CoCA: Population-Economy-Land Multifactor Coordinated Development Prediction Model 1.1.0

Instructions for Use



November 2023 HPSCIL

目录

1.	Proc	luct Introduction	3
	1.1.	Installation Method	3
	1.2.	Interface display effect	3
	1.3.	Software control description	3
		1.3.1. Menu bar	3
		1.3.2. Toolbar	4
		1.3.3. Data management module	4
		1.3.4. Data visualization area	5
		1.3.5. Function dialog box	5
		1.3.6. Exception prompt dialog box	6
2.	Data	a display function	7
	2.1.	Basic functions	7
	-	2.1.1. Data file import	7
		2.1.2. Importing and saving project files	8
		2.1.3. Exit	9
		2.1.4. Basic GIS function selection for raster data	9
		2.1.5. Basic GIS function selection for vector data	12
		2.1.6. Basic functionality selection for CSV data	19
3.	Data	a preprocessing	20
	3.1.	Data normalization - Setting null values	20
	3.2.	Data normalization - Resampling	21
	3.3.	Data normalization - Standardization	22
	3.4.	Data normalization - Reprojection	23
	3.5.	Spatial analysis - Natural breaks	24
	3.6.	Spatial analysis - Raster calculator	25
	3.7.	Image classification - Unsupervised classification	26
	3.8.	Image classification- Supervised classification	27
4.	Sim	ulating urban land use change based on the PLUS model	30

	4.1.	Extract land expansion area
	4.2.	Calculate overall development probability
	4.3.	Adaptive Cellular Automata simulation
	4.4.	Markov Chain calculation41
	4.5.	Accuracy assessment
	4.6.	Discrete data discretization45
5	5. Si	mulating urban feature continuity changes based on DensityCA
		model 47
	5.1.	Calculating initial density state of urban developmen47
	5.2.	Calculating overall density development probability of the city49
	5.3.	Extracting urban centers
	5.4.	Simulating the continuity changes of urban features
	5.5.	Accuracy evaluation
6.	Sim	ulating urban land-population-economy changes based on CoCA
		model 66
	6.1.	Simulating urban single-element changes
	6.2.	Simulating multi-factor coordinated changes in the city76
7.	Help	
	7.1.	Website and Update80
	7.2.	About us
8.	Сору	vright Statement and Contact Information81

1. Product Introduction

Target Audience

Geographic Information, Urban Planning Practitioners, and Researchers.

1.1. Installation Method

To extract the compressed file, open the extracted folder and simply click on the

CoCA.exe file to run it directly.

1.2. Interface display effect

secora	-	×
File Data Preprocessing PLUS Model Density CA CoCA Help		
- E 📓 🗅 📰 🖄 🕂 📲 C 🎯 🖺 🗹 🔷 🖄 C 🕺 📓 🎒 🛞 🛞		
Layers B x Carrier Cayer Cov File Cov File		

1.3. Software control description

1.3.1. Menu bar

The content consists of several sections: "Documents", "Data Processing", "PLUS Model", "Density Cellular Automata", "Collaborative Cellular Automata", and "Assistance".

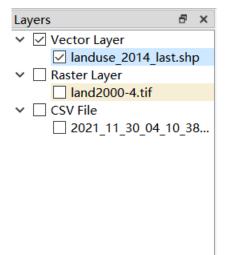
\$ C	CoCA		
File	Data Preprocessing	PLUS Model Density CA CoCA Help	
	S 🔜 🖸 👫	1⁄2 📫 🖽 🕒 🍥 🖺 🗹 🗣 🔷 🕒 🕂 🚳 🎒 🎒	

1.3.2. Toolbar

The content is divided into several sections: "Open Vector File", "Open Raster File", "Open CSV File", "Open Project File", "Save Project File", "Raster Calculator", "Image Supervised Classification", "Image Unsupervised Classification", "Extract Land Expansion Area using PLUS Model", "Calculate Overall Development Probability using PLUS Model", "Adaptive Cellular Automata Simulation using PLUS Model", "Calculate Markov Chain using PLUS Model", "Accuracy Assessment using PLUS Model", "Calculate Initial Density State for Urban Development using Density CA", "Calculate Overall Density Development State for Urban Development using Density CA", "Extract Urban Centers using Density CA", "Simulate Continuity Change in Urban Features using Density CA", "Accuracy Assessment using Density CA", "Simulate Collaborative Change in Single Urban Feature", "Simulate Collaborative Change in Multiple Urban Features", and "About Us". File Data Preprocessing PLUS Model Density CA CoCA Help 📑 📩 💷 🕒 🎯 🖺 🗹 🍼 🗥 🕒 🙉 🖾 🖬 う 📫 💤

1.3.3. Data management module

This area is used to display the opened data and perform some basic GIS functionalities. The data consists of "vector data," "raster data," and "CSV file data." Each module shows the data that has been imported into the system.



By right-clicking on the data that needs to be processed, you can open the toolbar for basic GIS functionalities. The vector data includes five options: "Zoom to Layer," "Open Attribute Table," "Select as Current Operational Layer," "Symbolize," and "Remove Layer."

	Zoom to Layer
⊞	Show Attribute Table
\bigcirc	Select the Current Layer to Operate
5	Edit Vector Symbol
$[\rightarrow$	Remove Layer

The raster data includes four options: "Zoom to Layer," "Select as Current Operational Layer," "Raster Symbolization," and "Remove Layer."

Zoom to Layer	
Select the Current Layer to Operate	
Edit Raster Symbol	
Remove Layer	

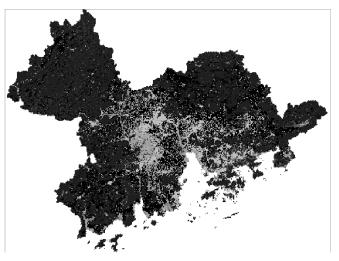
The CSV file includes two options: "Text Preview" and "Remove Layer."

```
Text Preview
Remove Layer
```

1.3.4. Data visualization area

This area is used to display imported vector and raster files, supporting the display

of data after operations such as classification.



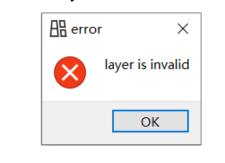
1.3.5. Function dialog box

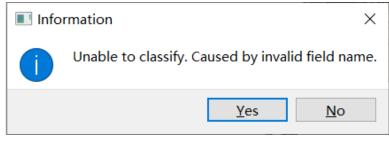
This dialog box is utilized for the selection of the import and save file locations.

🌲 Open vector file		×	
← → ~ ↑ 🖡 « C	CoCA > data > 🗸 🗸) ∕ 搜索"data"	
组织▼ 新建文件夹		:== - [] ?	
🔜 图片 🛛 🖈 ^	` 名称 [^]	修改日期	빝
📙 LanduseDatas	AuxiliaryVariableDatas	2021/11/29 20:48 文华	抣
📜 manageSystem	GDPDatas	2021/11/29 20:48 文件	抣
📙 schoolSystem	📕 LanduseDatas	2021/11/29 20:48 文件	抣
System	PopulationDatas	2021/12/17 21:36 文件	判
langthead of the other sectors and the other	📕 tmp	2021/11/30 16:00 文件	抣
此电脑			
🔮 网络 🛛 🗸	· <		>
文作	件名(N):	 ✓ *.shp 	
		打开(O) 取消	

1.3.6. Exception prompt dialog box

This dialog box is used to prompt the user about the current abnormal state and the reason for the operation in the system.





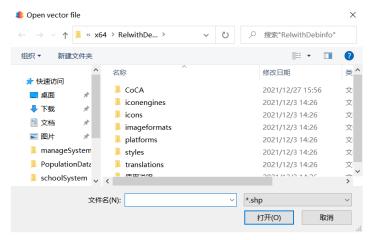


2. Data display function

2.1. Basic functions

2.1.1. Data file import

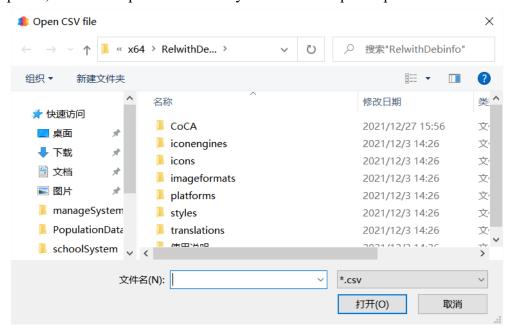
Click on "Open Vector Layer" under the File directory or the icon in the menu bar Open the dialog box for selecting vector files, 用 Users can choose the desired vector files to be added to the main interface for visualization. Import the selected vector file into the system for subsequent operations.



Please click on "Open Raster Layer" under the "File" directory or the corresponding icon on the menu bar to open the "Select Raster File" dialog box. Users can choose the desired raster file and add it to the main interface for visualization. By selecting the raster file to be opened, it can be imported into this system for subsequent operations.

🌲 Open raster file	×
$\leftarrow \rightarrow \checkmark \uparrow$ \blacksquare « x64 > RelwithDe > \checkmark \circlearrowright	
组织 ▼ 新建文件夹	:= • 🔳 🕐
 ★ 快速访问 ● 桌面 ◆ 下载 ◆ 下载 ◆ 下载 ◆ ご 口 ☆ 四月 ◆ 四月 ◆ 四月 ◆ 四日 ◆ 四日	修改日期 美 2021/12/27 15:56 文 2021/12/3 14:26 文
文件名(N):	remote sensing image(*.tif *. ~ 打开(O) 取消

Please click on "Open CSV File" under the "File" directory or the corresponding icon on the menu bar Open the "Select CSV File" dialog box, where users can choose the desired CSV file to add it to the main interface. By selecting the text file to be opened, it can be imported into this system for subsequent operations.



2.1.2. Importing and saving project files

Please click on "Open Project File" under the "File" directory or the corresponding icon on the menu bar Open the "Select Project File" dialog box, where users can choose the desired project file and apply it.

Open project					×
$\leftarrow \rightarrow \land \uparrow$	📙 « хб4	4 > RelwithDebi	~ Ŭ ,	○ 搜索"RelwithDebinfo"	
组织▼ 新建3	文件夹			↓ ► ▼	?
📌 快速访问	^	名称 个		修改日期	类1
	*	CoCA		2021/12/27 15:56	文,
		📜 iconengines		2021/12/3 14:26	文'
➡ 下载	*	icons		2021/12/3 14:26	文⁄
🗐 文档	*	📒 imageformats		2021/12/3 14:26	文,
▶ 图片	*	platforms		2021/12/3 14:26	文,
📜 manageSy	/stem	📜 styles		2021/12/3 14:26	文,
📕 Populatio	nData	translations		2021/12/3 14:26	文'
📕 schoolSys	tem 🗸	▲ (本田)¥n日		2021/12/21/14/26	>
	文件	名(N):	~ *. x	cml	\sim
				打开(O) 取消	

Please click on "Save Project File" under the "File" directory or the

corresponding icon on the menu bar Den the "Save Project File" dialog box,

where users can save the current project at a specified location.

alect Project S	ave Path		×	
← → · ↑	$\leftarrow \rightarrow \lor \uparrow$] « x64 > RelwithDe > \lor O			
组织▼ 新建文	件夹	1 -	?	
📌 快速访问	^ 名称 ^	修改日期	类 ^	
桌面	CoCA	2021/12/27 15:56	文'	
_	iconengines	2021/12/3 14:26	文'	
↓ 下载	icons	2021/12/3 14:26	文,	
🗐 文档	imageformats	2021/12/3 14:26	文,	
■ 图片	platforms	2021/12/3 14:26	文,	
📕 manageSys		2021/12/2 14:26	☆. ¥ >	
文件名(N)	:		~	
保存类型(T)	: xml(*.xml)		\sim	
▲ 隐藏文件夹		保存(S) 取消		

2.1.3. Exit

Clicking on "Exit" under the File directory will close the application.

2.1.4. Basic GIS function selection for raster data

Right-click on the raster data layer that needs to be operated, and after clicking the right mouse button, the following interface will appear:

	Zoom to Layer
⊞	Show Attribute Table
\bigcirc	Select the Current Layer to Operate
<u>.</u>	Edit Vector Symbol
$[\rightarrow$	Remove Layer

2.1.4.1.Zoom to layer

Click on the "Zoom to Layer" option to display the selected vector data layer in its entirety within the data visualization area.

2.1.4.2. Select the current working layer

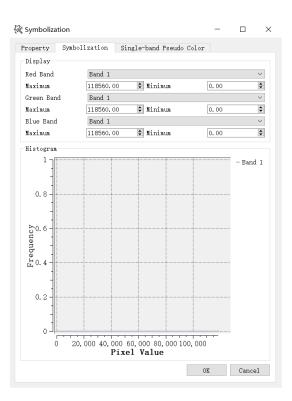
By clicking on the "Select Current Working Layer" option, you can edit the selected data.

2.1.4.3.Symbolize

If the data in the current working layer is raster data, click on the "Edit Raster Symbol" option to open the interface for raster layer symbology.



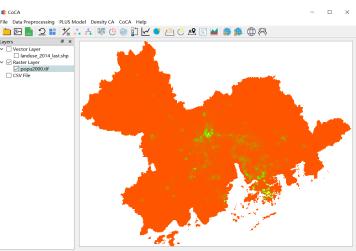
The "Properties" page displays the basic parameters of the selected layer, including the layer name, path, resolution, data storage type, extent, number of bands, and the maximum and minimum pixel values for each band.



The "Symbolization" page can compute the frequency of different bands within a user-specified pixel range.

Syı Syı	🕅 Symbolization					\times
Prop	perty Symbolization	Single-band Pseudo	Color			
Pr	operties (Double click	to change)				
	Code	Condition		Color		
1	0.0636995	> 0.0636995				
2	29640.1	> 29640.1				
3	59280.1	> 59280.1				
4	88920.1	> 88920.1				
Numb	per of Categories					\$
			OK		Cancel	

The "Single-band Pseudo Color" page allows the user to display a single band in pseudo-color. Users can set the number of categories in the "Number of Categories"



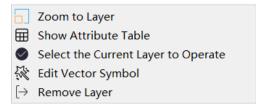
field and click on "Color" to change the color. The effect is as follows:

2.1.4.4.Remove layer

Click on the "Remove Layer" option to remove the selected raster data.

2.1.5. Basic GIS function selection for vector data

Click on "Exit" under the "File" directory to close the application:



2.1.5.1.Zoom to layer

Click on the "Zoom to Layer" option to display the selected vector data layer in its entirety within the data visualization area.

2.1.5.2.Open attribute table

Clicking on the 'Open Attribute Table' option will take you to the attribute table interface, where the attribute table of the selected data will be displayed. We can also edit the attribute table by selecting specific entries. Please refer to the example below:

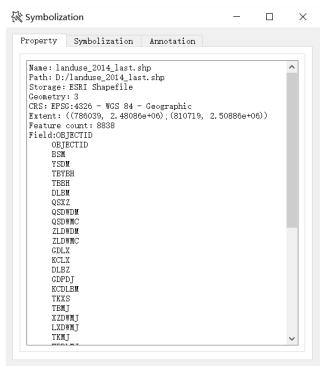
	XHDLMC	街道代	行政区	SHAPE_AREA	SHAPE_LEN	NEW_XHDLMC	type_id	center_lon	center_lat	DL ′
105	公共设施用地	440306007	宝安区	781.56304726800	118.49490266900	市政公用设施用地	9	113.92393315600	22.62350051530	1
106	批发零售用地	440306007	宝安区	420.19099583900	92.00666447480	商业用地	6	113.92421796200	22.62357290030	2
107	农村道路	440306007	宝安区	430.81893770000	251.26439815900	农用地	5	113.92328930500	22.61778341700	0
108	农村道路	440306007	宝安区	366.72908832600	144.18635719900	农用地	5	113.92555638600	22.61673630570	0
09	其他草地	440306007	宝安区	3872.99699557000	344.08097714200	未利用地	10	113.92645219000	22.61633968180	0
10	坑塘水面	440306007	宝安区	5754.32019813000	295.15730851800	农用地	5	113.92408964100	22.61413891470	0
11	坑塘水面	440306007	宝安区	3354.16125365000	222.59141774300	农用地	5	113.92332451100	22.61376555990	0
12	裸地	440306007	宝安区	771.65586216600	183.40319159600	未利用地	10	113.92406183200	22.61843666160	0
13	其他草地	440306007	宝安区	688.27256448400	107.85498704300	未利用地	10	113.92481006300	22.61843986970	0
14	水浇地	440306007	宝安区	2788.46210689000	214.33833141300	农用地	5	113.92447589500	22.61827631220	0
15	果园	440306012	龙华新区	2066.83391973000	254.45811421600	农用地	5	114.01180021500	22.60943511990	0
16	果园	440306007	宝安区	4157.92589519000	302.12723370700	农用地	5	113.92303722800	22.61556439750	0
17	空闲地	440306007	宝安区	270.56095674000	66.26824098400	未利用地	10	113.92371357400	22.61852571420	0
18	工业用地	440306007	宝安区	2497.48993677000	434.61159956300	工业用地	8	113.92380217500	22.61827752850	4
19	空闲地	440306007	宝安区	2952.68624249000	284.05346778100	未利用地	10	113.92347894000	22.61820106530	0
20	其他商服用地	440306007	宝安区	1134.28493804000	145.85045229400	商业用地	6	113.92392630300	22.62311047880	2
21	水浇地	440306007	宝安区	1127.57841342000	176.95434907700	农用地	5	113.92432411400	22.62407444110	0
22	果园	440306007	宝安区	53748.51825070000	1992.17882531000	农用地	5	113.92415979900	22.61993512660	0
23	其他林地	440306007	宝安区	6260.79778191000	1866.09399509000	农用地	5	113.92442725800	22.61470828440	0
24	きまえる	440206007	⇔⇔⊳	1076 21465212000	120 07221024700	sh ⊞th	5	112 02420560100	22 61770620460	ŝ

2.1.5.3. Select the current working layer.

Click on the "Select Current Operating Layer" option to modify the symbology or adjust other parameters of the selected data.

2.1.5.4.Symbolize

If the data of the current operating layer is vector data, click on the "Edit Vector Symbols" option to open the vector layer symbology interface.



The "Properties" page displays the basic parameters of the selected layer, including the layer name, path, storage method, geographic feature type, reference system, coordinate range, number of features, and all attribute field names.

👯 Symbolizati	ion		—		\times
Property	Symbolization	Annotation			
Setup Corr	esponding Colors	and Values for B	ach Land	Use Typ	• 7
Classifica	ation			~	
Value OF	BJECTID			~	
Label OF	BJECTID			~	
Land Use (Code Land Use T	ype Color Selection	on C	olor	1
Classify		elete All			
Classily				-	
		OK		Cancel	

Symbolization page allows you to classify and render features of vector layers. In the "Classification" dropdown menu^{Classification}

You can choose the method for symbolizing the current operating data, and the "Field

Value" dropdown menu allows you to select the field value for symbolization

Value OBJECTID

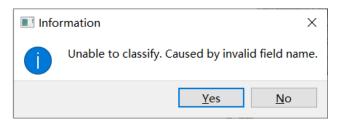
You can choose the field name that will be used for classification of the current layer. Additionally, the "Label" dropdown menu allows you to specify the labeling

option for the classified features.

Label	OBJECTID	~	
			÷

If a non-numeric field is selected in the "Field Value" dropdown menu, an error popup will appear, requesting the user to select a valid field value again:

 \sim



After adjusting the parameters, click the "Classify" button Classify, The

classification symbolization will be performed based on the current parameters. The classification results will be displayed as shown in the following image:

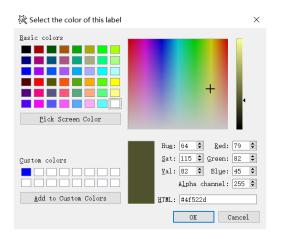
Property Symbolization Annotation Setup Corresponding Colors and Values for Each Land Use Type Classification ~ Value type_id ~						
Classification ~						
Value type id						
value type_ru						
Label OBJECTID ~						
and Use Code and Use Type Solor Selection Color						
1 10 居住用地 Set Color						
2 5 道路 Set Color						
3 13 农用地 Set Color						
4 7 水体 Set Color						
5 8 商业用地 Set Color						
6 9 工业用地 Set Color						
7 6 特殊用地 Set Color						
8 4 保护区 Set Color						
Classify Delete All						

In addition, click the "Add a Class" button A new class can be automatically added by clicking the "Add a Class" button, as shown in the image below:

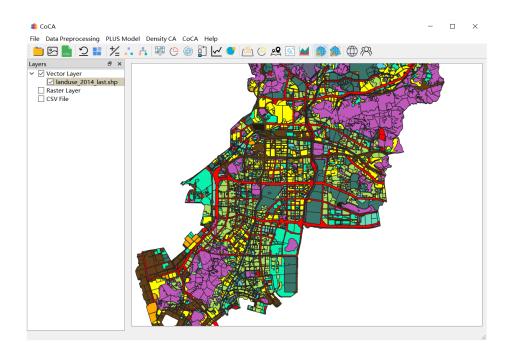
15 14	Set Color	

Click the "Delete All" button. Delete All The current classification results can be deleted, and the table content will be automatically cleared. However, if the user adjusts the classification values and label values through the dropdown boxes after classification, clicking the "Classify" button again will initialize the process and complete the reclassification parameter settings.

After the classification is completed, click on the "Select Color" attribute for each category Set Color, By doing so, you will be redirected to the interface as shown in the image below, where you can modify the color of the category according to your needs:



After setting the relevant parameters, click the "OK" button. OK, After exiting the "Layer Properties" interface, the original layer style with symbolization rendering will be displayed in the visualization area, as shown in the following images:



Annotation page can display corresponding fields on features.

👯 Symboliza	ation		-		×
Property	Symbolization	Annotation			
Annotatic Annotatic OBJECTID	on Field:				~
Annotatio	on Style:				
Font		SimSun			
Size		9			
Color					
Bold		0			
Italics		0			
Preview		Example!			
			OK	Cance	1

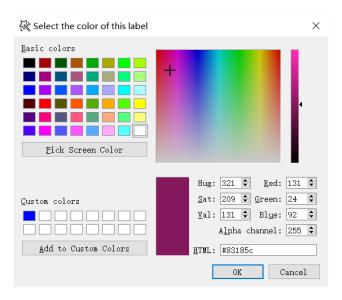
Annotation fields are used to select the fields that need to be displayed.

Annotation Text	
Annotation Field:	
OBJECTID	\sim

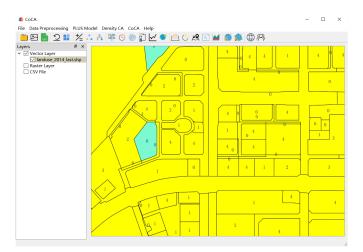
Click on "Font" to change the font.

Select Font				×
<u>F</u> ont AcadEref		Font st <u>y</u> le Regular	Size 9	
AcadEref	^	Regular	6	^
Agency FB			7	
AIGDT			8	
Algerian	~		9	
<	>		10	~
Effects		Sample		
Stri <u>k</u> eout		AgB	bYyZz	
Wr <u>i</u> ting System Any	~			
		OK	Cance	əl

Click on "Color" to change the font color.



The effect is as shown in the image:



2.1.5.5.Remove layer

Clicking on the "Remove Layer" option will remove the selected vector data.

2.1.6. Basic functionality selection for CSV data

After right-clicking on the desired CSV data, a menu will appear similar to the image shown below:



2.1.6.1. Text preview

Clicking on the "Text Preview" option allows you to preview the selected CSV data.

Pr	eview CSV	- 0	×
	1	2	
1	0.00000000	32.0000000	
2	0.00000000	61.0000000	
3	0.00000000	73.0000000	
4	0.0000000	84.0000000	
5	0.00000000	90.0000000	
6	0.0000000	96.0000000	
7	0.00000000	102.0000000	
8	0.0000000	109.0000000	
9	0.00000000	113.00000000	
10	0.0000000	117.00000000	
11	0.00000000	123.0000000	
12	0.0000000	129.0000000	
13	0.00000000	134.0000000	
14	0.0000000	138.0000000	
15	0.00000000	141.00000000	

2.1.6.2. Remove layer

Clicking on the "Remove Layer" option will remove the selected CSV data.

3. Data preprocessing

3.1. Data normalization - Setting null values

After selecting the desired raster data on the main interface, click on the "Data Normalization - Set Null Values" option to open the corresponding interface.

습 D	efine NoData Value	- 🗆	×			
cons	ne NoData Value (Th secutive integers an operties of Land Use T	d start from 1, not	t 0)			
	Land Use Code	NoData Option	Pixel Statistics	^		
1	0	valid Data	73026			
2	2	valid Data	28335			
3	3	valid Data	3715			
4	1	valid Data	13824			
5	6	valid Data	4783	~		
Output						
				•		
			Cancel Acc	ept		

In the "Land Use Code" column, the values of the raster pixels are displayed. The "Pixel Statistics" column shows the number of pixels corresponding to each pixel value. Considering that land use type codes should be continuous integers starting from 1, users can double-click on the "Valid Data" under the "NoData Option" to set invalid pixel values as null values, which will not be included in subsequent calculations.

	Land Use Code	NoData Option	Pixel Statistics	^
1	0	NoData Value	73026	
2	2	valid Data	28335	
3	3	valid Data	3715	
4	1	valid Data	13824	
5	6	valid Data	4783	~

In the Output section, click on Select the output path to export the

edited data.

	■ information ×
■ information ×	
The file selected is not a raster file!	i No land use data
Yes No	ОК

3.2. Data normalization - Resampling

Click on the 'Data Normalization - Rescaling' option to open the corresponding interface. Add the file to this interface and select a base image for resampling to

change t	the	resolution
----------	-----	------------

arget Paras				
dth				
				ł
eight				

User clicks on "Pending Files" Insert the raster file. The table in

"Pending Files" will display the basic information of the input data.

	Path	Name	Data Type	Width	Height	Band Count	Finish
1	D:/vspro	popu200	Float64	416	315	1	False

Pending Files

In the "Target Parameters" section, set the desired width and height for the resampled data.

Target Paras	
Width	
500	-
Height	
400	-

Set the output path in the "Output Path" field, and then click "Run" to output the results.

Output Path	
D:/vsprograms/CoCA/data/PopulationDatas	
Run	

3.3. Data normalization - Standardization

Click on the 'Data Normalization - Standardization' option to open the corresponding interface. Then add the single-band raster data to this interface and standardize it.

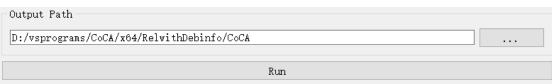
[II] Normalize					_		\times
Add files to this module to nor key to delete) Pending Files	malise the vario	ous types of si	ngle band dat	ta. (Note: Select t	he file and pi	ess the de	lete
Path Name Output Path	Data Type	Width	Height	Band Count	Finish	· · · ·	
						•••	
		R	un				

User clicks on "Pending Files" Insert the raster file. The table in

"Pending Files" will display the basic information of the input data.

Set the output path in the "Output Path" field, and then click "Run" to output the

results.



3.4. Data normalization - Reprojection

Click on the 'Data Normalization - Reprojection' option to open the corresponding interface. Then add the single-band raster data to this interface and reproject it.

Reprojectio	n					_		×
d files to this m y to delete) cending Files		project the vario	us types of si	ngle band dat	a. (Note: Select ti	he file and pr	ess the de	lete
Path	Name	Data Type	Width	Height	Band Count	Finish		
Target Paras Target Raster	r File]	
Output Path]	
			R	un				

The user clicks on the raster file in 'Pending Files' Insert the raster file,

and the table in Pending Files will display the basic information of the input data..

Please set the target raster file in the "Target Raster File" field and set the output path in the "Output Path" field.

Target Paras	
Target Raster File	
D:/vsprograms/CoCA/data/PopulationDatas/popu2000.tif	
Output Path	
D:/vsprograms/CoCA/x64/RelwithDebinfo/CoCA	
Run	

Click "Run". The software will change the reference system of the original single-

band data to the reference system of the target raster file and output the results.

3.5. Spatial analysis - Natural breaks

Click on the 'Spatial Analysis - Natural Breaks' option to open the corresponding interface. Then add the raster data to this interface and perform segmentation clustering on the continuous data, discretizing the data by finding natural breakpoints.

Natural Breaks	—		×
Note: This method allows for segmented clustering of continu of the data by finding the natural break points.	ous data ai	ıd discret	ization
Paras			
Input Image			
Output Image			
Expected Number of Categories			
3			-
Run			

The user sets the raw data in the "Input Image" and clicks on "Expected Number of Categories" to set the interval count. Then, the user sets the output path in the "Output Image".

3.6. Spatial analysis - Raster calculator

Click on the "Spatial Analysis - Raster Calculator" option to open the corresponding interface. Users can add raster data to this interface and perform raster calculations on the pixel values of different bands in the data. Please note that the Raster Calculator operates based on the raster data already added to the main interface.

Therefore, users need to ensure that the data is loaded into the main interface before using this feature.

½ Raster Calculator	-		×
Band Calculator			
Expressions (double-click to execute)			
Expression			
Create Expressions (Enter to add to the list of a	expressi	ons)	
Output Path			
Band Reference (Double click to add)			
Band Number	Band		
1 band(00) "land2000.tif" E	Band: 0		
5			

Users can create expressions in the "Create Expressions" section. The "Band Reference" contains all the bands of the existing raster data. Users can double-click on a band to add it to the current expression.

,	Band Number	Band
band(00))	"land2000.tif" Band: 0
Sana(o	· /	

After creating the expression, users can press Enter to save the expression in the "Expressions" section.

Exp	pressions (double-click to execute)
	Expression
1	"band(00)"*"band(00)"
2	"band(00)"+"band(00)"

Users can set the output path in the "Output Path" field. To calculate and output the result of the formula in the expression list, users can double-click on it.

3.7. Image classification - Unsupervised classification

Please note that the following translation is provided for reference only, as it contains prohibited content. It is important to adhere to Chinese laws and regulations.

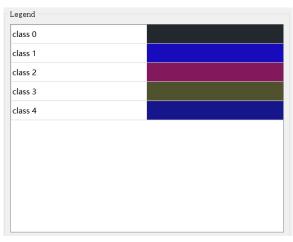
Click on the "Image Classification - Unsupervised Classification" option to open the corresponding interface. Users can add raster data to this interface and perform unsupervised classification on the raster data.

Please note that the unsupervised classification is based on the raster data already added to the main interface. Before using this feature, users need to ensure that the data is loaded into the main interface and click on the "Input Raster File" to switch to the desired data.

Unsupervised Classification	-	>
aster Data Classification		
Parameter Settings		
Input Raster File		
D:/vsprograms/CoCA/data/LanduseDatas/land2000.tif		\sim
Clustering Methods		
k-means clustering algorithm (kmeans)		\sim
Expected Number of Categories		
5		٢
Output Path		
🔽 Save as single-band image		
Classify		

Users can click on the "Clustering Methods" to switch between different unsupervised clustering methods. In the "Expected Number of Categories" section, users can set the desired number of clusters for the analysis. Users can also set the output path in the "Output Path" field and choose whether to save the result as a singleband data by checking the corresponding option.

Once all the settings are configured, users can click on "Classify" to perform the clustering analysis and output the results. The classification results will be displayed in the "Legend" section and added to the main interface.



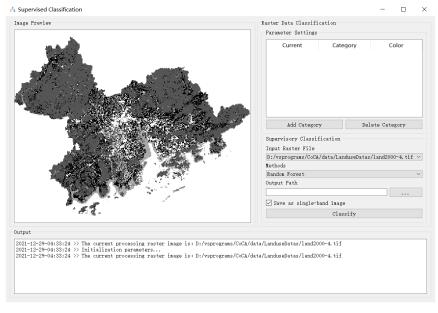
3.8. Image classification- Supervised classification

Please note that the following translation is provided for reference only, as it

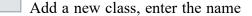
contains prohibited content. It is important to adhere to Chinese laws and regulations.

Click on the "Image Classification - Supervised Classification" option to open the corresponding interface. Users can add raster data to this interface and perform supervised classification on the raster data.

Please note that the supervised classification is based on the raster data already added to the main interface. Before using this feature, users need to ensure that the data is loaded into the main interface.



Users can click on



of the new type in the popped-up window.

🔳 Add	a cate	gory	,			?		×
Please	enter	the	name	of	the	new	ca	tegory
				OK		(Can	cel

Add Category

After adding categories, users can click on the corresponding category's "Current" button to enter the editing mode for that category. Users can annotate objects belonging to that category in the data displayed in the "Image Preview". The annotation method is to click the left mouse button to add points and click the right mouse button to complete the annotation of the region.

	Current	Category	Color
1	Checked	А	
2	Unchecked	В	
3	Unchecked	С	

Users can click on the "Color" button of the corresponding category, which will bring up a color selection dialog. After selecting a new color, the annotated region will change to the selected color.

	Parameter Settings	
a sub	Current Category Color	
	1 Unchecked A	
	2 Unchecked B	
	3 Unchecked C	
	Add Category Delete Category Supervisory Classification Input Raster File D:/vsprograas/CoCA/data/LanduseDatas/land2000-4. tif Methods Randoa Forest Output Path Save as single-band inage Classific	~
`#>`€_	Classify	

Delete Category Users can click on

Then the selected class will be deleted.

Please note that the following translation is provided for reference only, as it contains prohibited content. It is important to adhere to Chinese laws and regulations.

Users can click on the "Methods" option to switch between different supervised classification methods. In the "Output Raster Path" field, users can set the output path and choose whether to save the result as a single-band data by checking the corresponding option.

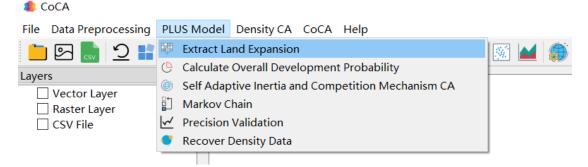
Finally, users can click on the corresponding button to initiate the supervised Classify classification process Once the classification is completed, the results will be outputted. However, if the user has not annotated any classes, a prompt dialog box will appear to remind them to perform the annotations before proceeding with the classification process.

4. Simulating urban land use change based on the PLUS model

4.1. Extract land expansion area

Click on the "PLUS Model" menu bar and select "Extract Land Expansion" from

the popped-up menu.



We can also open the "Extract Land Expansion" module by clicking on the "Extract Land Expansion" button on the toolbar, as shown in the following image:

🐺 Extract Land Expansion	_		×
Note: If only the changed land is considered, the changed land the non-changed land will be set to Nodata.	type will I	oe extract	ted and
Land-Use Data			
Previous land-use data			
Subsequent land-use data			
Output Path			
Run			

Click on the "Previous Land-use data", "Subsequent Land-use data", and "Output Path" buttons in order, In the pop-up folder selection dialog, select the storage paths for pre-change land-use data, post-change land-use data, and extracted expansion land data respectively.

After	completion,	click	the	"Run"	button
	Run		to execu	te the land	l expansion

extraction function.

4.2. Calculate overall development probability

Click on the "PLUS Model" menu bar and select "Calculate Overall Development

Probability" from the popped-up menu.

Soca 🖉				
File Data Preprocessing	PLUS Model Density CA CoCA Help			
늡 🖂 🔜 쑷 💕	🕮 Extract Land Expansion	💽 🖬 🎒 i		
Layers	🕒 Calculate Overall Development Probability			
Vector Layer	Self Adaptive Inertia and Competition Mechanism CA			
Raster Layer	Darkov Chain			
□ CSV File ✓ Precision Validation				

We can also use the "Calculate Overall Development Probability" button on the

toolbar \bigcirc By doing so, you can open the module for calculating overall development

probability. Please refer to the image below for a visual representation:

🕒 Calculate Overall Development Probability) ×
[]	Subsequent Land-use Samples		
	Land Use Data		
	Cot No.	Data Value	
	Driving Data (Select and press the delete key		
	Input Samples		
	input samples	Patri	
			••••
	Related Params		
	Mining method of overall development probabil	ity	
	random forest		\sim
	Sampling rule © Uniform Sampling	○ Manual Sampling ○ Stationary Sa	
	Sampling Rate (1/1000)	300	ampiing
	Sample file data (Polygon vector data)	300	•
	Sample file data (Point data)		
	RF-based Paras NN-based Paras		
	Mr. Daseu Faras MN Daseu Faras		
	Decision Trees Number	80	\$
	Output Pg Path		
	Output Pg Path		
		povert	

First, click on the button in "Land Use Data" , The system will automatically pop up a dialog box where the user needs to select the updated land use data.

Next, click on the button in "Driving Data", The system will

automatically display a dialog box where the user needs to select the dataset of driving factors for training.

Driving Data (Select and press the delete key to delete)	
Input Samples Path	

Afterwards, in the dropdown menu labeled "Mining method of overall development probability," select the mining method for overall development probability. The default option is the random forest model. It should appear as follows: Mining method of overall development probability random forest

random	forest				
neural	network				
	-	-	· · ·		

Then, in the "Sampling rule" section, select the sampling rule from options such as rule-based sampling, random sampling, manual sampling, or static sampling. It should appear as follows:

```
Sampling rule

 Uniform Sampling O Random Sampling O Manual Sampling O Stationary Sampling
```

If you choose random sampling, you need to set the sampling rate by using the "Sampling Rate" option. It should appear as follows:

```
Sampling Rate (1/1000) 300
```

If you choose manual sampling, you need to import the specified sampling area .shp file by using the "Sampling File data (Polygon vector data)" option. It should appear

```
as follows:
Sample file data (Polygon vector data)
```

The specified sampling area .shp file should be in the format of polygon vector data within the same projected area range.

If you choose static sampling, you need to import the specified sampling pixel

location file by using the "Sampling File data (Point data)" option. It should appear as

follows: Sample file data (Point data)

The specified sampling pixel location file should be in the format of "row number, column number,". Here is an example of the data format:

12,	132,
123,	141,
142,	124,
88,	616,
686,	919,

According to the chosen method for mining overall development probabilities, you can set the model parameters in either "RF-based Paras" or "NN-based Paras" as follows:

RF-based Paras NN-based Paras	
Decision Trees Number	80
Lastly, click the button in the "Output	at Pg Path" section, In the pop

up dialog, select the location where you want to store the overall development probability file as shown below:

Output Pg Path	
H:/App/data/test/q.tif	

Click "OK" to start mining the overall development probability (Pg), and the system will display the execution status in the left-side log as shown below:

. . .

```
2021-12-27-21:41:18 >> read land use data.

2021-12-27-21:41:19 >> introducing the driver

"H:/App/data/data/drivingFactors_01/

airport.tif".

2021-12-27-21:41:19 >> introducing the driver

"H:/App/data/data/drivingFactors_01/

city.tif".

2021-12-27-21:41:19 >> introducing the driver

"H:/App/data/data/drivingFactors_01/L1.tif".

2021-12-27-21:41:19 >> introducing the driver

"H:/App/data/data/drivingFactors_01/L2.tif".

2021-12-27-21:41:19 >> training sample

initialization completed.
```

4.3. Adaptive Cellular Automata simulation

Click on the "PLUS Model" in the menu bar, and then select "Self Adaptive Inertia and Competition Mechanism CA" from the pop-up menu.

a CoCA		
File Data Preprocessing	PLUS Model Density CA CoCA Help	
늘 🖂 🔜 🖊 📘	🕮 Extract Land Expansion	🐼 🖬 🏔
Layers	🕒 Calculate Overall Development Probability	
Vector Layer	Self Adaptive Inertia and Competition Mechanism CA	
Raster Layer	🖺 Markov Chain	
CSV File	✓ Precision Validation	
	💙 Recover Density Data	

We can also open the simulation of urban land use change module by clicking on the "Self Adaptive Inertia and Competition Mechanism CA" button in the toolbar, as shown in the following figure:

Simulation Result Accuracy Evaluation			Basic Params	Output			
		Iteration F	om PA	UA	Iteration Rounds 10 Land-use Data	•	
					Land-use Data (Reference)		
					Pg File Path		
					Constrain File Path		
					Neighborhood Size 3 Patch Generate 0.90	•	
					Patch Generate 0.90 Step Size 400	•	
					Land-use Demand Cost Matrix Weights		
nge Curve of Various Land Parce	ls C	hange Curve of th	e Accuracy Indices				
00		Accuracy 6 and a solution 6 and a solution 7 and a solution 8 and 8 and					
00		0.6			🗹 Use Default Symbolization Plan		
.00		ਹੋ ਦ 0. 4			Set Symbolic Scheme		
200					Output File Path of Simulation Result		
E		0-14			Export Parameter File (.xml)		
0 200 400 600	800 1.000	0 2	00 400 600	800 1,000	Run		

iterations the First, number of in input enter the box -10 Please set the number of iterations Iteration Round for this simulation. This parameter represents the number of times the simulation will iterate.

Next, click on the buttons on the right side of "Land-use Data", "Land-use Data (Reference)", "Pg File Path", and "Constrain File Path" in order ______, In the pop-up folder selection dialog, select the path for the pre-change real land-use data, post-change real land-use data, Pg file storage, and constraint development file storage, respectively, as shown below:

Land-use Data	
Land-use Data (Reference)	
Pg File Path	
Constrain File Path	
Constrain File Path	

Please note that the "Constrain File Path" function is used to restrict the development of specific areas, and the path can be left empty if not needed. If you want to use this function, make sure that the data format is as follows: GByte raster data with

only 0 and 1 values, within the same projection range. 0 represents prohibited development land, and 1 represents developable land.

Next, we need to select the relevant parameters required for the model simulation. Set the neighborhood size on the right side of "Neighborhood Size" Neighborhood Size 3 : Set the decay coefficient size on the right side of "Patch Generate" to determine the rate of decay for patch generation : Set the step size on the right side Patch Generate 0.90 "Step Size" determine the size of each step in the simulation of to • Step Size 400

Click on the button below "Land-use Demand", In the pop-up dialog, you can choose a CSV file to customize the number of developments for each land-use type. The format of the CSV file should be "Type_1, Type_2, Type_3...Type_n". If you ignore this function, the system will automatically use the number of developments for each land-use type based on historical data.

Land-use Demand	Co	st Matr	ix	Weights	
		Type 1	Туре	e	
Future Pixel Numb	er	/	/		
<			>	•	

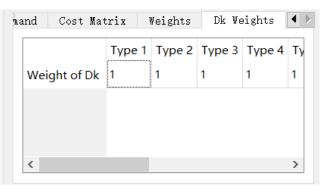
To customize the conversion restrictions for each land-use type, double-click on the conversion matrix in "Cost Matrix". You can define the restrictions as follows (to indicate that Type 1 cannot be converted to Type 2):

Land-us	e Demand	l Cost	Cost Matrix			∛eights	; I I I
	Type 1	Type 2	Type 3	1	^		
Type 1	True	False	True	Т			
Type 2	True	True	True	т			
Type 3	True	True	True	т			
- -	-	Ŧ	-	>	~		

To customize the neighborhood weight for each land-use type, double-click on the neighborhood weights in "Weights". In the pop-up dialog, you can define the weights as follows, with the default value being 1:

Land-use Demand	Cost M	atrix	Weights	s 1 •
		Type 1	Type 2	Type 3
Weight of Neighb	orhood	1	1	1
<				>

To customize the Dk weights for each land-use type, double-click on the Dk weights in "Dk Weights". In the pop-up dialog, you can define the weights as follows, with the default value being 1:



After setting the above parameters, if you want to customize the display symbols for different parcels, you can click on the "Use Default Symbolization Plan" checkbox

 Set Symbolic Scheme
 To use a custom symbolization plan, click on the

 "Set Symbolic Scheme" button
 Set Symbolic Scheme

	operties of Land	ngo)				
1,	opercies of Land					
	Land Use Code	NoData Option	Pixel Statistics	Name	Color	^
1	2	valid Data	28335	Type 2		
2	3	valid Data	3715	Туре 3		
3	1	valid Data	13824	Type 1		
4	6	valid Data	4783	Туре б		
5	9	valid Data	2080	Туре 9		
6	7	valid Data	4331	Type 7		
7	4	valid Data	824	Туре 4		
8	5	valid Data	103	Type 5		~

box will pop up to allow you to set symbols for vector parcels as follows:

Clicking on the color of each category will take you to a screen like the one shown

Select the color of this label	×
Basic colors	+
Pick Screen Color	
Custom colors	Hug: 212 Red: 35 Sat: 61 Green: 40 Val: 46 Blue: 46 Alpha channel: 255
Add to Custom Colors	<u>H</u> TML: #23282e
	OK Cancel

below, where you can modify the color according to your needs:

Click the "OK" button K, you will complete the customization of symbolization settings.

In order to facilitate future research, you need to click the button in the "Output File Path of Simulation Result" function _____, In the pop-up dialog box, select

the	path	where	you	want	to	save	the	simu	lation	results.
Outpu	ut File Path	of Simulatio	on Result							
					o					
	Click	the	"	Export		Parameter	•	File	"	button
	Export Parameter File (.xml), You can save and export all the parameter									
setti	ngs on th	e current in	nterface	in XML f	ile f	format.				

Finally,	click	the	"Run"	button	on	the	simulation	interf	àce
	Run			, It car	1 auto	matica	lly simulate	changes	in

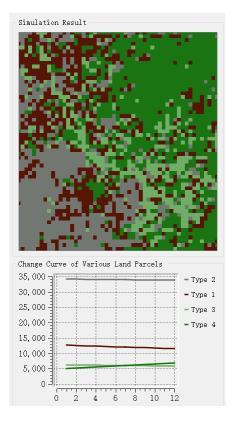
urban land use types, as shown in the figure below:

Simulation Result	Accuracy Evaluation	Basic Params	Output
	Iteration FoM PA UA	Iteration Rounds 12 🗘	2021-12-27-14:58: 48 >> Iteration
		Lambres Data Lambres Data V1_04/data/lata/lamd-4/land2000-4.tif Landruse Data (Reference) V1_04/data/lata/land-4/land2010-4.tif Fg File Path App/CoCA_App_v1_04/data/test/Pg_1.tif Constrain File Path Reighborhood Size S Patch Generate 0, 90 Step Size Mand Cost Matrix Veights Dk Veights Type 1 Type 2 Type 4	5. 2021-12-27-14:58: 49 >> Result is saved to B:/App/ CoCA_App_v1_04/ data/ust/5.1:58: 49 >> Iteration 6. 2021-12-27-14:58: 49 >> Result is saved to B:/App/ CoCA_App_v1_04/ data/test/6.1:1 2021-12-27-14:58: 2021-12-27-14:58: > Iteration 5. 2021-2-27-14:58: 2021-12-27-14:58: 2021-22-27-14:58: 9.> Result is saved to B:/App/
ange Curve of Various Land Parcels	Change Curve of the Accuracy Indices	Weight of Dk 1 1 1 Image: Set Symbolization Plan Set Symbolization Result Utput File Path of Simulation Result H:/App/CoCA_App_v1_04/dta/test Export Parameter File (_xal)	CoCA_App_v1_04/ dta1/test/7.tif. 2021-12-27-14:58: 0 >> Iteration 8 0 >> Revail tis saved to H:/App/ CoCA_App_v1_04/ dta1/test/8.tif. 2021-12-27-14:58: 50 >> Iteration 9. 2021-12-27-14:58: 50 >> Iteration 9. 2021-12-27-14:58: 50 >> Iteration 9.

After the program finishes running, this system will display the final land use type map, accuracy evaluation indicators for each iteration, a line graph showing the number of changes in each land plot type, and line graphs depicting the changes in each accuracy evaluation indicator, as shown in the figure below:

ulation Result	Accuracy Evalu	uation			Basic Params Output
	Iteration 0. 1 0. 2 0. 3 0. 4 0. 5 0.	FoM .016332 .0295753 .0449303 .0566728 .0639636	0.0532006 0.0705548 0.083926	0.197302 0.211061 0.211064 0.201228	Iteration Rounds 12 saved to H:/App Land-use Data CoCA_App_ul_04/data/test/7.ti CoCA_App_ul_04/data/test/7.ti Land-use Data (Reference) 2021-12-27-14: M_1_04/data/data/land-4/land2010-4.tif 2021-12-27-14: Pg File Path CoCA_App_ul_04/data/test/Pg_1.tif App/CoCA_App_ul_04/data/test/Pg_1.tif Costrain File Path Costrain File Path Costrain File Path Costrain File Path
	7 0. 8 0.	.0742893 .0815476 .0899905 .0969042	0.116927 0.134282	0.204105 0.201273 0.202575 0.202294	9. Neighborhood Size 3 Patch Generate 0.90 Step Size 400 tand Cost Matrix Weights Dk Weights August Cost Matrix Weights Dk Weights
nge Curve of Various Land Parcels		.110467	0.167852 0.184353 uracy Indice	0.203941 0.204223	Type 1 Type 2 Type 3 Type 4 Weight of Dk 1 1 1 1 U 1 1 1 1 U 0:02-12-27-14: 50 > Result is aved to B:/App.vl.04 U 0:02-12-27-14: 0:02-12-27-14: 0:02-12-27-14:
000 000 000 000 000 000 000 000	Accuracy F 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	2 4	6 8	- Fol - PA - UA	50 ≫) Iteration Use Default Symbolization Plan Set Symbolic Scheme Output File Path of Sizulation Result B:/App/CcCA_App_v1_04/data/test I: B:r/App/CcCA_App_v1_04/data/test Set Symbolic Scheme Output File Path of Sizulation Result B:/App/CcCA_App_v1_04/data/test Set Symbolic Scheme Set Symbolic Scheme Output File Path of Sizulation Result B:/App/CcCA_App_v1_04/data/test Set Symbolic Scheme Set Symbolic Scheme Set Symbolic Scheme Output File Path of Sizulation Result Set Symbolic Scheme Set Set Scheme Set

The land use type map module in the top-left corner can be traversed by zooming in and out to display each area. The line graph below it, showing the number of changes in each land plot type, corresponds to the changes in each type of land plot in this simulation.



The accuracy evaluation indicator module located in the middle of this system

displays the changes in various accuracy indicators in this simulation. The line graph below it, showing the changes in accuracy evaluation indicators, corresponds to the changes in each accuracy indicator in this simulation.

Iteration	FoM	PA	UA	^
1	0.016332	0.0173542	0.205387	
2	0.0295753	0.0332859	0.197302	
3	0.0449303	0.0532006	0.211061	
4	0.0566728	0.0705548	0.211064	
5	0.0639636	0.083926	0.201228	
6	0.0742893	0.101849	0.204105	
7	0.0815476	0.116927	0.201273	
8	0.0899905	0.134282	0.202575	
9	0.0969042	0.150498	0.202294	
10	0.104222	0.167852	0.203941	
11	0.110467	0.184353	0.204223	,
11	0.110467		0.204223	PA
0.2 0.2	0 2 4		10 12	

In addition, we also provide a Log output interface for checking relevant outputs. The Log output interface for the urban land use change simulation module is shown in the figure below:

```
Output
saved to H:/App/
                    \land
CoCA_App_v1_04/
data/test/7.tif.
2021-12-27-14:58:
49 >> Iteration
8.
2021-12-27-14:58:
50 >> Result is
saved to H:/App/
CoCA_App_v1_04/
data/test/8.tif.
2021-12-27-14:58:
50 >> Iteration
9.
```

4.4. Markov Chain calculation

Click on the "PLUS Model" in the menu bar and select "Markov Chain" from the

popup menu.

😩 CoCA		
File Data Preprocessing	PLUS Model Density CA CoCA Help	
Layers Vector Layer Raster Layer CSV File	 Extract Land Expansion Calculate Overall Development Probability Self Adaptive Inertia and Competition Mechanism CA Markov Chain Precision Validation Recover Density Data 	

We can also open the Markov Chain calculation module by clicking on the

"Markov Chain" button in the toolbar 🔋 as shown in the figure below:

Demand Prediction				-		×
Land-Use Data						
Path	Name	Data Type	Year			
Constrain					Save	1
Markov Chain						
Predict Year						\$
Output Path						
		Run				

First, click on the button in "Land-Use Data" to import multiple land-use data for different years. Then, double-click on the corresponding year of each land-use data to make modifications as shown below:

Lai	nd-Use Data			
	Path	Name	Data Type	Year
1	H:/App/data/data/l	land2000-4.tif	Land-Use Data	2021

Please note that due to the inherent characteristics of Markov chains, it is necessary to ensure that the land-use data corresponds to different years and that the intervals between adjacent years' land-use data are consistent.

Next, in "Constrain", you can double-click on the transition matrix to customize the conversion restrictions for each land-use type. Then, click on "Save" to save the

Constrain							
	Type 1	Type 2	Type 3	Type 4			
Type 1	True	True	True	True			
Type 2	True	True	True	True			
Type 3	True	True	True	True			
Type 4	True	True	False	True			

Then, in "Predict Year", set the desired year value to be predicted, as shown below .:

Predict Year	
2000	-
Finally, click on the button in "Output Path" to select the path	
where you want to save the results in the pop-up dialog box	
Output Path	

Click on the "Run" button to start the execution of the Markov Chain calculation.

Run

4.5. Accuracy assessment

Click on the "PLUS Model" in the menu bar, and select "Precision Validation"

from the pop-up menu.

🥼 CoCA		
File Data Preprocessing	PLUS Model Density CA CoCA Help	
Layers Vector Layer Raster Layer	 Extract Land Expansion Calculate Overall Development Probability Self Adaptive Inertia and Competition Mechanism CA Markov Chain 	x 🖬
CSV File	✓ Precision Validation	
	Recover Density Data	

We can also open the Precision Validation module by clicking on the "Precision

Validation" button in the toolbar in the following image:

Land-Use I	Evaluation Data Land-use da	ta				$- \Box \rangle$ FoM = B / (A + B + C + D) PA = B / (A + B + C)
Zubacaucari	t land-use	data				UA = B / (B + C + D)
subsequen	t Tanu use	uata				A denotes parcel that remains unchanged in simulation while in ground-truth the parcel has changed.
Accuracy						B denotes parcel that correctly predicts land - use change as well as the land - use type.
Path	Name	FoM	PA UA Kappa OA Change as vell C denotes parce change however T D represents pa sinulation whil	C denotes parcel that correctly predicts land - use change however with a wrong land - use type. D represents parcel that has land - use change in simulation while in ground - truth the parcel remains unchanged.		
					 ulate	

First, click on the button to the right of "Previous land-use data" and "Subsequent land-use data" respectively, III, III the pop-up file selection dialog box, select the paths where the land-use data before and after the change are stored, as shown below:

Previous land-use data	
Subsequent land-use data	

Then, click on the button to the right of "Accuracy" and in the pop-up dialog box

	, import the land-use data for accuracy assessment, as shown below:								
ł	Accuracy -								
	Path	Name	FoM	PA	UA	Карра	OA		

After completing the above steps, click on the "Calculate" button

```
Calculate
```

start the execution of the accuracy assessment function.

4.6. Discrete data discretization

Click on the "PLUS Model" in the menu bar, and select "Recover Density Data" from the pop-up menu. 🌲 CoCA Data Preprocessing PLUS Model Density CA CoCA Help File Extract Land Expansion 🕒 Calculate Overall Development Probability Layers ۲ Self Adaptive Inertia and Competition Mechanism CA Vector Layer Markov Chain Raster Layer Precision Validation CSV File **Recover Density Data**

We can also open the module for morphological erosion and dilation calculations by clicking on the "Recover Density Data" button in the toolbar, as shown in the following image:

to

🧳 Recove	r Discret	e Data				_	\times
Paras							
Original	Density	Data					
Discrete	Data						
Files							
Path	Name	ata Typ	Width	Height	ind Cou	Finish	
							_
Output Pa	th						
				Run			

Click on the buttons to the right of "Original Density Data" and "Discrete Data"

respectively, In the pop-up file selection dialog box, select the corresponding continuous urban development factor data and discrete urban development factor data, as shown below:

1 47 49	
Original Density Data	
Discrete Data	

Then, in the "Files" section, set the discrete data that needs to be updated and the urban development factor data that needs to be continuous. The system will calculate the average value of the corresponding continuous values for each discrete category, completing the process of updating discrete data to continuous data, as shown below:

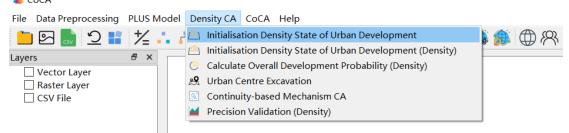
Windeow	Size (odd)			
3				•
Click	on	the	"Run"	button
	Run		, To start	executing the

function of updating discrete data to continuous data, click on the "Run" button.

5. Simulating urban feature continuity changes based on DensityCA model

5.1. Calculating initial density state of urban developmen

Click on the "Density CA" in the menu bar, and select "Initialization Density State of Urban Development" from the pop-up menu.



We can also open the module for calculating the initial density state of urban development by clicking on the "Initialization Density State of Urban Development" button in the toolbar in the following image:

🙆 Initialisation Density State of Urban	Development	_		\times
Land Use Data Previous land-use data				
Subsequent land-use data				
Classification of Urban Land and	Non-urban Land			
Index	Pixel value	Urban Lan	ıd	
Output Path				
	Run			

First, click on the buttons to the right of "Previous Land-use data" and	l
"Subsequent Land-use data" respectively, In the pop-up file	e selection
dialog box, select the storage paths of the land-use data before and after the	e change, as
shown below:	
Previous land-use data	
Subsequent land-use data	

To classify the land-use data into "Urban Land" and "Non-urban Land," you can double-click on the corresponding land-use type under "Classification of Urban Land and Non-urban Land" and set its status as urban or non-urban land, as shown below: Classification of Urban Land and Non-urban Land

	Index	Pixel value	Urban Land	^
1	1	2	True	
2	2	3	True	
3	3	1	True	
4	4	6	True	
5	5	9	True	
6	6	7	True	
7	7	4	True	~

Finally, click on the button in the "Output Path" section ..., In the pop-up dialog box, select the path to save the results. The results will be output in the .Tif format. Output Path

Click on the "Run" button

Run , to start the

calculation for the initial density state of urban development.

In addition, we also provide a method for initializing urban development density based on continuous data. Click on the "Density CA" in the menu bar, and select "Initialization Density State of Urban Development (Density)" from the pop-up menu.

. . .

File Data Preprocessing PLUS Model Density CA CoCA Help Image: State of Urban Development Image: State of Urban Development Image: State of Urban Development Image: State of Urban Development Image: State of Urban Development
E S S S S S S S S S S S S S S S S S S S
Initialisation Density State of Urban Development (Density)
Lavers B ×
Calculate Overall Development Probability (Density)
Raster Layer & Urban Centre Excavation
CSV File Continuity-based Mechanism CA
Precision Validation (Density)

In this interface, you need to input the urban development density data (Density Data) and the density threshold (Density Threshold (Value for Urban Areas)). The system will identify grid cells with densities greater than the threshold as urban areas and save them to the output file (Output Path).

🖄 Initialisation Density State of Urban Development	-	×
Paras		
Density Data		
Density Threshold (Value for Urban Areas)		
100.00		-
Output Path		
Run		

5.2. Calculating overall density development probability of

the city

Click on the "Density CA" in the menu bar, and select "Calculate Overall Development Probability (Density)" from the pop-up menu.

CoCA			
File Data Preprocessing	PLUS Model	Density CA CoCA Help	
늘 🖸 🌄 🚺 🚼	⁺∠	Initialisation Density State of Urban Development	i í 🌐 🕅
Layers	ъ×	Initialisation Density State of Urban Development (Density)	
Vector Layer		Calculate Overall Development Probability (Density)	
Raster Layer		😤 Urban Centre Excavation	
		Continuity-based Mechanism CA	
		Magnetic Precision Validation (Density)	

We can also open the module for calculating the overall development probability by clicking on the "Calculate Overall Development Probability (Density)" button in the toolbar , as shown in the following figure :

Calculate Overall Development Probability	- 🗆 X
Subsequent Land-use Samples	
Land Use Data	
	Set NoData Value
Driving Data (Select and press the	
	but Samples Path
· · · · · · · · · · · · · · · · · · ·	Sur Samples Fath
Related Params	
Mining method of overall development	ut probability
random forest	~
Sampling rule	
O Uniform Sampling O Random S	
Sampling Rate (1/1000) Sample file data (Polygon vector da	
Sample life data (rolygon vector da	
Sample file data (Point data)	
Sample file data (Foint data)	
RF-based Paras NN-based Paras	
Decision Trees Number	80
DECISION HERS WONDER	80
Output Pg Path	
	Convert

First, click on the button in the "Land Use Data" section, The system will automatically open a dialog box, and you need to select the updated land use data.

Next, click on the button in the "Driving Data" section, The system will automatically open a dialog box, and you need to select the dataset of driving factors for training.

Driving Data (Select and press the delete key to delete)	
Input Samples Path	
	1

After completion, select the mining method for the overall development probability from the dropdown menu under "Mining method of overall development probability". The default option is the Random Forest model, as shown below:

Mining method of overall development probability
random forest ~
random forest
neural network

Next, select the sampling rule from "Sampling rule" section. The options include

Rule-based sampling, Random sampling, Manual sampling, and Static sampling, as shown below:

Sampling rule			
◉ Uniform Sampling	🔘 Random Sampling	🔘 Manual Sampling	🔿 Stationary Sampling

If you choose Random sampling, you need to set the sampling rate using the "Sampling Rate" option, as shown below:

Sampling Rate (1/1000) 300

If you choose Manual sampling, you need to import the specified sampling area .shp file using the "Sampling File data (Polygon vector data)" option, as shown

Sample file data (Polygon vector data)

below:

The specified sampling area .shp file should be in the format of polygon vector data

within the same projected area range.

If you choose Static sampling, you need to import the specified sampling pixel

location file using the "Sampling File data (Point data)" option, as shown below: Sample file data (Point data)

The specified sampling pixel location file should be in the format of "row number, column number,". Here is an example of the data:

12,	132,
123,	141,
142,	124,
88,	616,
686,	919,

Next, based on the selected mining method for overall development probability, set the model parameters in either "RF-based Paras" or "NN-based Paras", as shown below:

RF-based Paras	NN-based Paras		
Decision Trees N	umber	80	-

Finally, click on the button in "Output Pg Path" , and select the storage

location for the overall development probability file in the dialog box that appears, as shown below:

Output Fg Path	
H:/App/data/test/q.tif	

After clicking "OK", the system will start mining the overall development probability (Pg), and the execution status will be displayed in the left-side log, as shown below:

```
2021-12-27-21:41:18 >> read land use data.

2021-12-27-21:41:19 >> introducing the driver

"H:/App/data/data/drivingFactors_01/

airport.tif".

2021-12-27-21:41:19 >> introducing the driver

"H:/App/data/data/drivingFactors_01/

city.tif".

2021-12-27-21:41:19 >> introducing the driver

"H:/App/data/data/drivingFactors_01/L1.tif".

2021-12-27-21:41:19 >> introducing the driver

"H:/App/data/data/drivingFactors_01/L2.tif".

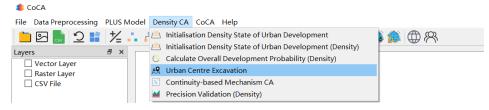
2021-12-27-21:41:19 >> training sample

initialization completed.
```

5.3. Extracting urban centers

Click on the menu bar "Density CA" and select "Urban Centre Excavation" from

the pop-up menu.



Alternatively, you can open the Urban Centre Excavation module by clicking on

the "Urban Centre Excavation" button in the toolbar, as shown in the image below:

A Urban Centre Excavation	- 🗆 X
Preview	Paras
	Density Data
	Number of Urban Centres
	4
	Density Threshold (Value for Urban Areas)
	100.00
	Search Radius
	Generate Initial Clustering Centres
	Urban Centres
	Longitude Latitude Density
	Add Delete
	Convert

First, click on the button to the right of "Density Data" _____, to select

the folder where the urban development density data is stored, as shown below:

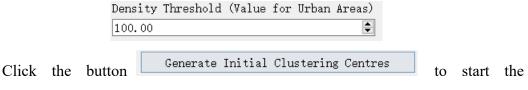
Density Data	

Next, click on "Number of Urban Centres" to set the desired number of urban centers to be extracted, as demonstrated below:

Number	$\circ f$	Urban	Centres
4			\$

After that, click on the "Density Threshold (Value for Urban Areas)" to set the

threshold value for identifying urban areas in raster units, as depicted below:



extraction of urban centers. Once the extraction is complete, you can view them in the "Urban Centres" section. Additionally, you can manually modify the "Density" of each urban center by double-clicking on it. To delete a selected urban center, click on "Delete"

to export

A Urban Centre Excavation \times Preview Paras Density Data PopulationDatas/popu2010.tif Number of Urban Centres \$ 11 Density Threshold (Value for Urban Areas) 1000.00 -Search Radius -3 Generate Initial Clustering Centres Urban Centres Longitude Latitude Density 196901 2.50737... 11142.6 1 2.63181... 229.938 2 -5182.71 52967.9 2.47263... 290.603 3 4 106951 2.54358... 3373.35 δ₹. Add Delete Convert Convert Finally, click the button

After clicking on the "Add" function, you can simply click on the desired location on the map area to add a point.

the calculated urban center data in .CSV format. In the dialog box that appears, select the storage location for the urban center data.

5.4. Simulating the continuity changes of urban features

Click on the menu bar "Density CA" and select "Continuity-based Mechanism

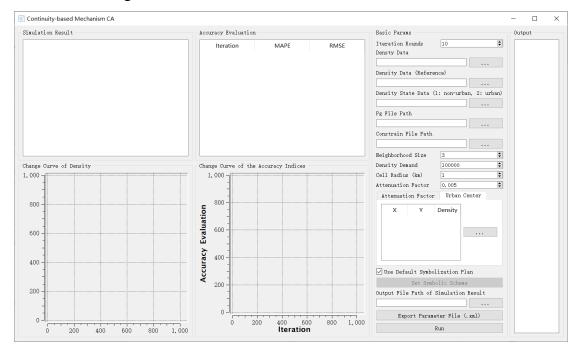
CA" from the pop-up menu.

🔱 CoCA		
File Data Preprocessing PL	US Model Density CA CoCA Help	
Layers 5	Initialisation Density State of Urban Development (Density)	\$ \$ @ R
CSV File	Continuity-based Mechanism CA	
	Precision Validation (Density)	

Alternatively, you can open the Continuity-based Mechanism CA module by

clicking on the "Continuity-based Mechanism CA" button in the toolbar

shown in the image below:



First, set the number of iterations for this simulation in the iteration rounds input box Iteration Rounds 10 This parameter represents the number of iterations for the simulation.

Then, click on the buttons to the right of "Density Data", "Density Data (Reference)", "Density State Data", "Pg File Path", and "Constrain File Path" respectively...., In the dialog box that appears, select the folder paths for

the pre-change real density data, post-change real land-use data, initial density data before urban change, Pg file path, and constraint development file path, as shown below:

Densty Data	
Density Data (Reference)	
Density State Data (1: non-urban,	2: urban)
Pg File Path	
Constrain File Path	

Note that the "Constrain File Path" function is used to restrict development in specific areas, and the path can be left empty. If you want to use this function, make sure the data format is a GByte raster, within the same projection range, containing only 0 and 1. 0 represents prohibited development, and 1 represents permissible development.

Next, we need to select the relevant parameters required for the model simulation. Set the neighborhood size on the right side of "Neighborhood Size," Neighborhood Size 3 set the desired density demand size on the right side of "Density Demand," ; set the cell radius size on the right side Density Demand 100000 of "Cell Radius," Cell Radius (km) ■ 。 and set the
 1 attenuation factor size on the right side of "Attenuation Factor." . 0.005 Attenuation Factor

The "Attenuation Factor" will automatically lock based on the above parameters.

Attenuation Factor	Urban Center

In "Urban Center," click the button _____, to import a city center .CSV

data file in the popup dialog box, and the system will automatically read the file information.

Attenuati	on Factor	Urban	Center
X	Y	Density	

After setting the parameters above, if you need to customize the display symbols for different land parcels, you can click the checkbox "Use Default Symbolization Plan"

✓ Use Default Symbolization Plan

 Set Symbolic Scheme
 to switch to a custom symbolization scheme.

Click the "Set Symbolic Scheme" button Set Symbolic Scheme

to open the following interface for setting the symbols and zoning display of land parcels:

	or Scheme		Heterogeneity Analys			
Pr	operties of	Density	(Double click to cha	nge)		
	Densit	y Code	Value	Col	or	
1	0.0636995		> 0.0636995			
2	23712.1		> 23712.1			
3	47424.1		> 47424.1			
4	71136.1		> 71136.1			
5	94848.1		> 94848.1			
_	mber of Cat	egories				
5						-

Click on the colors of each category to jump to the interface shown below, where you can modify the color for that category based on user needs. Clicking on the values of each category can switch the color breakpoints. In addition, adding or deleting categories can be done through the category setting box at the bottom:

Ø Select the color of this label	X
Easic colors	+
Custom colors	Hu <u>e</u> : 212 Red: 35 Sat: 61 Green: 40 ¥al: 46 Bl <u>u</u> e: 46 Alpha channel: 255 HTML: #23282e OK Cancel

Another important point is that this model supports the display of zoning data, which can be achieved through the "Zoning Statistical Analysis" module. It includes selecting zoning polygonal data, zoning labeling fields, and color settings, similar to

the above m	ethod.
-------------	--------

	Color Scheme Spatial Heterogeneity Analysis									
	Spatial Heterogeneity Analysis artition File Path									
计与	 开发/CoCA/data/Spa	tialData/City/GBA_bou	rder_city.shp							
Labe	l Field									
ENAM				\sim						
Pro	operties of Partit:	ion File (Double click	to change)							
	Index	Name	Color	^						
1	1	Guangzhou								
2	2	Shenzhen								
3	3	Zhuhai								
4	4	Foshan								
5	5	Jiangmen								
6	6	Zhaoqing								
7	7	Huizhou								
8	8	Dongguan		~						

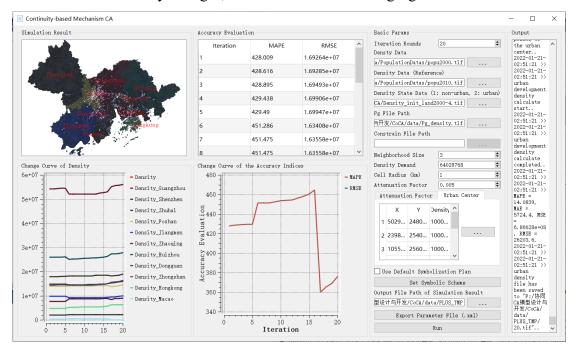
Click the "OK" button OK, to complete the custom symbolization settings.

To facilita	ate further	research, click	the button in t	he "Output F	File Path of
Simulation Res	ult" feature	, and	select the save pat	h for the simul	lation results
	Ou	tput File Path of	Simulation Result		
in the pop-up d	ialog box.				
Click	the	"Export	Parameter	File"	button
Export Parameter File (.xml) to save and export all current param					

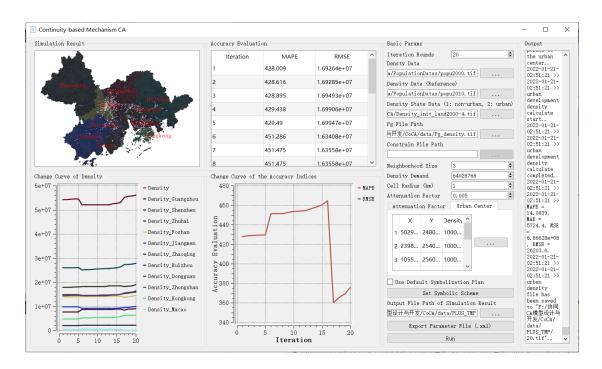
settings in XML file format.

	Finally,	in	the	simulation	interface,	click	the	"Run"	button
Run				to automati	cally pe	rform	the simul	ation of	

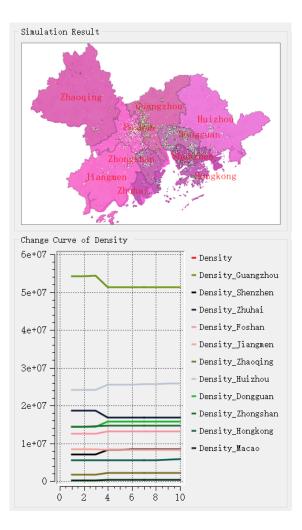
urban feature continuity changes, as shown in the following figure:



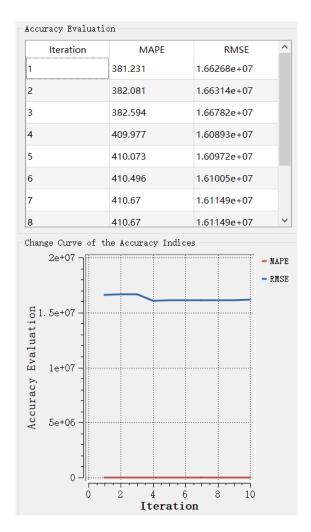
After the program finishes running, this system will display the final urban feature change map, accuracy evaluation indicators for each iteration, density change line graph, and line graphs showing changes in various accuracy evaluation indicators, as shown in the following figure::



The module for urban feature change map in the top left corner allows you to traverse and display each area by zooming in. The density change line graph below corresponds to the changes in density during the simulation process.



The accuracy evaluation indicators module, located in the middle of this system, displays the changes in various accuracy indicators in this simulation. The accuracy evaluation indicators change line graph below corresponds to the changes in each accuracy indicator in this simulation (under the zoning statistical settings, the calculation units are polygonal zones rather than grids).



In addition, we provide a Log output interface for checking relevant outputs. The Log output interface for the urban feature density change simulation module is shown in the figure below:

```
Output
update the
distance
from all
points to
the urban
center..
2021-12-27-
23:43:02 >>
2021-12-27-
23:43:02 >>
urban
development
density
calculate
start..
```

5.5. Accuracy evaluation

"Click on the 'Density CA' option in the menu bar and select 'Precision Validation

(Density)' from the pop-up menu.

🅼 CoCA			
File Data Preprocessing	PLUS Mod	el Density CA CoCA Help	
늘 🖂 🔜 💆 📫	1/	🚰 🕮 Initialisation Density State of Urban Development	
Layers	8 ×	🖄 Initialisation Density State of Urban Development (Density)	
Vector Layer		Calculate Overall Development Probability (Density)	
Raster Layer		😫 Urban Centre Excavation	
CSV File		Continuity-based Mechanism CA	
		Precision Validation (Density)]

Alternatively, you can open the precision evaluation module by clicking on the 'Precision Validation (Density)' button in the toolbar, as shown in the figure below:

Accuracy Evaluation (Density)	- 🗆 ×
Density Data Evaluation Model Normal O Partitioned Real Density Data 	MSE (Mean Square Error) $MSE = \frac{1}{n} \sum_{i=1}^{n} (\hat{y}_i - y_i)^2$ RMSE (Root Mean Square Error)
Accuracy Path MSE RMSE MAE	$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(\hat{y_i} - y_i)^2}$ MAE (Mean Absolute Error) $MAE = \frac{1}{n}\sum_{i=1}^{n} \hat{y_i} - y_i $ MAPE (Mean Absolute Percentage Error) $MAPE = \frac{100\%}{n}\sum_{i=1}^{n}\left \frac{\hat{y_i} - y_i}{y_i}\right $ SMAPE (Symmetric Mean Absolute Percentage Error) $SMAPE = \frac{100\%}{n}\sum_{i=1}^{n}\left(\frac{ \hat{y_i} - y_i }{ \hat{y_i} + y_i }\right)/2$ Where <i>n</i> is the number of all samples, <i>y_i</i> is the true value and $\hat{y_i}$ is the
< >> Calculate	< >>

First, click on the button to the right of 'Real Density Data' ..., and select the path where the real data is stored in the pop-up folder selection dialog, as shown below:

Real Density Data	
H:/App/data/data/PopulationDatas/popu2020.tif	

Next, click on the button to the right of 'Accuracy', and import the land data for accuracy assessment in the pop-up dialog, as shown below:

	File Path	MSE	RMSE	^
1	F:/协同CA模型	575036011.795	23979.909	562 ⁻
2	F:/协同CA模型	575697189.828	23993.691	5627
3	F:/协同CA模型	576814444.432	24016.962	563(
4	F:/协同CA模型	569332646.157	23860.692	5596
5	F:/协同CA模型	569432331.896	23862.781	5598
6	F:/协同CA模型	5698155 <mark>44</mark> .176	23870.809	5602
7	F:/协同CA模型	570137451.641	23877.551	5604
B	F:/协同CA模型	570451304.231	23884.122	560(
ŝ	┍. ᄮᆂᄃᆜᄼᄮᆤᆓᅖᆘ	E71406700 C41	22004 447	- C47 V

If users need to perform zone-based statistics, please select the 'Zoning Statistics' mode and choose the zone data for calculation through the file selection dialog.

Density Data	
Evaluation Model	
🔘 Normal	Partitioned
Real Density Data	
Administrative divisions	data(vector type)

After completing these steps, click the 'Calculate' button

Calculate

to start

the execution of the precision evaluation function."

6. Simulating urban land-population-economy

changes based on CoCA model

6.1. Simulating urban single-element changes

Click on the 'CoCA' option in the menu bar and select 'Step-wise Synergetic

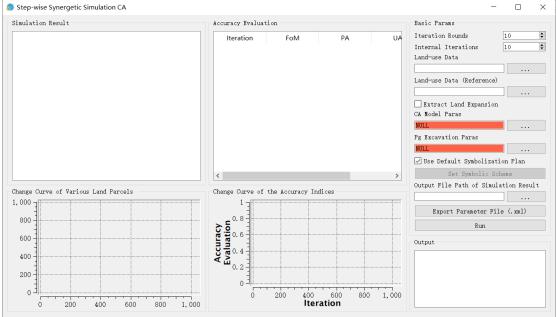
Simulation CA' from the pop-up menu. File Data Preprocessing PLUS Model Density CA CoCA Help Step-wise Synergetic Simulation CA Layers

 Image: Step-wise Synergetic Simulation CA (Multi-factor)

 Image: Step-wise Synergetic Simulation CA (Multi-factor)

 Image: Step-wise Synergetic Simulation CA (Multi-factor)

Alternatively, you can open the Simulation of City Land-Population-Economy Changes module by clicking on the 'Step-wise Synergetic Simulation CA' button in the toolbar, as shown in the figure below:



First, set the number of iterations for each collaboration by entering the value in the internal iteration count input box Iteration Rounds 10 💽 Set the collaboration count by entering the value in the external collaboration count input box Internal Iterations 10

Next, click on the buttons to the right of 'Land-use Data' and 'Land-use Data

(Reference)', and select the respective paths where the real land-use data

is stored before and after the change in the pop-up folder selection dialog, as shown below:

Land-use Data	
Land-use Data (Reference)	

Also, select whether to extract the expansion area Extract Land Expansion .

Next, we need to set the parameters for the Cellular Automata (CA) model. Click

	CA Model Paras	
	NULL	
the 'CA Model Paras' button		

and the system will automatically display the CA parameter setting sub-

interface, as shown below:

on

. . .

🎒 Set CA Model Paras				—		\times
Basic Params		Land-use Demand	Cost	Matrix	Weights	
Iteration Rounds Land-use Data	10		Ту	pe 1 Typ	þ	
04/data/data/land-4/	/land2000.tif	Future Pixel Numb	er /	/	-	
Land-use Data (Refer	ence)					
04/data/data/land-4/	/land2010.tif					
Constrain File Path						
Neighborhood Size	3					
Patch Generate	0.90	<		>		
Step Size	400					
				OK	Can	cel

In the CA parameter setting sub-interface, the 'Iteration Rounds', 'Land-use Data', and 'Land-use Data (Reference)' will be automatically set based on the parameters from the previous interface and cannot be modified externally, as shown below:

Iteration Rounds	10	-
Land-use Data		
pp/data/data/land-4/la	and2000.tif	
Land-use Data (Referer	ісе)	
pp/data/data/land-4/la	and2010.tif	

The 'Constrain File Path' is default empty. If you want to limit the development in

	Constrain File Path	
specific areas,		 click on the button to the right

, select the path where the restriction file is stored in the pop-up folder selection dialog. Please note that the data format must be: GByte raster data within the same projection range containing only 0 and 1. 0 indicates prohibited development land, and 1 indicates permissible development land.

After that, set the neighborhood size by entering the value in the input box to the right of "Neighborhood Size" Neighborhood Size 3 🕏 ; Set the attenuation coefficient size by entering the value in the input box to the right of "Patch Generate" Patch Generate 0.90 : Set the step size by value the right "Step Size" entering the in the input of box to €. Step Size 400

Click on the button under "Land-use Demand" , In the pop-up dialog, you can select a CSV file that customizes the development counts for each land-use type. The format of the CSV file is "Type_1,Type_2,Type_3...Type_n". If the user ignores this function, the system will automatically use the development counts for each land-use type based on historical data.

Land-use Demand	Co	st Matr	ix	١	Veights 🛛	
		Type 1	Тур	be		
Future Pixel Numb	er	/	/			
<				>		

Double-click on the conversion matrix in "Cost Matrix" to customize the conversion restrictions for each land-use type, as shown below (indicating that Type 1 cannot be converted to Type 2):

Land-us	e Demano	l Cost	t Matrix	:	1	Weights	
	Type 1	Type 2	Type 3	1	^		
Type 1	True	False	True	Т			
Type 2	True	True	True	Т			
Type 3	True	True	True	Т			
- -	-	-	-	>	~		

Double-click on the neighborhood weights in "Weights" to customize the weights for each land-use type in the pop-up dialog. The default value is 1, as shown below:

Land-use Demand C	Cost M	atrix	Weight	s 1 •
		Type 1	Type 2	Type 3
Weight of Neighbor	hood	1	1	1
<				>

Double-click on the Dk weights in "Dk Weights" to customize the weights for each land-use type in the pop-up dialog. The default value is 1, as shown below:

'naı	nd	Cost Ma	trix	Weights	Dk We	eights	•
			Type 1	Type 2	Type 3	Type 4	Ту
	Weię	ght of Dk	1	1	1	1	1
	<						>

After setting the parameters mentioned above, click "OK" to complete the CA parameter settings. At the same time, the system will automatically save the current parameters as an XML project file.

Next, we need to excavate the overall development probability (Pg) of the CA model. Click on the button in "Pg Excavation Paras"



automatically pop up a sub-interface for excavating the overall development probability (Pg), as shown below:

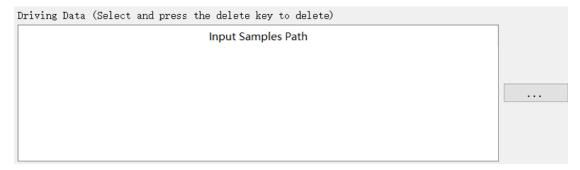
Set Pg Model Paras		_		×
Land Use Data				
H:/App/data/data/land-4/land2000.tif				
Driving Data (Select and press the delete key t) delete)			
Input Samples	Path			
Related Params				
Mining method of overall development probabili	tv			
random forest	•,			\sim
Sampling rule				
◉ Uniform Sampling	🔘 Random Sampling			
Sampling Rate (1/1000)	300			-
RF-based Paras NN-based Paras				
Decision Trees Number	80			
		OK	Canc	el

In the sub-interface for excavating the overall development probability (Pg), the "Land-use Data" will be automatically set based on the parameters from the previous level, and it cannot be modified externally, as shown below:

H:/App/data/data/land-4/land2000.tif ...

Next, click on the button in "Driving Data", and the system will

automatically pop up a dialog box where the user needs to select the driving factor dataset for training.



Once that is done, select the mining method of the overall development probability

from the drop-down box labeled "Mining method of overall development probability".

The default method is the random forest model, as shown below:

Mining method of overall development probability
random forest 🗸
random forest
neural network

Then, choose between rule-based sampling or random sampling in the "Sampling rule". If random sampling is selected, you can set the sampling rate in the "Sampling Rate", as shown below:

Sampling rule	
🔘 Uniform Sampling	🔿 Random Sampling
Sampling Rate (1/1000)	300

Finally, based on the selected method for excavating the overall development probability, set the model parameters in either "RF-based Paras" or "NN-based Paras", as shown below:

RF-based Paras	NN-based Paras		
Decision Trees Number		80	

Click "OK" to complete the parameter settings for excavating the overall development probability (Pg). At the same time, the system will automatically save the current parameters as an XML project file.

If you need to customize the display symbols for different land parcels, you can click on the checkbox "Use Default Symbolization Plan" to use a custom symbolization

	🗹 Us	se Defa	ult Syml	oolization H	Plan						
scheme			Set	Symbolic Sc	heme		。 Click c	on th	ne "S	et Symbolic	Scheme"
button	to	set	the	vector	land	parcel	symbols	in	the	popped-up	interface
		Set	Symbo	lic Schem	le		as shown	belo	ow:		

Properties of Land Use Type (Double click to change)								
	Land Use Code	NoData Option	Pixel Statistics	Name	Color	^		
1	2	valid Data	28335	Type 2				
2	3	valid Data	3715	Туре 3				
3	1	valid Data	13824	Туре 1				
4	6	valid Data	4783	Туре б				
5	9	valid Data	2080	Туре 9				
6	7	valid Data	4331	Туре 7				
7	4	valid Data	824	Type 4				
8	5	valid Data	103	Type 5				

Click on the color of each category to jump to the interface shown in the following figure to modify the color of the category according to user needs:

③ Select the color of this label	×
Basic colors	+
Custom colors	Hu <u>e</u> : 212 <u>R</u> ed: 35 <u>S</u> at: 61 <u>G</u> reen: 40 <u>¥</u> al: 46 Bl <u>u</u> e: 46 <u>Alpha channel: 255 </u> <u>H</u> TML: #23282e OK Cancel

Click the "OK" button OK , to complete the customization of symbolization.

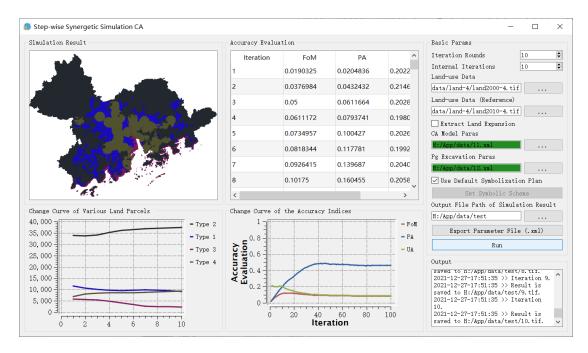
To facilitate further research, click the button in the "Output File Path of Simulation Result" feature, and select the path to save the simulation results

		Output File Pa	ath of Simul	ation Res	ult		
in the poppe	d-up dialog	g box				••••	
Click	the	"Export	Р	aramete	r	File"	button
Expo	ort Parameter	File (.xml)	, to s	ave and	expo	ort all current	parameter
settings in X	ML file for	mat.					
Finally,	click	the "Run"	button	on	the	simulation	interface
	Run		, to aut	omatica	lly pe	erform the sin	nulation of

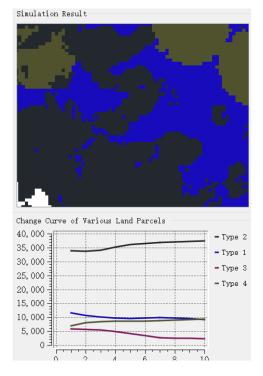
urban land-population-economic changes, as shown in the figure below:

imulation Result	Accuracy Evaluation		Basic Params	
	Iteration FoM	PA	UA Iteration Rounds 10	
			Internal Iterations 10	
			Land-use Data	
			data/land-4/land2000-4.tif	
			Land-use Data (Reference)	
			data/land-4/land2010-4.tif	
			Extract Land Expansion	
			CA Model Paras	
			H:/App/data/11.xml	
			Pg Excavation Paras	
			H:/App/data/12.xml	
			🖂 Use Default Symbolization Pla	an
	<		> Set Symbolic Scheme	
			Output File Path of Simulation	Recul
	Change Curve of the Accuracy	Indices	H:/App/data/test	
		Indices	H:/App/data/test Export Parameter File (.xm	
		ndices	Export Parameter File (.xm	
800		- Indi ces		
		- Indices	Export Parameter File (.xm Run Output	
800			Export Parameter File (.xm Run Output (grivingractors_ui/trail.tir.	 nl)
000 800 600 400			Export Parameter File (.xm Run Output mrivingractors_Ui/trail.tir. 2021-12-27-17:48:58 >> training sample initialization completer	 nl) g
000 800 600 400			Export Parameter File (.xm Run Output griving actors_UI/trail.tl1 . 2021-12-27-17:48:58 >> training	 nl) g d.
600		00 600 800	Export Parameter File (.xm Run Output COL12-27-17:48:58 >> training sample initialization complete 2021-12-27-17:48:58 >> start	 nl) g d.

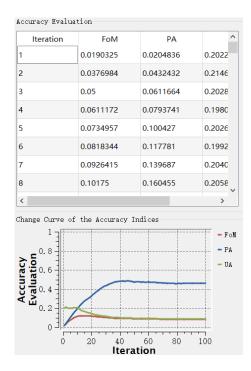
After the program finishes running, the system will display the final land use type map, accuracy evaluation indicators for each iteration, line graphs showing the changes in the number of land parcels for each type, and line graphs showing the changes in accuracy evaluation indicators, as shown in the figure below:



The land use type map module in the top left corner allows for zooming in and out to display each area. The line graph below shows the changes in the number of land parcels for each type of land during this simulation.



The accuracy evaluation indicators module in the middle of the system displays the changes in various accuracy indicators during this simulation. The line graph below shows the changes in each accuracy indicator during this simulation.



In addition, we provide a Log output interface for checking relevant outputs. The Log output interface for the urban land-population-economic change simulation module is shown in the following figure:

```
Output

saved to H:/App/data/test/8.tlf.

2021-12-27-17:51:35 >> Iteration 9.

2021-12-27-17:51:35 >> Result is

saved to H:/App/data/test/9.tif.

2021-12-27-17:51:35 >> Iteration

10.

2021-12-27-17:51:35 >> Result is

saved to H:/App/data/test/10.tif.
```

6.2. Simulating multi-factor coordinated changes in the city

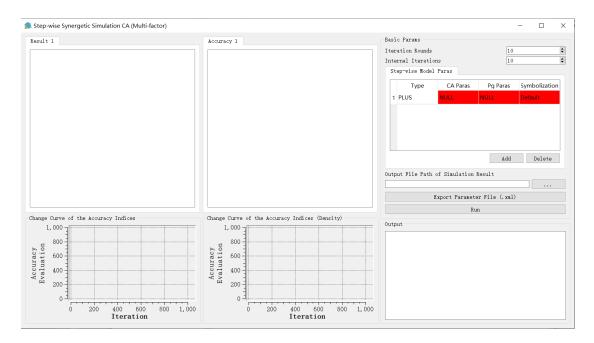
Click on the menu bar "CoCA" and select "Step-wise Synergetic Simulation CA

(Multi-factor)" from the pop-up menu



We can also open the module for simulating urban land-population-economic changes by clicking the "Step-wise Synergetic Simulation CA (Multi-factor)" button on

the toolbar as shown in the figure below:

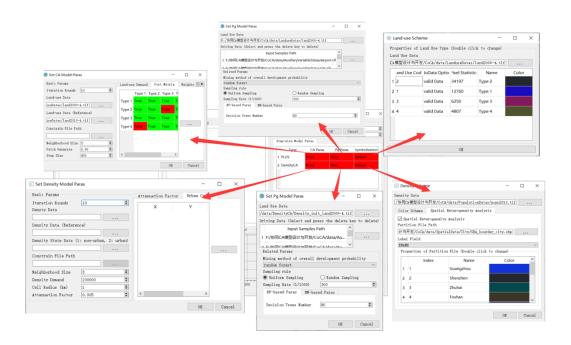


First, set the number of iterations for each collaboration in the internal iteration count input box Iteration Rounds 10 ; Set the collaboration count using the external collaboration count input box Internal Iterations 10 •

We can add or delete sub-CA models using the "Add" and "Delete" buttons. By double-clicking on the sub-CA model parameter table, you can switch models, set CA parameters, set Pg parameters, and visualize them, as shown in the figure below:

St	ep-wise Model	Paras						
	Туре	CA Paras	Pg Paras	Symbolization				
1	PLUS	F:/协同CA模	F:/协同CA模	F:/协同CA模				
2	DensityCA	F:/协同CA模	F:/协同CA模	F:/协同CA模				
3	PLUS	F:/协同CA模	F:/协同CA模	Default				
	Add Delete							
			nuu	Delete				

Next is the parameter setting for each sub-CA model, which is similar to the previous content, as shown below:

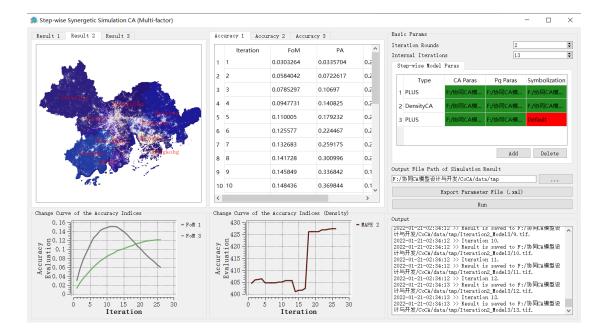


For the CA parameter and Pg parameter settings interface of the PLUS model, refer to section 6.1, and for symbolization, refer to section 4.3. For the DensityCA model, refer to section 5.4 for the CA parameter setting interface, section 6.1 for the Pg parameter setting interface, and section 5.4 for symbolization.

To facilita	ate fut	ture res	earch, click th	e button in th	e "Outp	ut File P	ath of Sir	nulation
Result" feature		,	in the dialog	g box that ap	pears, s	elect the	e path to a	save the
	01	utput Fil	tput File Path of Simulation Result					
simulation resu	ılts.∟							
Click	t	he	"Export	Param	neter	Fil	e"	button
Export Parameter File (.xml) , to save and export all the current parameter								
settings in XM	L file	e forma	t.					
Finally,	in	the	simulation	interface,	click	the	"Run"	button
Run				to automa	tically	simula	te urbar	ı land-

population-economic changes, as shown in the figure below.:





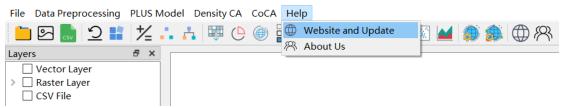
To ensure efficient model execution, this version of the software supports a maximum of 5 collaborative simulations of cellular automata. The accuracy display section only shows FoM and MAPE, while the rest of the sections are similar to the above modules.

7. Help

7.1. Website and Update

Click on the menu bar "Help" and select "Website and Update" from the pop-up

menu. .



We can also open the official website of the development team by clicking the "Website and Update" button on the toolbar providing convenience for obtaining timely software updates and other related information in the future.

7.2. About us

To access information about the development team, click on the menu bar "Help"

and select "About Us" from the pop-up menu.

File Data Preprocessing	PLUS Model Density CA	CoCA Help
늘 🖂 🔜 💆 📫	1/	🖗 💮 🚰 Website and Update 🛛 🚺 🞑 🎒 🎒 🥀 🕅
Layers	5 ×	About Us
Vector Layer		
> 🗌 Raster Layer		
CSV File		

We can also view information about the development team by clicking the "About

Us" button on the toolbar \mathcal{R} , as shown below:

8. Copyright Statement and Contact Information

CoCA: Cooperation Development Mechanism CA

Version 1.1.0

CoCA was developed by the following laboratories:

High-Performance Spatial Computational Intelligence Laboratory, School of Geography and Information Engineering, China University of Geosciences, Wuhan, China.

Http://www.urbancomp.net

Geospatial Information Research Team, School of Architecture and Urban Planning, Shenzhen University, Shenzhen, China. <u>https://geospatial.szu.edu.cn/index.htm</u>

Algorithm developers:

Wei Tu, Shenzhen University, Shenzhen, China.
Yao Yao, China University of Geosciences, Wuhan, China.
Zhenhui Sun, East China Normal University, Shanghai, China.
Mingxiao Li, Shenzhen University, Shenzhen, China.
Wei Gao, Shenzhen University, Shenzhen, China.
Linlong Li, Wuhan University, Wuhan, China.
Tao Cheng, Tongji University, Shanghai, China.
Jiayao Liu, China University of Geosciences, Wuhan, China.

User interface developers:

Zhenhui Sun, East China Normal University, Shanghai, China. Linlong Li, Wuhan University, Wuhan, China. Tao Cheng, Tongji University, Shanghai, China. Yao Yao, China University of Geosciences, Wuhan, China. Jiayao Liu, China University of Geosciences, Wuhan, China.

Website: http://www.urbancomp.net

Copyright by HPSCIL@CUG and GeoSpatial@SZU