoAI-based software for the simulation and prediction of urban land-use change process by using vector-based analysis.

UrbanVCA has been well applied in the fields of urban analysis, urban planning and urban landscape index tool.

UrbanVCA supports the display, roaming and interaction of multi-rule mining models, multi-spatial variation and landscape index tool.

UrbanVCA was developed by the following
High-Performance Spatial Computational Intelligence Research Center
School of Geography and Information Engineering
China University of Geosciences, Wuhan, China
[Http://www.urbancomp.net](http://www.urbancomp.net)

User interface developers:
Zhenhui Sun, China University of Geosciences
Linlong Li, China University of Geosciences

Demand Prediction

Simulation Result

Accuracy Evaluation

Iteration	Evaluation
1	0.0
2	0.1
3	0.1
4	0.1
5	0.1
6	0.1
7	0.1
8	0.1

Change Curve of Various Land Parcels

Change Curve of Accuracy Evaluation

城市之光 – Light of A City

HPSCIL@CUG 城市计算小组



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← Accurate Estimation of the Proportion of Mixed Land Use at the Street-Block Level by Integrating High Spatial Resolution Images and Geospatial Big Data

UrbanVCA v1.0.0: 基于真实地块的城市土地利用变化模拟和预测系统

发表于2020年11月8日由yaoyi 511 次浏览

标题: UrbanVCA v1.0.0: 基于真实地块的城市土地利用变化模拟和预测系统即将发布!

Title: UrbanVCA v1.0.0: Actual Land-parcel based Urban Land-use Simulation and Prediction System will be released soon!

在地理智能(GeoAI)快速发展背景下, UrbanVCA是一款基于真实地块和矢量元胞自动机(Vector-based CA) 的城市土地利用变化模拟和预测系统。该系统同时支持城市内的土地利用相互转换和城市用地扩张过程(Yao et al. 2017, Zhai et al. 2020)。

UrbanVCA is a GeoAI-based software for the simulation and prediction of urban land-use change process by using vector-based analysis.

Process

<input checked="" type="checkbox"/> Data Load
<input checked="" type="checkbox"/> DLPS Parameter
<input type="checkbox"/> Conversion Rule Parameter
<input checked="" type="checkbox"/> Pg Parameter
<input type="checkbox"/> Neighborhood Parameter
<input type="checkbox"/> RA Parameter
<input type="checkbox"/> Accuracy Parameter



2009.shp

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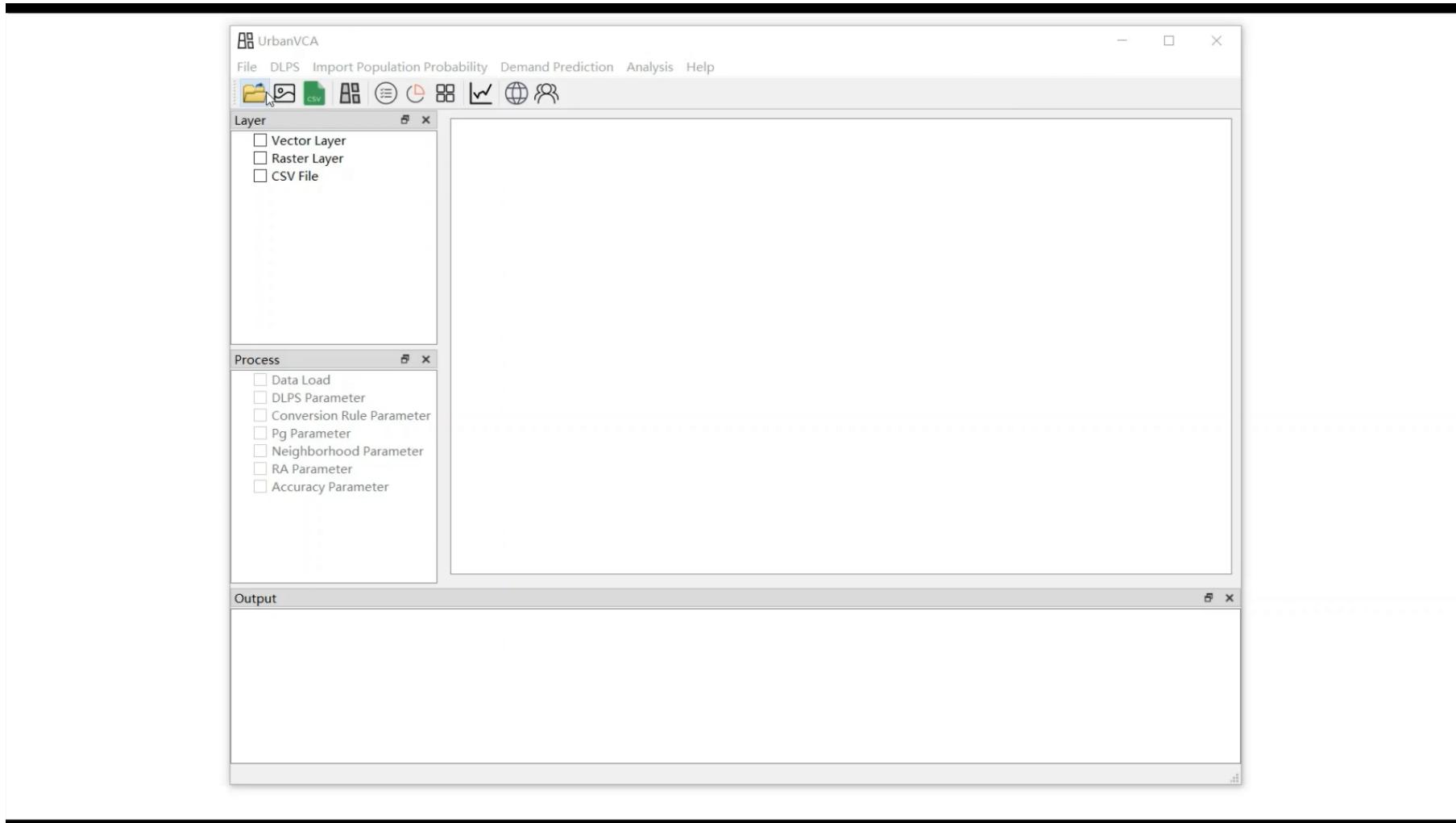


3.3 | UrbanVCA模型 – 运行界面及下载地址



UrbanVCA v1.0.0: 基于真实地块的城市土地利用变化模拟和预测系统，即将发布，敬请期待！

http://www.urbancomp.net/2020/11/08/urbanvca_v1/

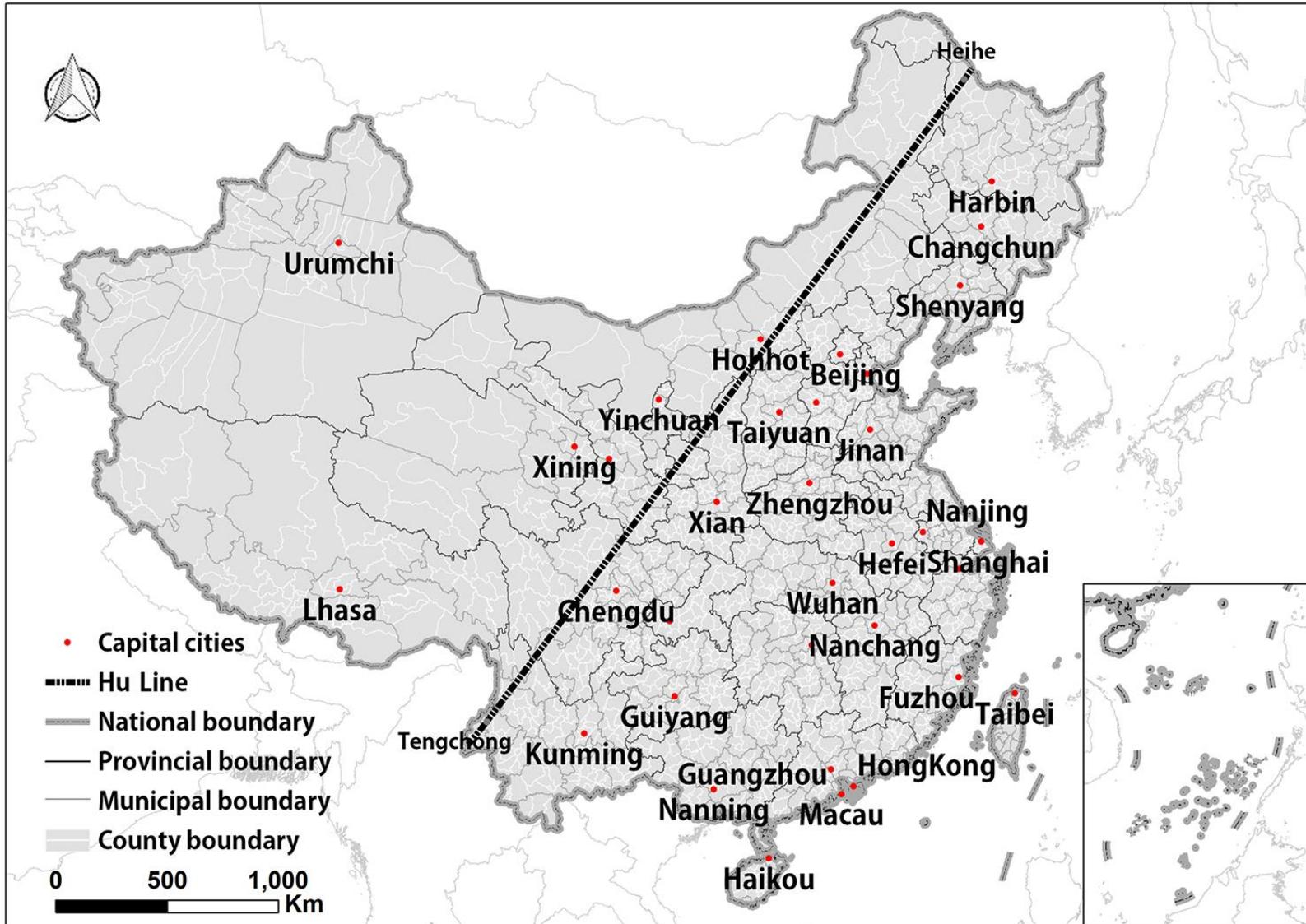




主要内容

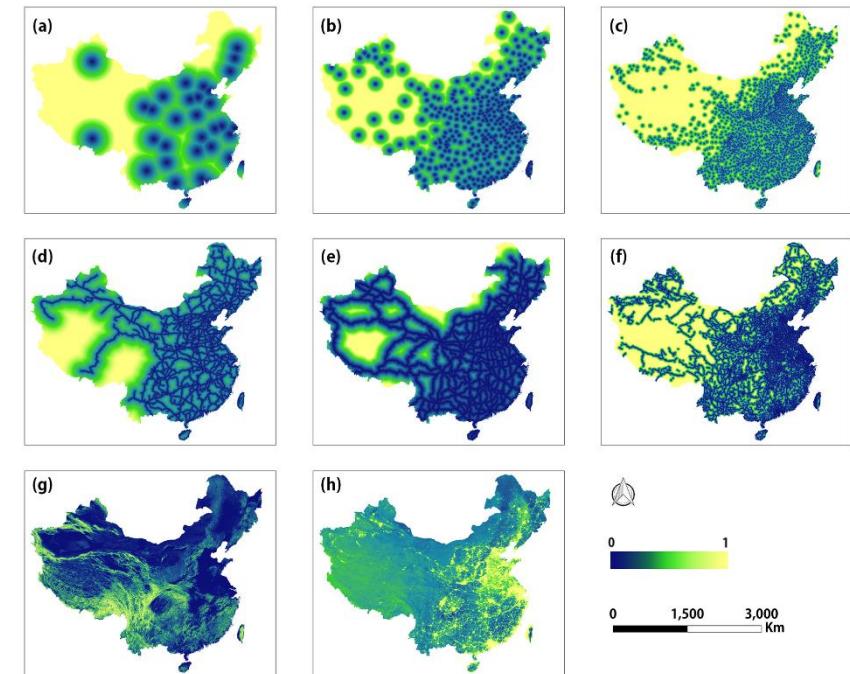
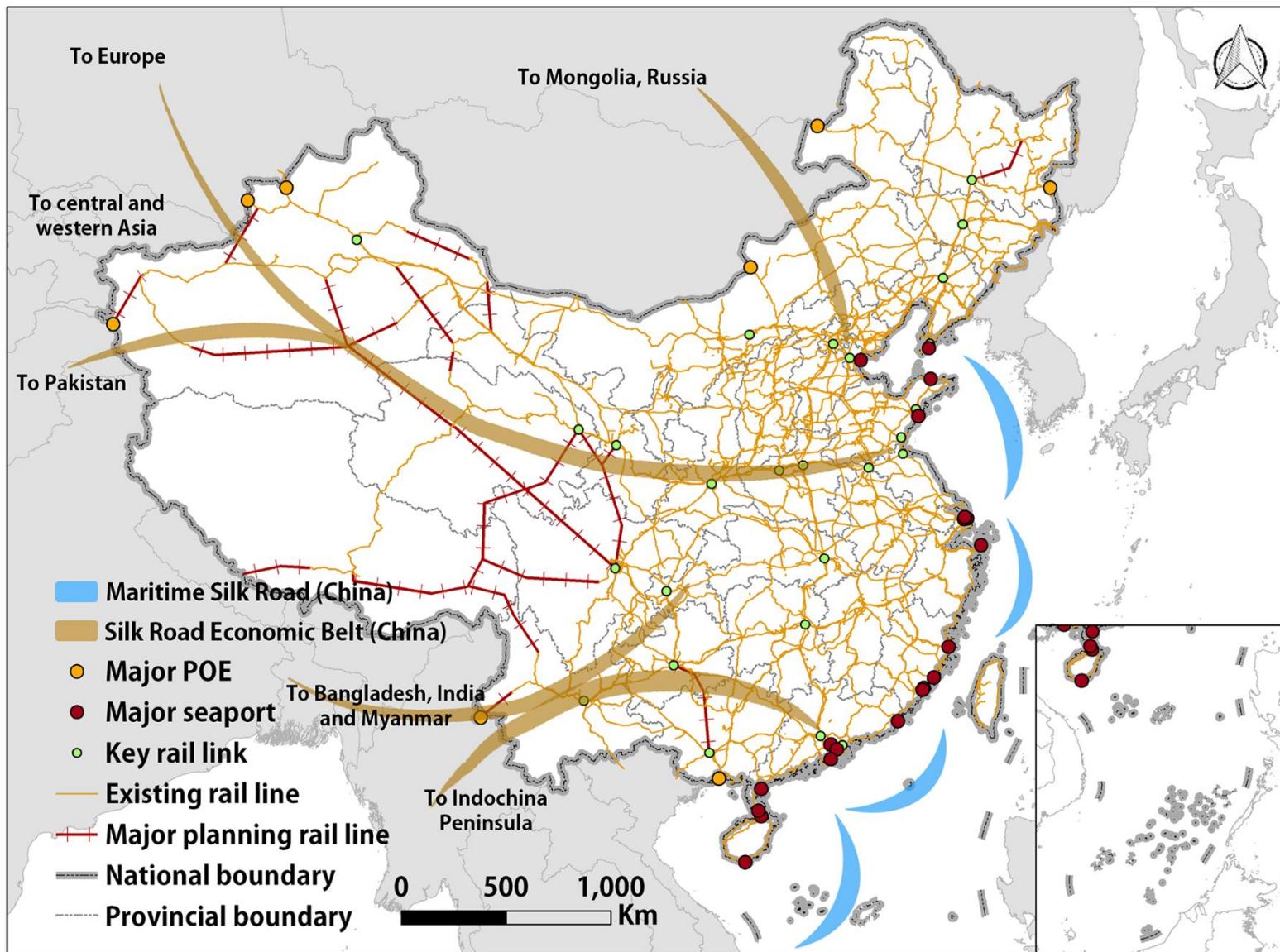


- 1 生命游戏模型
- 2 地理元胞自动机
- 3 城市发展动态模拟模型
- 4 回答 “总理之问”
- 5 微观尺度城市发展模拟



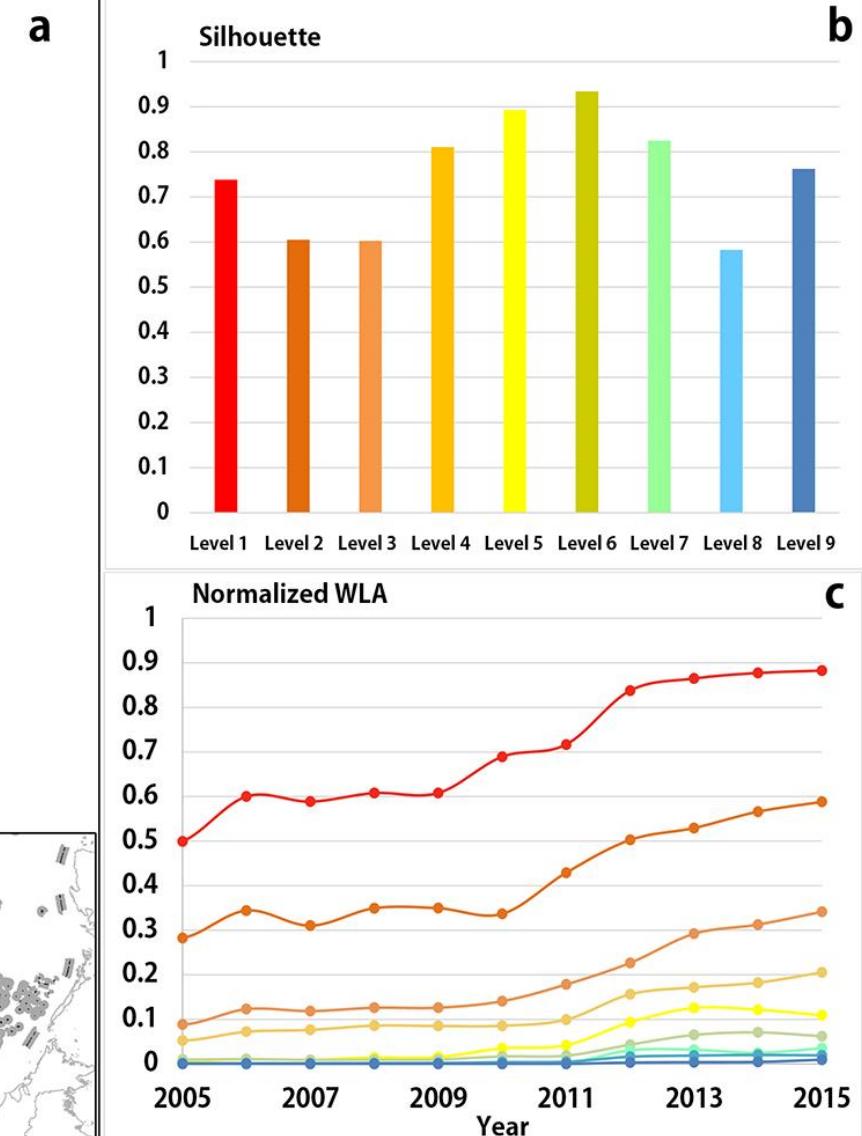
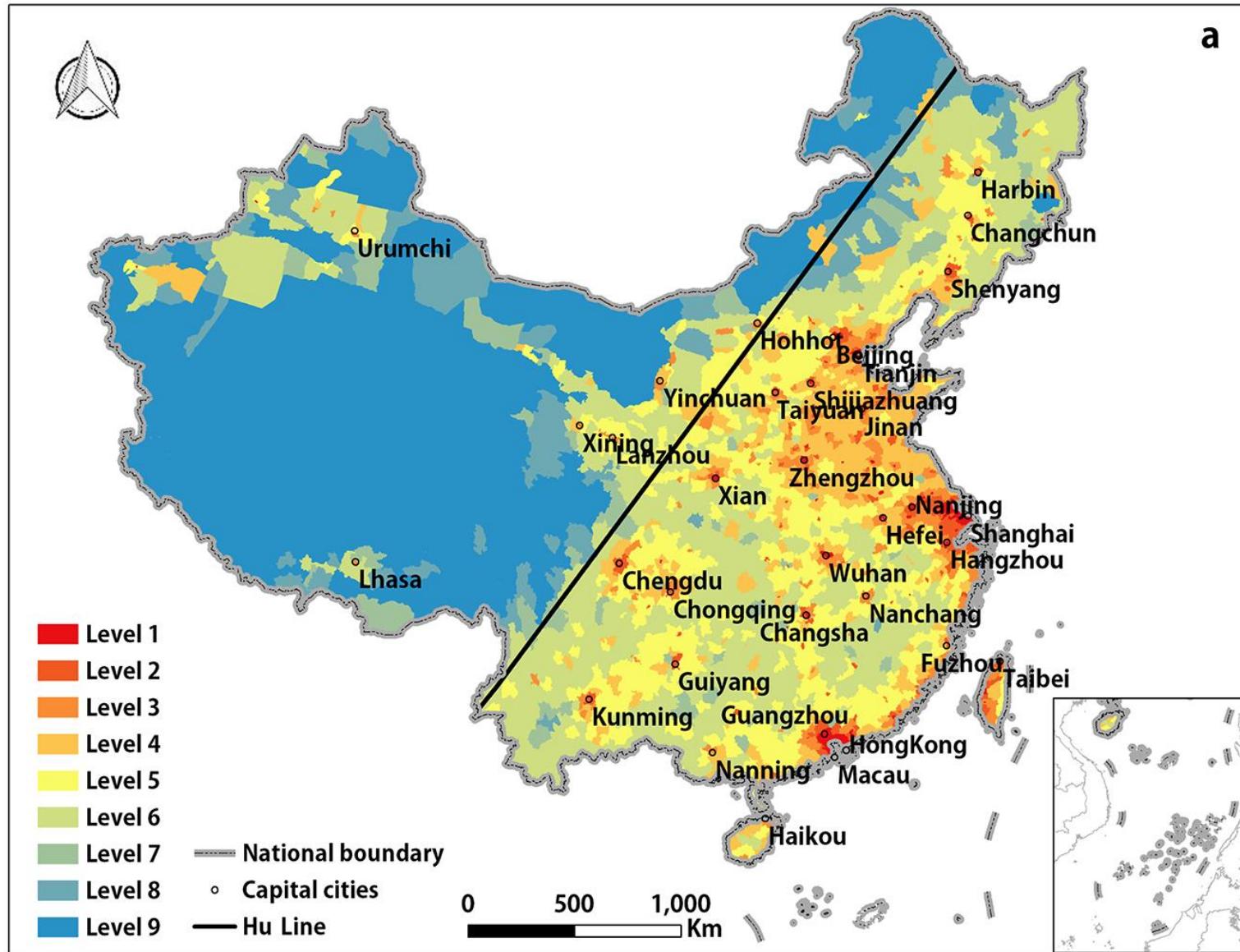
- “胡焕庸线”：
 - 两侧人口比重基本维持稳定
 - 人口密度的空间格局没有发生明显变化
 - 人口分布格局在较长时期内不会发生根本性变化
 - 国内外少有对“胡焕庸线”和中国土地城镇化的定量分析研究
- 新的背景：
 - 我国社会主要矛盾发生转变
 - “一带一路”倡议
 - 《国家新型城镇化规划》

总理之间-中国城市是否会突破胡线格局?

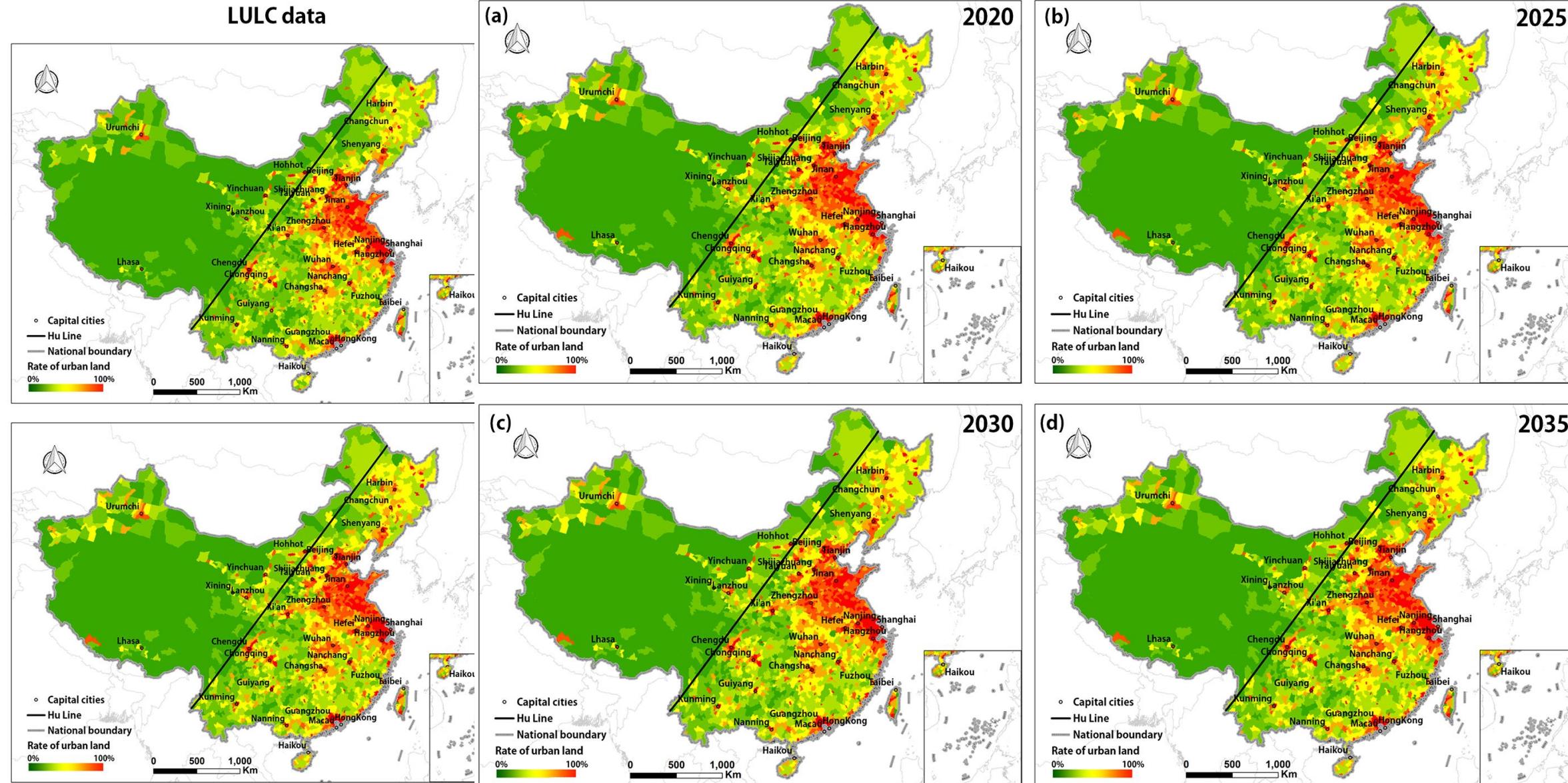


The spatial variables in mainland China. (a) The distance to the capital cities; (b) the distance to the administrative centers of cities; (c) the distance to the administrative centers of counties; (d) the distance to the major railways; (e) the distance to the main roads; (f) the distance to other roads; (g) terrain slope; (h) nighttime lights.

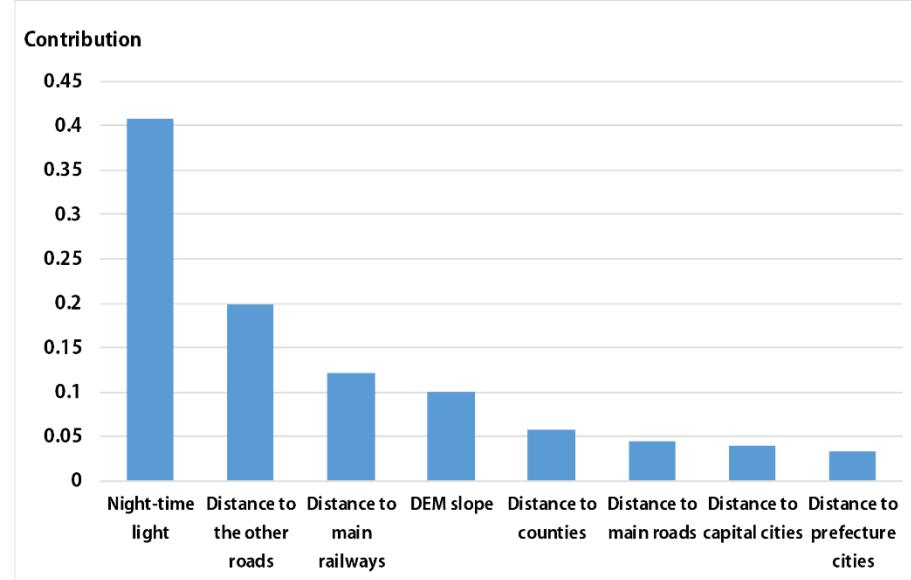
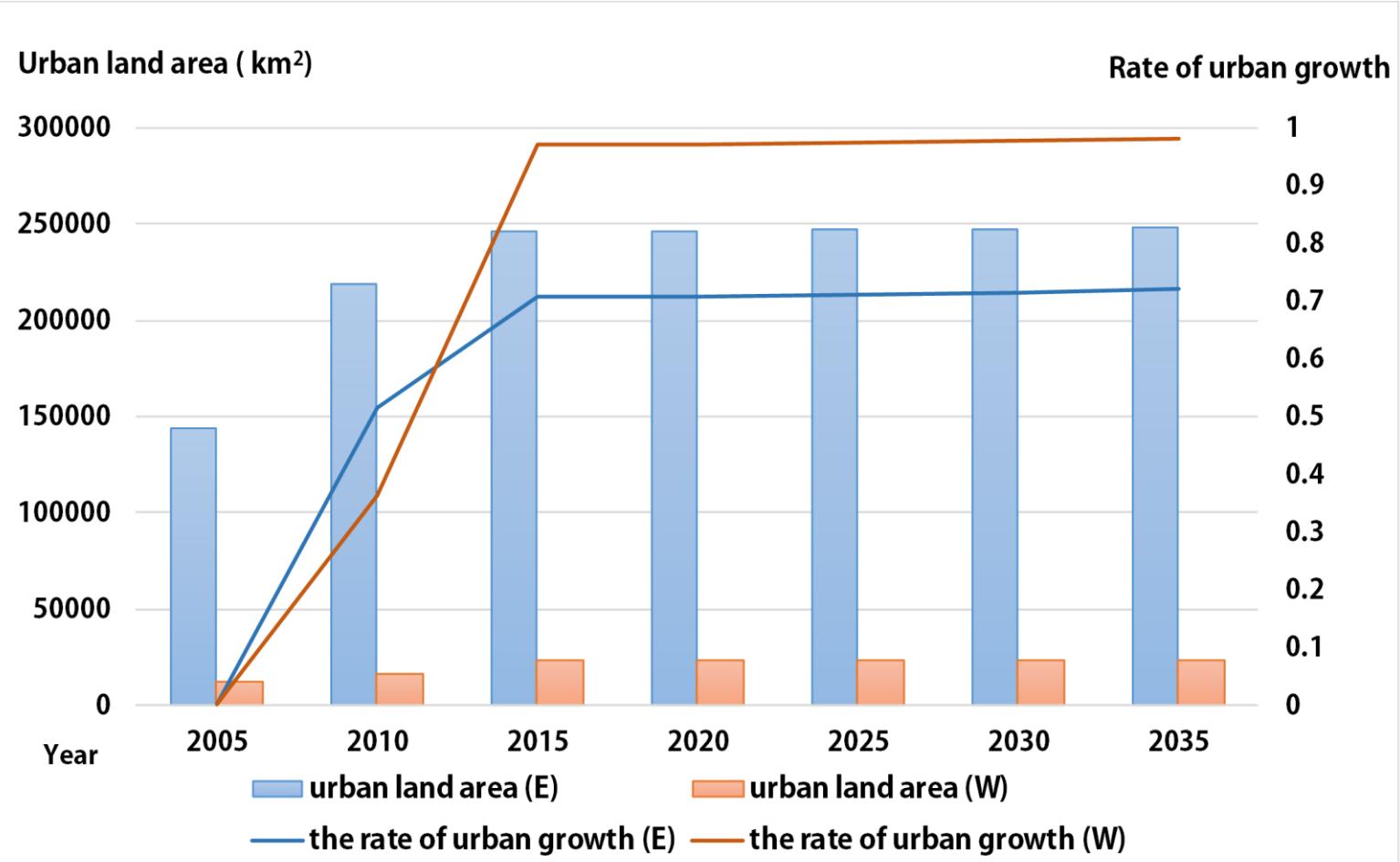
总理之间-中国城市是否会突破胡线格局？



总理之间-中国城市是否会突破胡线格局?



总理之间-中国城市是否会突破胡线格局？



Comparison of landscape metrics between the eastern side (E) and western side (W).

	Year	2020					2025					2030					2035					
		NP	CA	PLAND	COHESION	SHDI	NP	CA	PLAND	COHESION	SHDI	NP	CA	PLAND	COHESION	SHDI	AI	NP	CA	PLAND	COHESION	SHDI
E	2005	9448	3858175	19.69%	93.615	0.674	9408	5649150	28.83%	93.640	0.674	9386	6433525	32.83%	93.634	0.674	9298	6583050	33.59%	91.273	91.281	0.675
	2010	980	311650	1.59%	91.254	0.0296	987	439150	2.24%	91.262	0.0297	995	491550	2.51%	91.273	0.0297	1013	613950	3.13%	91.273	91.281	0.675
W	2005	980	311650	1.59%	91.254	0.0296	987	439150	2.24%	91.262	0.0297	995	491550	2.51%	91.273	0.0297	1013	613950	3.13%	91.273	91.281	0.675
	2015	980	311650	1.59%	91.254	0.0296	987	439150	2.24%	91.262	0.0297	995	491550	2.51%	91.273	0.0297	1013	613950	3.13%	91.273	91.281	0.675

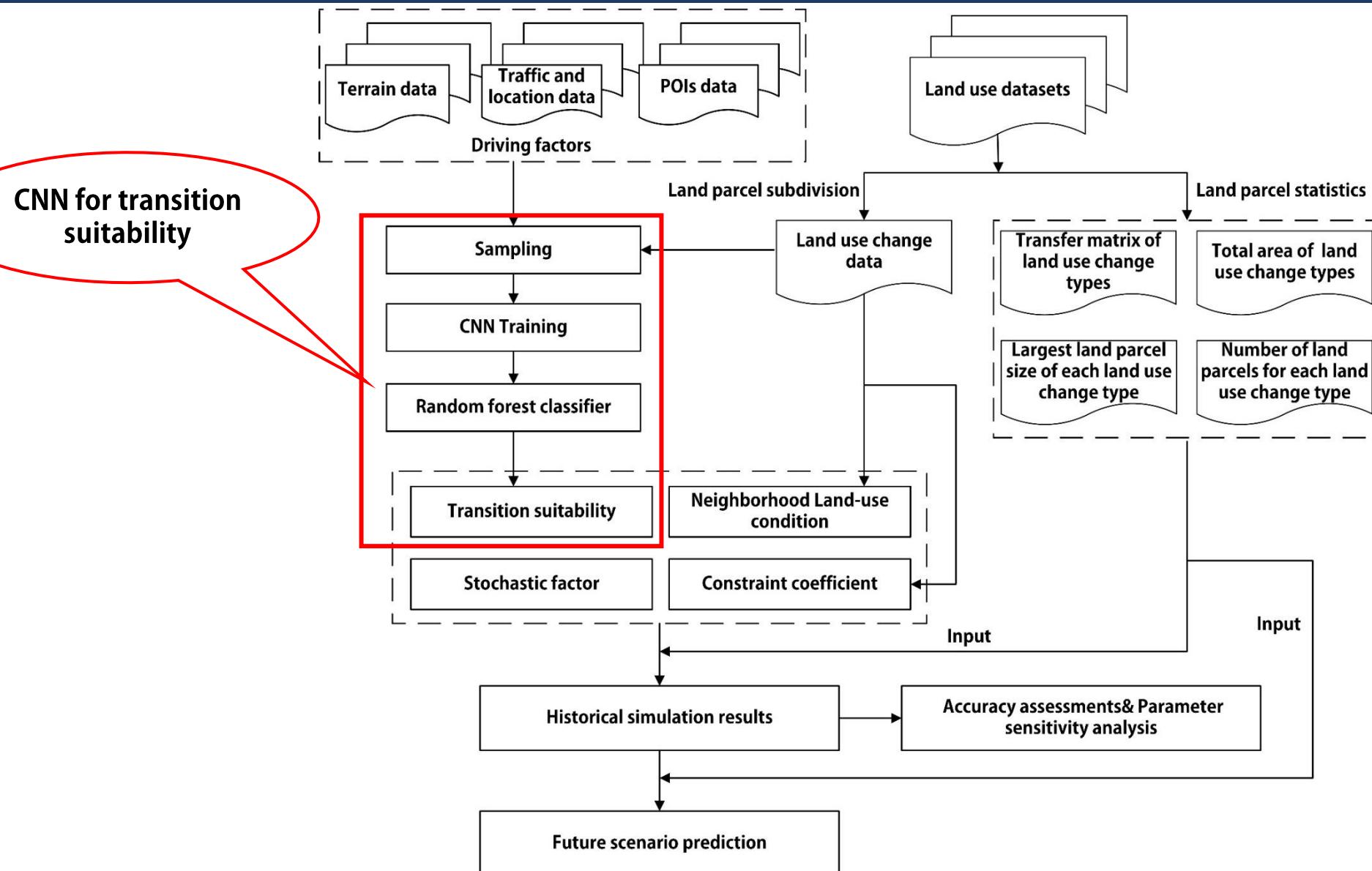
Chen, D., Zhang, Y., Yao, Y.*, Hong, Y., Guan, Q., & Tu, W. (2019). Exploring the spatial differentiation of urbanization on two sides of the Hu Huanyong Line--based on nighttime light data and cellular automata. *Applied Geography*, 112, 102081.



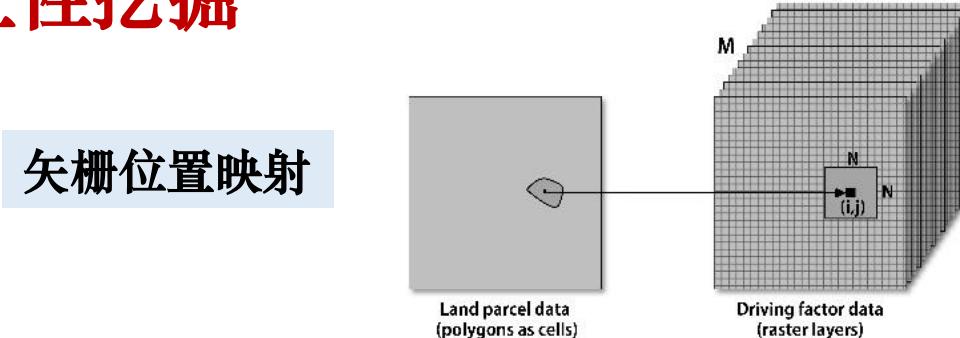
主要内容



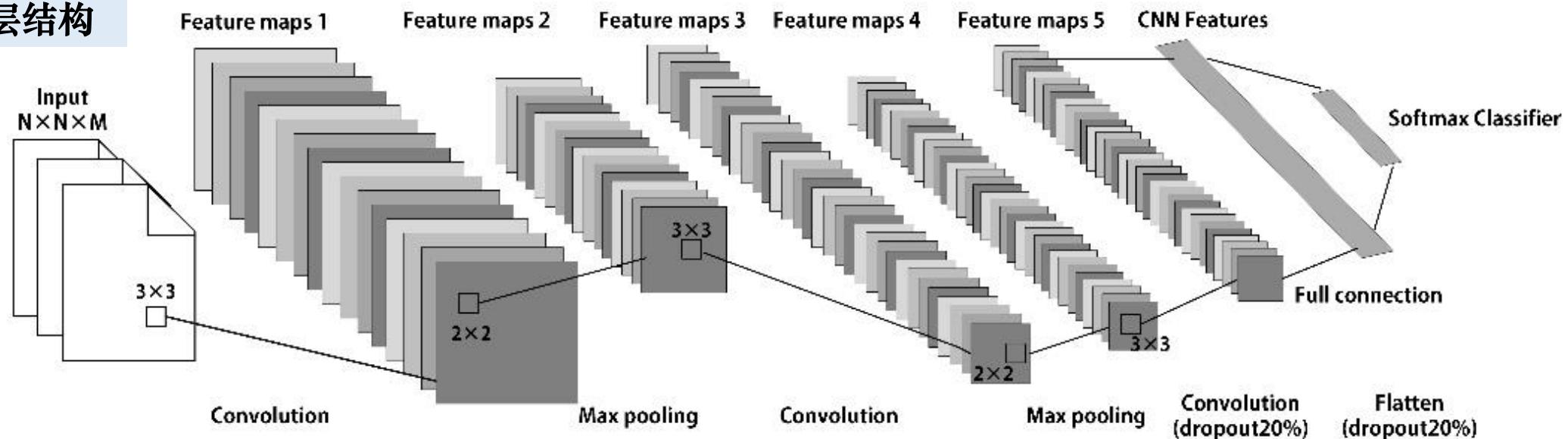
- 1 生命游戏模型
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- 4 回答 “总理之问”
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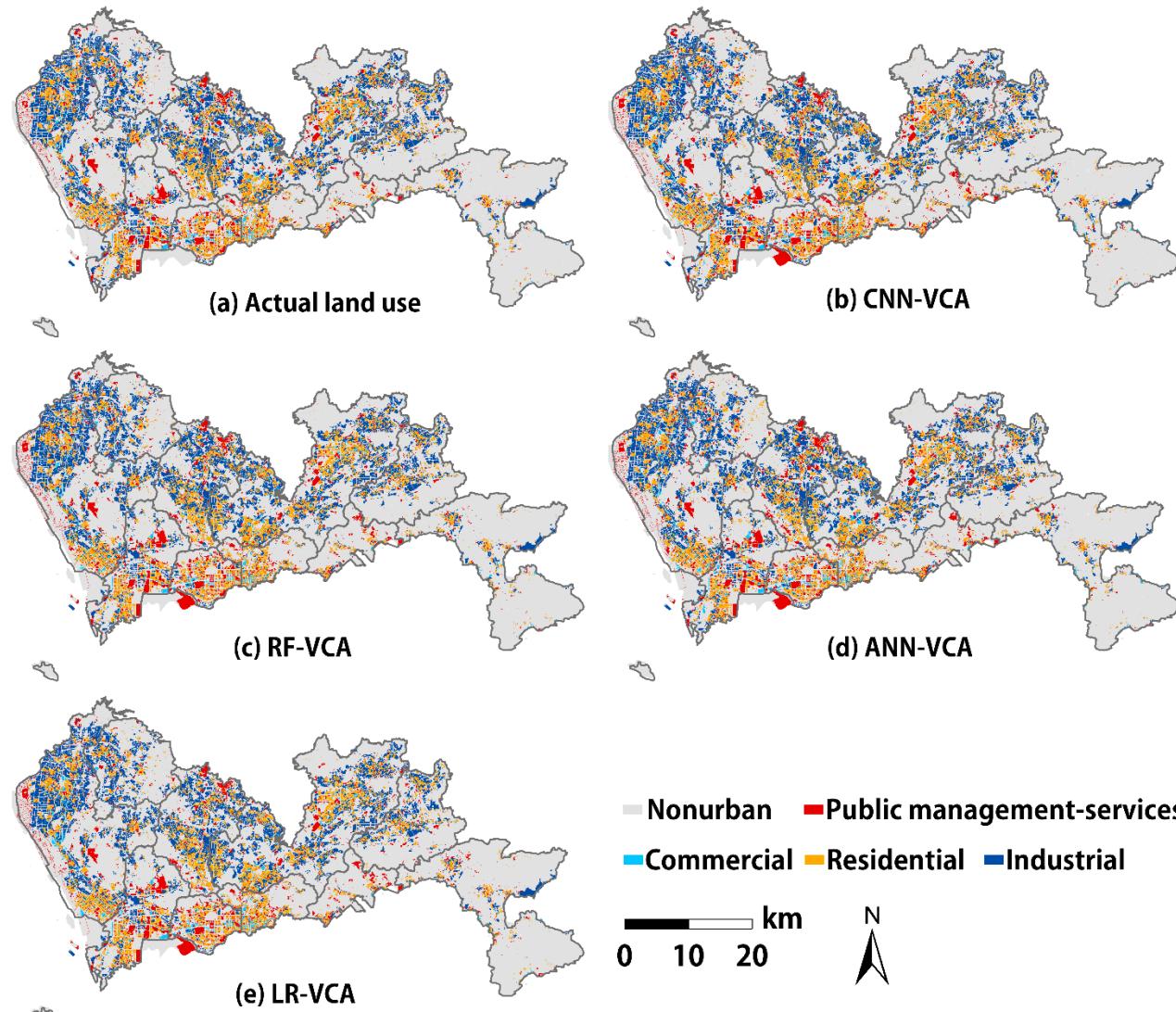


□转换适宜性挖掘



CNN网络层结构



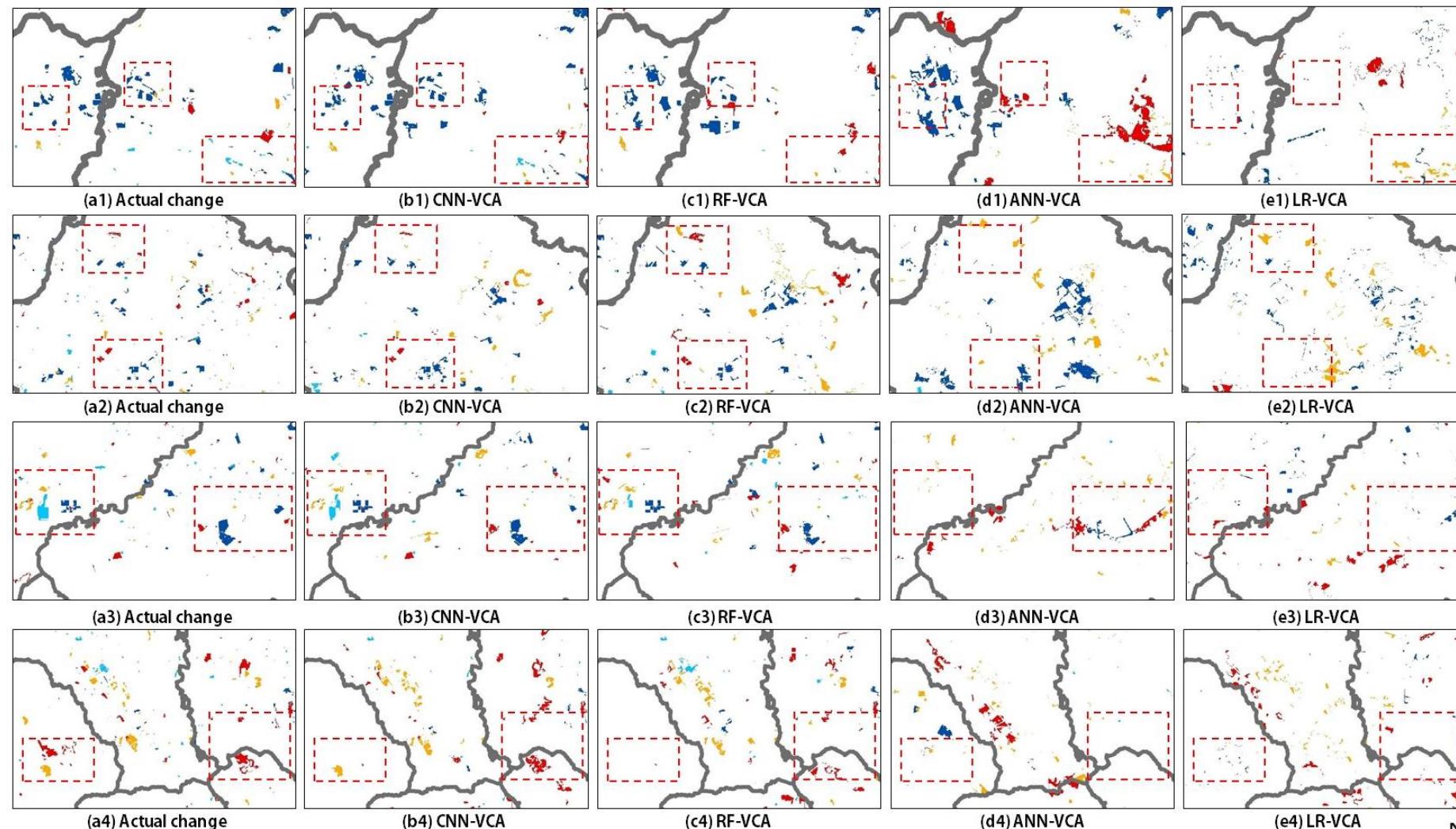


Actual and simulated land uses in 2012 in Shenzhen. (a) Actual land use, (b) simulated land use based on the CNN-VCA, (c) simulated land use based on the RF-VCA, (d) simulated land use based on the ANN-VCA, and (e) simulated land use based on the LR-VCA.

Results	LR-VCA	ANN-VCA	RF-VCA	CNN-VCA
FoM	0.023	0.078	0.323	0.361
PA	0.038	0.133	0.475	0.514
UA	0.054	0.149	0.498	0.539

Results	NP	LPI	ENN	PARA	Similarity
Actual land use	28658	67.566	123.548	907.810	—
LR-VCA	28181	67.036	119.633	908.540	0.855
ANN-VCA	28089	67.226	119.570	911.376	0.901
RF-VCA	28246	67.293	119.521	909.212	0.920
CNN-VCA	28329	67.411	119.762	914.829	0.948

微观尺度城市发展模拟 (CNN-VCA)



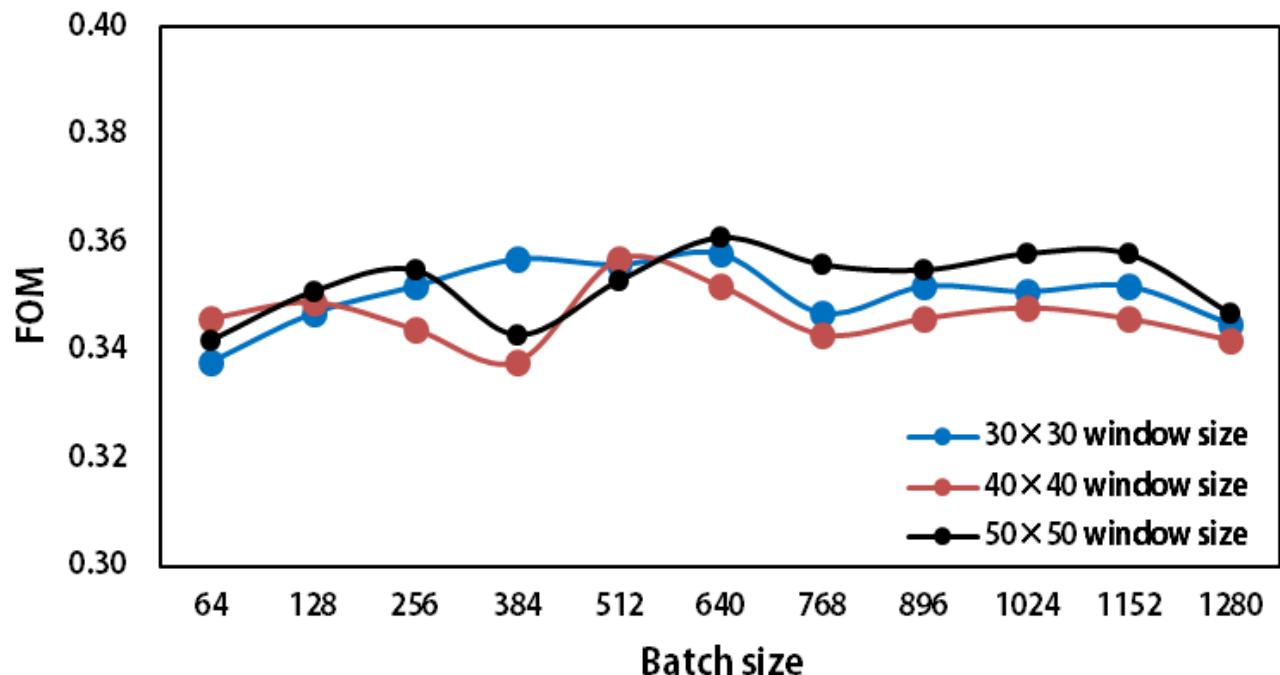
Unchanged ■ Nonurban to public management-services ■ Nonurban to commercial ■ Nonurban to residential ■ Nonurban to industrial



Details of actual and simulated land use changes from 2009 to 2012. (1) Baoan district and Longhua district; (2) Guangming district; (3) Longgang district and Pingshan district; (4) Nanshan district and Luohu district.

Districts	FoM	PA	UA	Actual change (km ²)
Futian	0.419	0.775	0.477	0.674
Luohu	0.259	0.529		
Nanshan	0.178	0.195		
Yantian	0.177	0.402		
Baoan	0.389	0.577		
Guangming	0.356	0.524		
Longhua	0.399	0.518		
Longgang	0.344	0.511		
Pingshan	0.434	0.535		
Dapeng	0.215	0.368	0.333	1.880
Shenzhen	0.361	0.514	0.539	38.163

参数敏感性分析



本章总结



本章介绍了生命游戏模型和地理元胞自动机的概念、组成和地理模拟时空数据，以及元胞自动机在多尺度城市动态模拟方面的应用。

生命游戏的本质是元胞自动机模型，能够根据简单的运算规则发展成为异常复杂的模型。

地理元胞自动机能够解决一些复杂的地理学问题，如城市发展演变、土地利用变化等。

根据元胞的不同形态，本章主要介绍了三种不同的CA模型：基于栅格的FLUS模型、基于斑块的PLUS模型和基于矢量的UrbanVCA模型。这些模型都能够很好地应用于城市发展和土地利用变化模拟，既能为国家制定长远的土地政策和土地战略提供有效的信息，也可以为城市规划部门提供有效的决策支持。

CA模型还能应用于特定城市场景的模拟中，比如：城市群土地利用布局优化、微观尺度城市发展模拟、经济开发区城市用地浮现等。