# CoCA v2.1.0: Spatial Cooperation Development Simulation Platform for "Land-Population-Economy" based on Cellular Automaton Model

**User Manual** 



UrbanComp Team for Location Intelligence and Urban Sensing <u>https://www.urbancomp.net/</u> April 2024

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# 1. Product Introduction

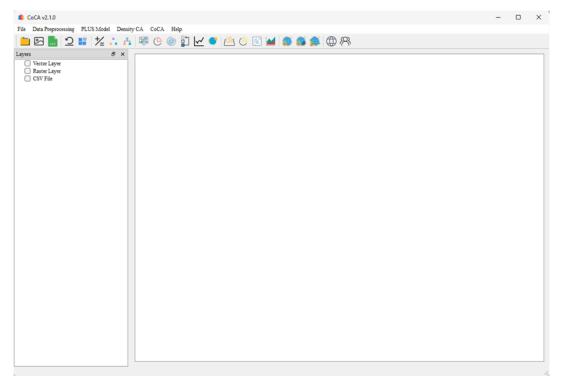
# 1.1. Target Audience

CoCA v2.1.0, the "Land-Population-Economy" spatial co-simulation platform based on the cellular automata model, provides simulation methods for discrete and continuous urban development elements. It adopts a "hierarchical progression" step-bystep dynamic driving factor update strategy to carry out multi-element spatial coordination simulations of "land-population-economy". This model provides assistance to a wide range of urban researchers and city planners.

# 1.2. Installation Method

To extract the compressed file, open the extracted folder and simply click on the CoCA.exe file to run it directly.

# 1.3. Interface display effect



# 1.4. Software control description

## 1.4.1. Menu bar

The content consists of several sections: "Documents", "Data Processing", "PLUS

Model", "Density Cellular Automata", "Collaborative Cellular Automata", and "Assistance".

CoCA v2.1.0						
Data Preprocessing	PLUS Model	Density CA	CoCA He			
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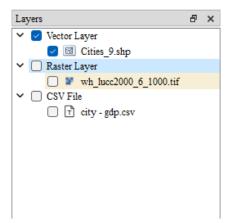
#### 1.4.2. Toolbar

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".

CoCA v2.1.0
File Data Preprocessing PLUS Model Density CA CoCA Help
Image: Solution of the second density of the second densit

#### 1.4.3. 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.



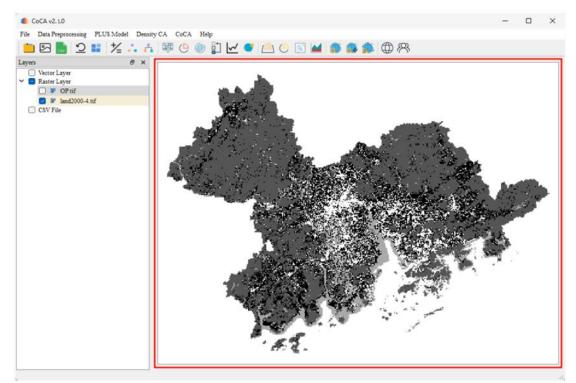
By right-clicking on the data that needs to be processed, you can open the toolbar for basic GIS functionalities. The vector data includes five options: "Zoom to Layer," "Open Attribute Table," "Select as Current Operational Layer," "Symbolize," and "Remove Layer."

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

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

## 1.4.4. Data visualization area

This area is used to display imported vector and raster files, supporting the display of data after operations such as classification.



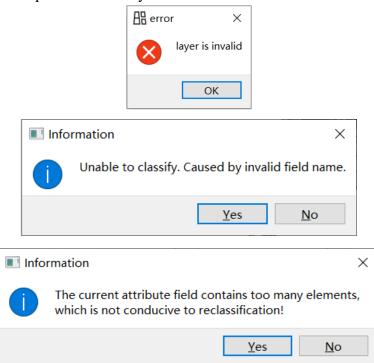
# 1.4.5. Function dialog box

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

🌲 Open vector file				×
← → ~ ↑ 🖡 « C	oCA > data > ∨	Ü	/─ 搜索"data"	
组织▼ 新建文件夹				?
🔄 图片 🛛 🖈 ^	名称 个		修改日期	类型
📕 LanduseDatas	📕 AuxiliaryVariableDatas		2021/11/29 20:48	文件到
manageSystem	GDPDatas		2021/11/29 20:48	文件到
📙 schoolSystem	📜 LanduseDatas		2021/11/29 20:48	文件到
📙 System	PopulationDatas		2021/12/17 21:36	文件到
OneDrive	📕 tmp		2021/11/30 16:00	文件判
此电脑				
🔮 网络 🛛 🗸 🗸	<			>
文作	‡名(N):	~	*.shp 打开(O) 取消	~

## 1.4.6. 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.

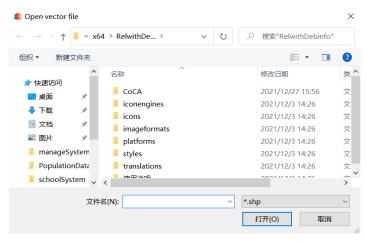


# 2. Data display function

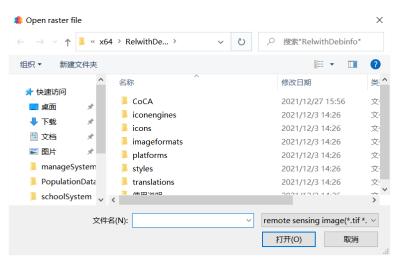
## 2.1. Basic functions

## 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.



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.

🌲 Open CSV file					×
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📌 快速访问	<b>^</b> 名称	^		修改日期	类 ^
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-	→ < ↑       ▲ × x64 > RelwithDe >       ✓       ど        沒 搜索"RelwithDebinfo"         ▲ 新建文件夹       ●       ●       ●       ●       ●       ②       ②         ●       ●       ●       ●       ●       ●       ●       ●       ②       ● </th				
🗐 文档	🖈 📃 imagef	ormats		2021/12/3 14:26	文
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📜 schoolSys				2021/12/21/14/20	>
	文件名(N):		~	*.csv 打开(O) 取消	

# 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 2 Open the "Select Project File" dialog box, where users can choose the desired project file and apply it.

🌲 Open project	file				×
$\leftarrow \  \  \rightarrow \  \   \checkmark \   \uparrow$	📜 « x64	> RelwithDebi	v Ü /	○ 搜索"RelwithDebinfo"	
组织▼ 新建	文件夹			: : ▼	?
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		📕 CoCA		2021/12/27 15:56	文⁄
		iconengines		2021/12/3 14:26	文,
• • • • •	*	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,
📜 manageS	ystem	Istyles		2021/12/3 14:26	文,
📕 Populatio	onData	translations		2021/12/3 14:26	文,
schoolSys	→ ▲ ↑       ▲ × x64 > RelwithDebi       ▲ ②       沙       沙       搜索"RelwithDebinfo"         新建文件夹       ● ○       ● ②       ● ②       ● ③       ● ③       ● ③       ● ③       ● ③       ● ③       ● ③       ● ③       ● ③       ● ③       ● ③       ● ③       ● ③       ● ○       ● ◎       ● ◎       ● ○       ●				
	文件名	(N):	~ *.;	xml	$\sim$
				打开(O) 取消	

Please click on "Save Project File" under the "File" directory or the corresponding icon on the menu bar Open the "Save Project File" dialog box, where users can save the current project at a specified location.

🌲 Select Projec						Х
$\leftarrow \rightarrow \checkmark \uparrow$	📜 « хб	4 > RelwithDe >	$\sim$	Ū	✓ 搜索"RelwithDebinfo"	
组织▼ 新建	建文件夹					?
📌 快速访问	^	名称 ^			修改日期	类 ′
三 桌面	*	📕 CoCA			2021/12/27 15:56	<b>文</b> ′
		📒 iconengines			2021/12/3 14:26	文'
↓ 下载	*	📕 icons			2021/12/3 14:26	文 <sup>,</sup>
🗐 文档	*	imageformats			2021/12/3 14:26	文 <sup>,</sup>
▶ 图片	*	platforms			2021/12/3 14:26	文 <sup>,</sup>
📕 manage	System ~	- ctuloc				<del>ک</del> ہ
文件名	(N):					~
保存类型	실(T): xml(*	.xml)				~
∧ 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.

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

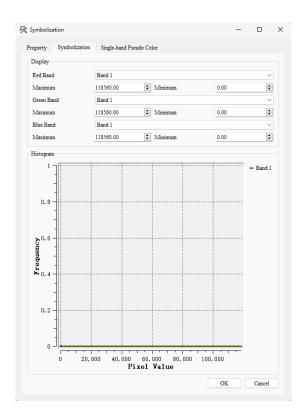
By clicking on the "Select Current Working Layer" option, you can edit the selected data.

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.

Property	Symbolization	Single-band Pseudo Color			
Name: land	12000-4.tif				
Path: D:/E:	xperiment/CoCA/d	wq-data/data/LanduseDatas/la	nd2000-4.tif		
Row Coun					
Col Count:					
Data Type	: Byte				
Band Cour		+06), (237977, 2.28954e+06))			
Band Cour Band 1:	11: 1				
Minimum	Value: 1				
Maximum					

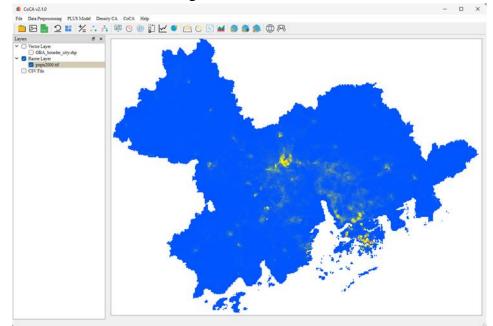
The "Properties" page displays the basic parameters of the selected layer, including the layer name, path, resolution, data storage type, extent, number of bands, and the maximum and minimum pixel values for each band.



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

ym				
ope	erty Symbolization	Single-band Pseudo Color		
Pro	perties (Double click to cl	hange)		
	Code	Condition	Color	
1	1	> 1		
2	1.75	> 1.75		
3	2.5	> 2.5		
4	3.25	> 3.25		
ml	ber of Categories			
uml	ber of Categories			

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:

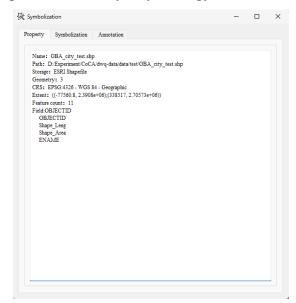
	OBJECTID	Shape_Leng	Shape_Area	ENAME
1	200	731466.61339299998	7231989540.86999988556	Guangzhou
2	202	394805.31605800003	1945386718. 30999994278	Shenzhen
3	203	651001.14153300005	1583741168. 50000000000	Zhuhai
4	205	583273.22997200000	3808871805. 11000013351	Foshan
5	206	1003393.87444000004	9404848841.65999984741	Jiangmen
6	209	808256.57622699998	14975637074. 60000038147	Zhaoqing
7	210	977010.23782499996	11328809470. 39999961853	Hui zhou
8	216	288140.23228300002	2453850842.30999994278	Dongguan
9	217	225333.00506800000	1748694877. 72000002861	Zhongshan
10	370	692041.74432699999	1116817436. 44000005722	Hongkong
11	371	50529.30491090000	34034727.15240000188	Macao

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.

	OBJECTID V OBJECTID V OBJECTID V Jse Code Land Use Type Color Selection Color
Property Symbolization Annotation	
Setup Corresponding Colors and Values for Each Land Use Type	
Classification	
Value OBJECTID ~	
Label OBJECTID ~	
Land Use Code Land Use Type Color Selection Color	
Classify + O Delete All	
OK. Cancel	

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

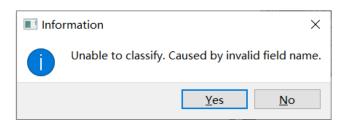
Classification You can choose the method for symbolizing the current operating data, and the "Field Value" dropdown menu allows you to select the field value for symbolization

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.



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:



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:

Classification Value type20 Label type		type20				2
		d Use Code	Land Use Type	Color Selection	Color	j
1	2		forest	Set Color		
2	1		cropland	Set Color		
3	3		grassland	Set Color		
4	0		construction	Set Color		
5	4		water	Set Color		
	Class	ify +	Delete A	1		

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:

1	200	200	Set Color	

Click the "Delete a Class" button The currently selected class can be deleted as shown in the image below:

1	2	forest	Set Color	

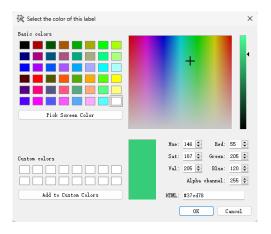
Delete All

Click the "Delete All" button.

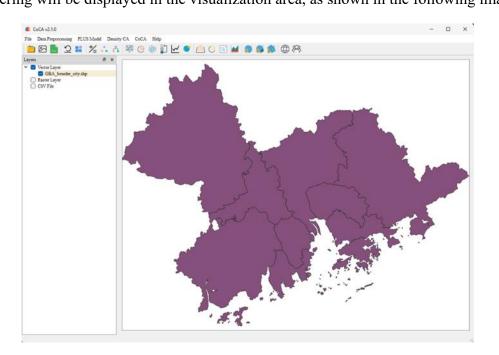
The current classification results can

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.

roperty	Symbolization	Annotation				
Annotatio	on Text					
Annotati	ion Field:					
OBJEC	TID				```	2
Annotatio	on Style:					
Font			SimSun			
Size			9			
Color						
Bold			0			
Italics			0			
Preview			Example!			

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

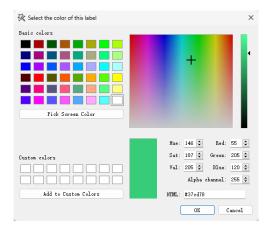
Annotation Text	
Annotation Field:	
OBJECTID	$\sim$

Click on "Font" to change the font.

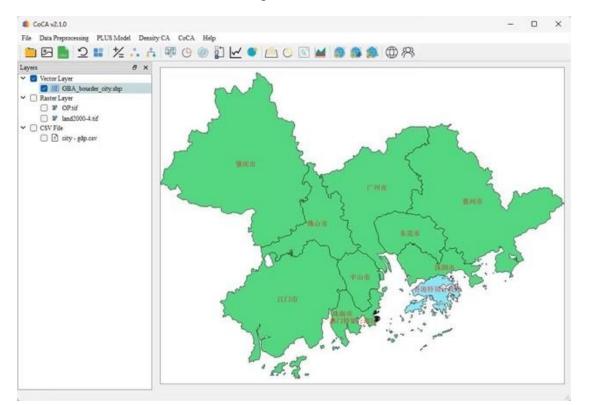
Select Font			×
Font Adobe Devanagari		Font style Regular	Size 8
Adobe Devanagari		Regular	6
Agency FB		Bold	7
Algerian		Bold Italic	8
Arial		Italic	9
Arial Black			10
Arial Narrow			11
Arial Rounded MT Bold			12
Bahnschrift			14
Effects		Sample	
Strikeout			
🗌 Underline		AaBbYyZz	
Writing System			
Any	$\sim$		
		OK	Cancel

Click on "Color" to change the font color.

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#### 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 .

#### 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	32.00000000	
2	0.00000000	61.0000000	
3	0.00000000	73.0000000	
4	0.00000000	84.0000000	
5	0.00000000	90.0000000	
6	0.00000000	96.0000000	
7	0.00000000	102.0000000	
8	0.00000000	109.0000000	
9	0.00000000	113.0000000	
10	0.00000000	117.00000000	
11	0.00000000	123.0000000	
12	0.00000000	129.0000000	
13	0.00000000	134.0000000	
14	0.00000000	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

This feature is mainly used to identify the NoData values of land use data, which is used for subsequent land use change simulation. Please note that the codes for land use types should be continuous integers starting from 1, not 0. If users mark the NoData values of related data in GIS-related software, there is no need to perform this operation.

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

Land Use Code		Pixel Statistics
127	valid Data	73026
2	valid Data	34059
1	valid Data	10994
3	valid Data	5912
4	valid Data	7049
ut		

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.

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

Please note that before opening the "Set Null Values" interface, you need to select the land use data of the raster type. Additionally, the pixel value type must be integer, otherwise a prompt box will appear.

	$\blacksquare$ information $\times$
■ information × The file selected is not a raster file!	No land use data
<u>Y</u> es <u>N</u> o	ОК

# 3.2. Data normalization - Resampling

This feature mainly performs resampling operations on raster data to change the spatial resolution of the data. It's important to note that the data used by the model should maintain a uniform resolution.

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 the resolution

🗹 Resampling						-		×
Add the file to this m identify the base file				without changing	g the actual geograph	ical range. (Note	Double cli	ck to
Pending Files								
Path	Name	Data Type	Width	Height	Band Count	Finish		
Target Paras								
Width								
1								÷
Height								
1								-
Output Path								
			Rur	1				

User clicks on "Pending Files" Insert the raster file. The table in "Pending Files" will display the basic information of the input data.

D:/Experiment/			Width	Height	Band Count	Finish
D	popu2000.tif	Float64	416	315	1	False
D:/Experiment/	popu2010.tif	Float64	416	315	1	False
D:/Experiment/			416	315		False

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

Width           500           Height           400	Target Paras	
500 Height	Width	
Height 400		<b>▲</b>
400	Height	
	400	<b>▲</b>

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

#### results.

Output Path		
D:/Experiment/CoCA/Data		
	Run	

# 3.3. Data normalization - Standardization

This feature is mainly used to normalize the spatial driver dataset, forming raster data with a range value of  $0\sim1$ . This makes it easier to calculate overall development probabilities in subsequent steps.

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.

Path	Name	Data Type	Width	Height	Band Count	Finish	
put Path							

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.

Output Path		
D:/Experiment/CoCA/Data		
	Run	

# 3.4. Data normalization - Reprojection

This feature mainly performs re-projection operations on raster data to change the projection coordinate system of the data. It's important to note that the data used by the model should maintain a uniform projection coordinate system.

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.

Path	Name	Data Type	Width	Height	Band Count	Finish	
get Params rget Raster File							

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 Params	
Target Raster File	
Output Path	

Click "Run". The software will change the reference system of the original singleband data to the reference system of the target raster file and output the results.

## 3.5. Spatial analysis - Natural breaks

This feature mainly discretizes continuous population and economic data, making it easier for subsequent discrete data simulations and calculations of future total demand.

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.

Images					
Path	Name	Data Type	Width	Height	Band
ut Path					

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.

		Expression	
		-	
reate Expressi	ions (Enter to add to the list of e	xpressions)	
reate Expressi	ons (Enter to add to the list of e	xpressions)	
reate Express	ions (Enter to add to the list of e	xpressions)	
reate Expressi hutput Path	ions (Enter to add to the list of e	xpressions)	
	ions (Enter to add to the list of e	xpressions)	
utput Path		apressions)	
utput Path	ons (Enter to add to the list of er	apressions)	
utput Path		apressions) Band	
utput Path	(Double click to add)		
utput Path and Reference	(Double click to add)	Band	

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)		"land2000-4.tif" Band: 0	

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

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.

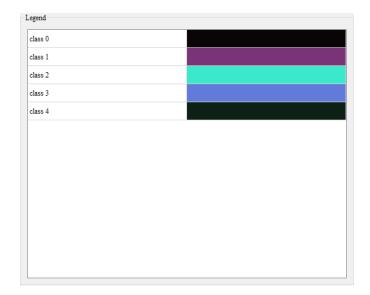
Click on the "Image Classification - Unsupervised Classification" option to open the corresponding interface. Users can add raster data to this interface and perform unsupervised classification on the raster data.

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.

ister Data Classification	
Parameter Settings	
Input Raster File	
D:/Experiment/CoCA/dwq-data/data/LanduseDatas/land2000-4.tif	
Clustering Methods	
k-means clustering algorithm (kmeans)	
Expected Number of Categories	
5	
Output Path	
Save as single-band image	
Classify	
Classify	
legend	

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.

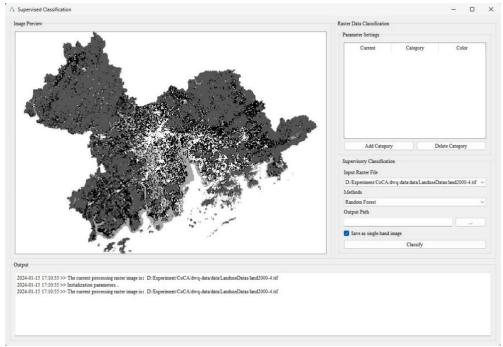


## 3.8. Image classification- Supervised classification

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.

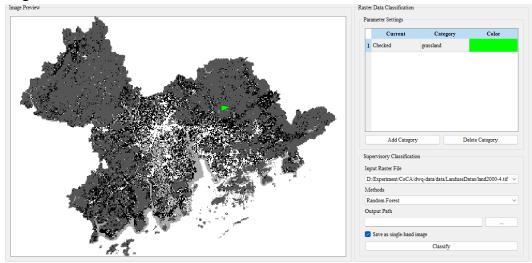
Click on the "Image Classification - Supervised Classification" option to open the corresponding interface. Users can add raster data to this interface and perform supervised classification on the raster data.

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.



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.

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.



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 classification process Classify 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.

4 CoCA v2.1.0		
File Data Preprocessing	PLUS Model Density CA CoCA Help	
2 🚽 🖂 🔁	Extract Land Expansion	🗏 🕒 🐼 🖬 🎒 🎒 🥐 🕅
Layers Vector Layer GBA_bourder_c Raster Layer Dopu2000.tif CSV File	○       Calculate Overall Development Probability         ⑩       Self Adaptive Inertia and Competition Mechanism CA         □       Markov Chain         ☑       Precision Validation         ●       Recover Density Data	

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 type will be extracted and t will be set to Nodata.	he nor	1-changeo	l land
Land-Use Data			
Previous land-use data			
Subsequent land-use data			
Output Path			
Run			

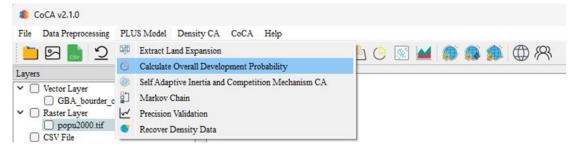
Click on the "Previous Land-use data", "Subsequent Land-use data", and "Output Path" buttons in order ..., In the pop-up folder selection dialog box, select the storage paths for the pre-change land use data, post-change land use data, and the extracted expanded land use data, in that order.

Aftercompletion,clickthe"Run"buttonRunto execute the land expansionextraction 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.



We can also use the "Calculate Overall Development Probability" button on the toolbar <sup>C</sup> 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			- 0	×
	Subsequent Land-use Samples			
	Land Use Data			
	Se	NoData Value		
	Driving Data (Select and press the delete key to delete)			
	Input Samp	es Path		
	Related Params			
	Mining method of overall development probability			
	random forest			~
	Sampling rule <ul> <li>Uniform Sampling</li> <li>Random Sampling</li> </ul>	Manual Sampling	O Stationary Sampling	
	Sampling Rate (1/1000)	300	<ul> <li>Stationary Sampling</li> </ul>	\$
	Sample file data (Polygon vector data)			
	Sample file data (Point data)			
	RF-based Paras NN-based Paras			
	Decision Trees Number	80	-	÷
	Output Pg Path			
		Convert		

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 pop up a dialog box, and the user needs to select the driver factor dataset to be trained after normalization.

Driving D	ata (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			
<ul> <li>Uniform Sampling</li> </ul>	C Random Sampling	O Manual Sampling	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:

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 Params" or "NN-based Params" as follows:

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

Lastly, click the button in the "Output Pg Path" section ...., In the pop-

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

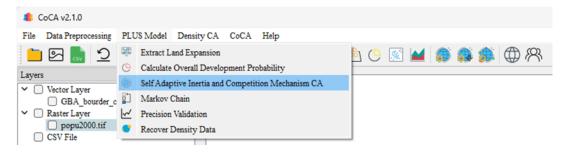
Output Pg Path

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:

(	Dutput	
	•	
	2024-01-14 20:55:59 >> Initialising the	
	model	
	2024-01-14 20:55:59 >> Launching the	
	PLUS-CA model	I
	2024-01-14 20:55:59 >> Iteration 1.	l
	2024-01-14 20:56:00 >> Result is saved to	l
	D:/Experiment/CoCA/dwq-data/test result/	I
	plus/1.tif.	I
	2024-01-14 20:56:00 >> Iteration 2.	I
	2024-01-14 20:56:00 >> Result is saved to	I
	D:/Experiment/CoCA/dwq-data/test result/	
	plus/2.tif.	

# 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.



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:

I Land-use Change Simulation by PLUS Model			- 🗆 X
Simulation Result	Accuracy Evaluation	Basic Params	Output
	Iteration FoM PA UA	Iteration Rounds 10 🔹 Land-use Data	
		Land-use Data (Reference)	
		Pg File Path	
		Constrain File Path	
		Neighborhood Size 3	
		Neighborhood Size 3  Patch Generate 0.90	
		Step Size 400 🕏	
		Land-use Demand Cost Matrix Weights Dk Weights	
Change Curve of Various Land Parcels	Change Curve of the Accuracy Indices		
600	44	🕑 Use Default Symbolization Plan	
400 -	ğ <sup>0,4</sup>	Set Symbolic Scheme	
200 -	Ž 0.2	Output File Path of Simulation Result	
		Export Parameter File (xml)	
	0 200 400 600 800 1,000 Iteration	Run	

First, enter the number of iterations in the input box Iteration Rounds 10 Please set the number of iterations 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	

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. the right side of "Neighborhood Size" Set the neighborhood size on Neighborhood Size 3 : Set the decay coefficient size on the right side of "Patch Generate" to determine the rate of decay for patch generation Patch Generate 0.90 : Set the step size on the right side of size of each step in "Step Size" determine the simulation to the 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 the user ignores this function, the system will default to using the development numbers of each land use type automatically calculated based on past data. If predictions for future years are needed, the user needs to fill in the quantity values obtained from the subsequent Markov chain calculation module for each category in this dialog box.

Land-use Demand	Cost Mat	rix W	eights	Dk We	ights
	Type 1	Type 2	Type 3	Type 4	
Future Pixel Numbe	r /	1	1	1	
			-		

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-use	Demand	i Cos	st Matrix	Wei	ghts	Dk Wei	ghts	
	Type 1	Type 2	Type 3	Type 4				
Type 1	True	False	True	True				
Type 2	True	True	True	True				
Type 3	True	True	True	True				
Type 4	True	True	True	True				

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:

and-use Demand	Cost	Matrix	Weigh	nts I	0k Weights	
		Type 1	Type 2	Type 3	Type 4	
Weight of Neighbo	orhood	1	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:

Land-use Demar	nd C	ost Matr	ix W	eights	Dk Weights	
	Type 1	Type 2	Type 3	Type 4		
Weight of Dk	1	1	1	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

Se Default Symbolization Plan		
Set Symbolic Scheme	To use a custom symbolization plan, c	lick

on the "Set Symbolic Scheme" button Set Symbolic Scheme

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

	Land Use Code	NoData Option	Pixel Statistics	Name	Color
1	2	valid Data	34197	Type 2	
2	1	valid Data	12760	Type 1	
3	3	valid Data	6250	Туре 3	
4	4	valid Data	4807	Type 4	

Clicking on the color of each category will take you to a screen like the one shown below, where you can modify the color according to your needs:

Select the color of this label	×
Basic colors	
Custom colors	Hue: 200 ↔ Red: 0 ↔ Sat: 255 ↔ Green: 170 ↔ Val: 255 ↔ Blue: 255 ↔ Alpha channel: 255 ↔ HTML: #00aaff OK Cancel

Click the "OK" button OK, 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

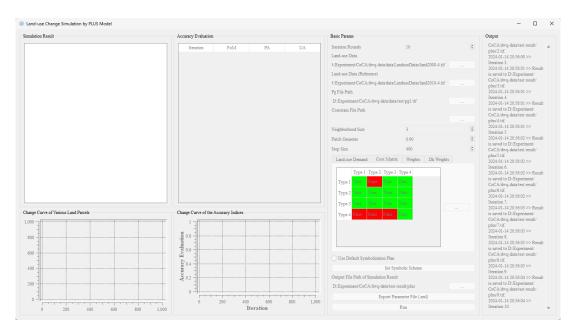
 path
 where
 you
 want
 to
 save
 the
 simulation
 results

Clickthe"ExportParameterFile"buttonExport Parameter File (xml).You can save and export all the parametersettings on the current interface in XML file format.

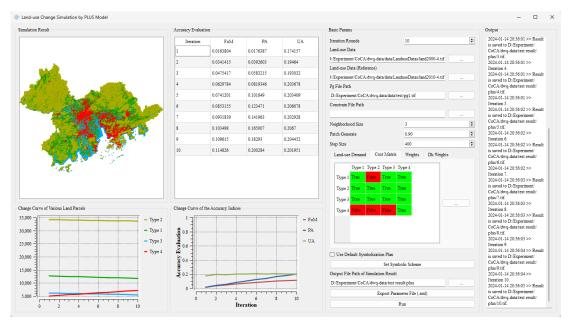
Finally, click the "Run" button on the simulation interface

 Run
 ,It can automatically simulate changes in

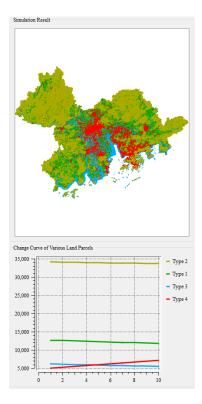
 urban land use types, as shown in the figure below:



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:



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	0.0163804	0.0176387	0.174157
2	0.0341415	0.0392603	0.19464
3	0.0475417	0.0583215	0.193032
4	0.0629784	0.0819346	0.203678
5	0.0741201	0.101849	0.203409
6	0.0853155	0.123471	0.206078
7	0.0931839	0.141963	0.202928
8	0.103498	0.165007	0.2067
9	0.109615	0.18293	0.204452
10	0.114826	0.200284	0.201951
hange Curve of ti	he Accuracy Indices		
1 -			
1			<b>=</b> PA
1			- Fol - PA - UA
1			<b>=</b> PA
1			<b>=</b> PA
Crutack Evaluation			<b>=</b> PA
1			= PA = UA
Crutack Evaluation			= PA = UA

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	
D:/Experiment/CoCA/dwq-data/test result/	
plus/1.tif.	
2024-01-14 20:56:00 >> Iteration 2.	
2024-01-14 20:56:00 >> Result is saved to	
D:/Experiment/CoCA/dwq-data/test result/	
plus/2.tif.	
2024-01-14 20:56:00 >> Iteration 3.	
2024-01-14 20:56:01 >> Result is saved to	
D:/Experiment/CoCA/dwq-data/test result/	L
plus/3.tif.	L
2024-01-14 20:56:01 >> Iteration 4.	L
2024-01-14 20:56:01 >> Result is saved to	L
D:/Experiment/CoCA/dwq-data/test result/	L
plus/4.tif.	L

# 4.4. Markov Chain calculation

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

popup menu.

a CoCA v2.1.0			
File Data Preprocessing	PLU	JS Model Density CA CoCA Help	
🗀 🖂 🔜 🖄	÷	Extract Land Expansion	占 🕒 📧 🖬 🎒 🎒 🌐 🕅
Layers	C	Calculate Overall Development Probability	
Vector Layer	۲	Self Adaptive Inertia and Competition Mechanism CA	
GBA_bourder_c		Markov Chain	
✓ □ Raster Layer	∽	Precision Validation	
popu2000.tif     CSV File	•	Recover Density Data	

We can also open the Markov Chain calculation module by clicking on the "Markov Chain" button in the toolbar

Path	Name	Data Type	Year	
		Data Type		
nstrain				
				Save
arkov Chain				
edict Year				
				\$
itput Path				

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:

```
Land-Use Data
```

	Path	Name	Data Type	Year
1	D:/Experiment/CoCA/dwq-dat	land2000-4.tif	Land-Use Data	2000

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 changes, as shown below (indicating that Type 4 cannot be converted to Type 3):

	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 The Markov chain

calculation function is now being executed. After the calculation is completed, a .csv data file will be obtained. Its content includes the total demand calculated by type, as shown below:

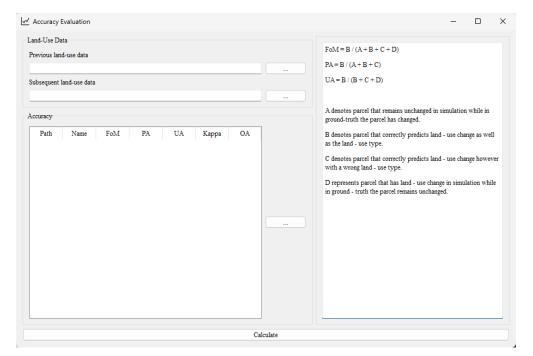
Type1	Type2	Type3	Type4	Type5	Туреб
27654	17423	1392	6409	4964	159

#### 4.5. Accuracy assessment

Click on the "PLUS Model" in the menu bar, and select "Precision Validation" from the pop-up menu.

CoCA v2.1.0			
File Data Preprocessing	PLU	VS Model Density CA CoCA Help	
🗀 🖂 🔜 🗅	сî,	Extract Land Expansion	占 (C) 📧 🖬 🎒 🎒 🎒 🕅 🕅
Layers	C	Calculate Overall Development Probability	
Vector Laver	۲	Self Adaptive Inertia and Competition Mechanism CA	
GBA_bourder_c	Ì	Markov Chain	
✓ □ Raster Layer	$\checkmark$	Precision Validation	
popu2000.tif	•	Recover Density Data	
CSV File	_		1

We can also open the Precision Validation module by clicking on the "Precision Validation" button in the toolbar  $\checkmark$  as shown in the following image:



First, click on the button to the right of "Previous land-use data" and "Subsequent land-use data" respectively, In 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:

Land-Use Data	
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

...

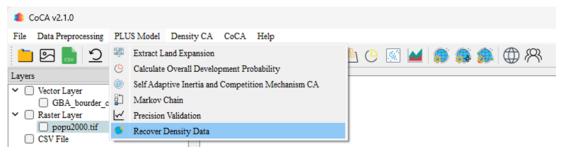
import the land-use data for accuracy assessment, as shown below:

	Dett	Name	FoM	PA	UA	V.		OA		
	Path	Ivame	FOIVE	FA	UP	L Ka	appa	UA		
After	con	npleting	the	above	steps,	click	on	the	"Calculate"	but
				Calculate					4	o s

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.



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:

🤍 Recover Dis	screte Data					-		$\times$
Params								
Original Dens	ity Data							
<u> </u>								
Discrete Data	l							
Files							1	
Path	Name	Data Type	Width	Height	Band Count	Finish		
Output Path								
			1	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:

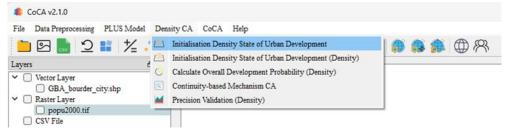
Params	
Original Density Data	
Discrete Data	

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, Click on the "Run" button \_\_\_\_\_\_\_, To start executing the function of updating discrete data to continuous data, click on the "Run" button.

# Simulating urban feature continuity changes based on DensityCA

## 5.1. Calculating initial density state of urban development

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 as shown in the following image:

Initialisation Density State of Urban Development		-	>
and Use Data			
Previous land-use data			
Subsequent land-use data			
Classification of Urban Land and Non-urban Land			
Index	Pixel value	Urban Land	
Dutput Path			
	Run		

First, click on the buttons to the right of "Previous Land-use data" and "Subsequent Land-use data" respectively, In the pop-up file selection dialog box,

select the storage paths of the land-use data before and after the change, as shown below:

Land Use Data	
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:

1 1 2 2			
2 2	2	True	
	1	True	
3 3	3	True	
4 4		True	

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

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.

Layers 6 Calculate Overall Develops Vector Layer 6 Calculate Overall Develops GBA_bourder_city.shp 6 Continuity-based Mechani	
Layers t Layers t Layers t Calculate Overall Develops GBA_bourder_city.shp	
Layers t Layers t Calculate Overall Develops Vector Layer SBA_bourder_city.shp State Calculate Overall Develops Continuity-based Mechanic	Jrban Development
Vector Layer     GBA_bourder_city.shp     GBA_bourder_city.shp     Calculate Overall Develop     Continuity-based Mechani	Jrban Development (Density)
Raster Layer     popu2000.tif	

This interface requires the user to input city development density data (Density Data) and a density threshold (Density Threshold (Value for Urban Areas)). The system will recognize grid units greater than the threshold as urban areas and save them to the output file (Output Path). The selection of the threshold can usually be done in other GIS software using an information identification tool to select the lowest density value among multiple city points.

A Initialisation Density State of Urban Development	-	×
Params		
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 v2.1.0 File Data Preprocessing PLUS Mode	l Density CA CoCA Help	
<u>►</u> 🖻 🖸 🖬 🏌	Initialisation Density State of Urban Development	<b>8 8 8</b>
Layers	Calculate Overall Development Probability (Density)	
<ul> <li>Vector Layer</li> <li>GBA_bourder_city.shp</li> <li>Raster Layer</li> </ul>	Continuity-based Mechanism CA Precision Validation (Density)	
popu2000.tif     CSV File		

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  $\bigcirc$ , as shown in the following figure:

Calculate Overall Development Probability			- 0 ×
	Subsequent Land-use Samples		
	Land Use Data		
		Set NoData Value	
	Driving Data (Select and press the delete key to delete)		
	Input Sa	mples Path	
	Related Params		
	Mining method of overall development probability		
	random forest		~
	Sampling rule		
	<ul> <li>Uniform Sampling</li> <li>Random Sampling</li> </ul>	O Manual Sampling	<ul> <li>Stationary Sampling</li> </ul>
	Sampling Rate (1/1000)	300	•
	Sample file data (Polygon vector data)		
	Sample file data (Point data)		
	RF-based Params NN-based Params		
	Decision Trees Number	80	•
	Output Pg Path		
		Convert	

First, click on the button in the "Land Use Data" section \_\_\_\_\_, The system will automatically pop up a dialog box. Users need to select the initial city development density state data obtained in the previous steps.

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	

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	$\sim$
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			
<ul> <li>Uniform Sampling</li> </ul>	○ Random Sampling	O Manual Sampling	O Stationary Sampling

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

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 below:

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 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 Params" or "NN-based Params", as shown below:

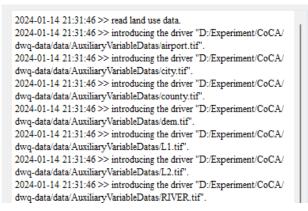
RF-based Params	NN-based Params		
Decision Trees Nun	ıber	80	<b>÷</b>

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 Pg Path
D:/Experiment/CoCA/dwq-data/data/test/pg2.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:



# 5.3. Simulating the continuity changes of urban features

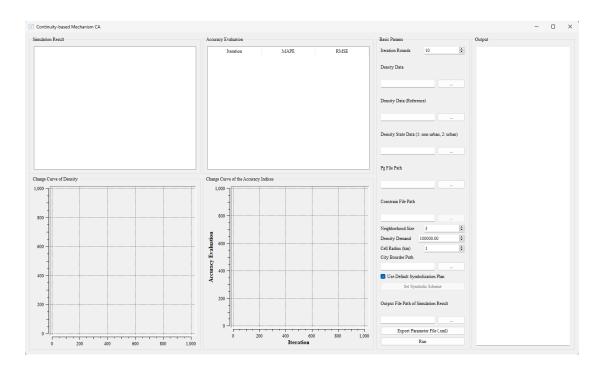
Click on the menu bar "Density CA" and select "Continuity-based Mechanism

CA" from the pop-up menu.

File Data Preprocessing PLUS Model	Density CA CoCA Help
	Initialisation Density State of Urban Development
<ul> <li>Vector Layer</li> <li>GBA bourder city.shp</li> </ul>	Calculate Overall Development Probability (Density) Continuity-based Mechanism CA
Raster Layer     popu2000.tif	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 as 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:

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

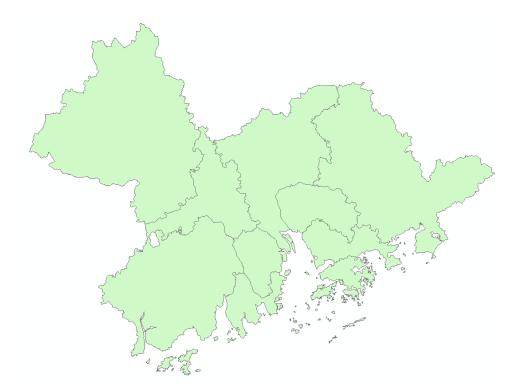
Note that the "Constrain File Path" function is used to restrict development in specific areas, and the path can be left empty. If you want to use this function, make

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," Density Demand 10000.00 The simulation experiment, the model will automatically calculate the total demand based on the density data that has been input. If it is an experiment to predict future years, you will need to manually modify the relevant values.; set the cell radius size on the right side of "Cell Radius," (etl Radius (km) 1

In version 2.0, the "Urban Center" module has been removed. Users need to click the button on the right side of the "City Border Path", and select the vector boundary data of the experimental research area (it is best to have data that is finely divided according to county boundaries) in the pop-up dialog box. As shown below:

City Bourder Path



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



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

	sity Scher		5 A 4 5	_	
		Spatial Heteroge Density (Double cli			
F10	-		Value	~ ·	
<b> </b> 1	0.063699	Density Code	Value > 0.0636995	Color	
1	23712.1		> 23712.1		
3	47424.1		> 47424.1		
4	71136.1		> 71136.1		
5	94848.1		> 94848.1		
	umber of C	ategories			
Nu 5	umber of C	ategories			

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:

Basic colors	
Fick Screen Color	
Custom colors	Hue: 200   Red: 0 Sat: 255   Green: 170 Val: 255   Blue: 255 Alpha channel: 255 HTML: #00aaff

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 method.

olor	Scheme Spatial Heterog	eneity Analysis	
sp	atial Heterogeneity Analysi	s	
Partiti	on File Path		
D:/Ex	periment/CoCA/dwq-data/d	ata/SpatialData/GBA_bourder_city.shp	
abel l			
	CTID		
Prop	perties of Partition File (Dou	ble click to change)	
	Index	Name	Color
1	1	200	
2	2	202	
3	3	203	
4	4	205	
5	5	206	
6	6	209	
7	7	210	
8	8	216	
9	9	217	
10	10	370	

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

To facilitate further research, click the button in the "Output File Path of

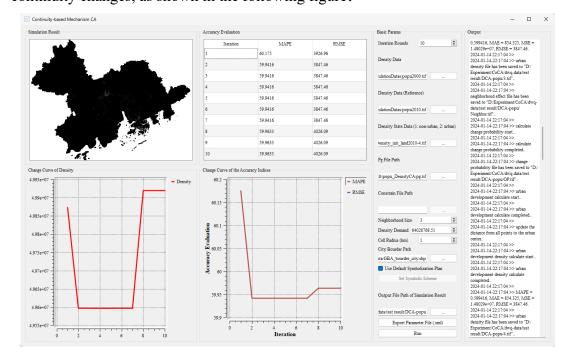
Simulation Result" feature \_\_\_\_\_, and select the save path for the simulation

Output File Path of Simulation Result					

Click the "Export Parameter File" button Export Parameter File (.xml) to save and export all current parameter settings in XML file format.

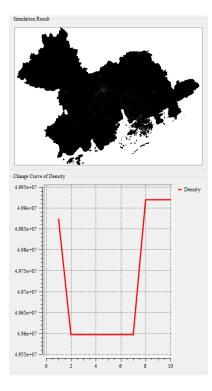
results in the pop-up dialog box.

Finally, in the simulation interface, click the "Run" button
Run
to automatically perform the simulation of urban feature
continuity changes, as shown in the following figure:

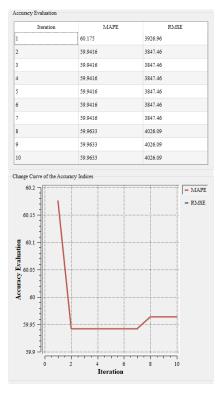


After the program finishes running, this system will display the final urban feature change map, accuracy evaluation indicators for each iteration, density change line graph, and line graphs showing changes in various accuracy evaluation indicators.

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).



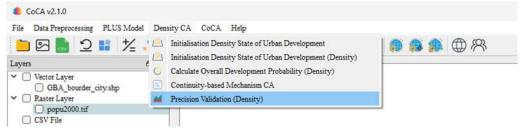
In addition, we provide a Log output interface for checking relevant outputs. The Log output interface for the urban feature density change simulation module is shown in the figure below:

Output	
>> neighborhood effi "D:/Experiment/CoC DCA-popu/Neighbo 2024-01-14 22:17:03 >> calculate change p 2024-01-14 22:17:03 >> calculate change p 2024-01-14 22:17:03 >> change probabilit	<pre>&gt;&gt; 2024-01-14-22:17:03 probability start &gt;&gt; 2024-01-14-22:17:03 probability completed &gt;&gt; 2024-01-14-22:17:03 y file has been saved to A/dwq-data/test result/</pre>

## 5.4. Accuracy evaluation

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

(Density)' from the pop-up menu.



Alternatively, you can open the precision evaluation module by clicking on the

Accuracy Evaluation (Den	sity)					- 0
ensity Data valuation Model						MSE (Mean Square Error)
Normal		C	Partitioned			$MSE = \frac{1}{n} \sum_{i=1}^{n} (\hat{y}_i - y_i)^2$
eal Density Data						$mSE = \frac{1}{n}\sum_{i=1}^{n} (y_i - y_i)^{-1}$
						RMSE (Root Mean Square Error)
dministrative divisions data	(vector type)					$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (\hat{y}_i - y_i)^2}$
curacy						MAE (Mean Absolute Error)
Path 1	MSE	RMSE	MAE	MAPE		$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)
						$SMAPE = \frac{100\%}{n} \sum_{i=1}^{n} \frac{ \hat{y}_i - y_i }{( \hat{y}_i  +  y_i )/2}$
						Where <i>n</i> is the number of all samples, $y_i$ is the true value and $\hat{y}_i$ is the e
				-		
					lculate	

First, click on the button to the right of 'Real Density Data' ..., and

57

select the path where the real data is stored in the pop-up folder selection dialog, as shown below:

Real Density Data	
D:/Experiment/CoCA/dwq-data/data/PopulationDatas/popu2000.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:

	Path	MSE	RMSE	MAE	MAPE	SMAPE
l	D:/Experiment/	5173621.544	2274.560	537.877	60.175	67.086
2	D:/Experiment/	4956253.915	2226.265	529.056	59.942	66.724
3	D:/Experiment/	4956253.915	2226.265	529.056	59.942	66.724
4	D:/Experiment/	4956253.915	2226.265	529.056	59.942	66.724
5	D:/Experiment/	4956253.915	2226.265	529.056	59.942	66.724
6	D:/Experiment/	4956253.915	2226.265	529.056	59.942	66.724
7	D:/Experiment/	4956253.915	2226.265	529.056	59.942	66.724

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.

Evaluation			O Parti	tioned		
Real Dens	aty Data					
D:/Experi	iment/CoCA/dwq-data/da	ta/PopulationD	atas/popu2010.ti	if		
Administr	rative divisions data(vecto	or type)				

to start the execution of the

precision evaluation function."

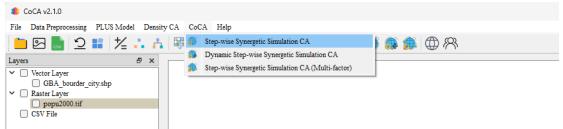
Run

# Simulating land use-population-economy changes based on CoCA

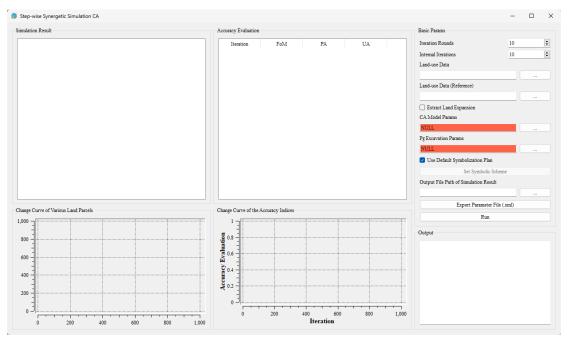
### 6.1. Simulating land use-population-economy changes

This feature is mainly for the simulation of a single factor using a "hierarchical progression" driver factor dynamic update strategy. Users can choose the corresponding function to simulate land use elements or population and economic elements respectively. The operation steps are basically consistent with those introduced in the previous sections.

Click on the 'CoCA' option in the menu bar and select 'Step-wise Synergetic Simulation CA' from the pop-up menu.



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)	
	C Entrant I and Empanying

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

NULL

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

on the 'CA Model Params' button

•••

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

interface, as shown below:

🔋 Set CA Model Paras						-		×
Basic Params			Land-use Demand	Cost Matrix	Weights	Dk W	Veights	
Iteration Rounds	10	-		Type 1 Ty	rpe 2 Type 3	Ty		
Land-use Data			Future Pixel Numbe	er / /	1	1		
ent/CoCA/dwq-data/data/La	nduseDatas/land2000-4.tif							
Land-use Data (Reference)								
ent/CoCA/dwq-data/data/La	nduseDatas/land2010-4.tif							
Constrain File Path								
Neighborhood Size	3	•						
Patch Generate	0.90	•						
Step Size	400	•			_			
					0	ĸ	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	<u>þ</u> 0	<b>÷</b>
Land-use Data		
nent/CoCA/dwq-data/data/Landusel	Datas/land2000-4.tif	
Land-use Data (Reference)		
nent/CoCA/dwq-data/data/Landusel	Datas/land2010-4.tif	

The 'Constrain File Path' is default empty. If you want to limit the development in specific areas, Constrain File Path 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 ; Set the 3 attenuation coefficient size by entering the value in the input box to the right of "Patch Generate" Patch Generate ; Set the step size by entering 0.90 of "Step Size" the value input the right in the 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	С	ost Matr	ix W	eights	Dk Weights
		Type 1	Type 2	Type 3	1
Future Pixel Numbe	r	1	1	1	1
	_		_		

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-use	Demand	Cos	st Matrix	We	ights	Dk Weights	
	Type 1	Type 2	Type 3	Type 4		]	
Type 1	True	False	True	True			
Type 2	True	True	True	True			
Type 3	True	True	True	True			
Type 4	True	True	True	True			

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	Cost	Matrix	Weigh	nts I	0k Wei∮t
		Type 1	Type 2	Type 3	Type 4
Weight of Neighbor	hood	1	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:

and	Cost Ma	trix	Weights	Dk W	/eights	•
		Type 1	Type 2	Type 3	Type 4	
We	ight of Dk	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 Params" Pg Excavation Params NULL , and the system will automatically pop up a sub-

interface for excavating the overall development probability (Pg), as shown below:

Calculate Overall Development Probability			- U ×
	Subsequent Land-use Samples		
	Land Use Data		
	D:/Experiment/CoCA/dwq-data/data/LanduseDatas/land2000-4.tif		
		Set NoData Value	
	Driving Data (Select and press the delete key to delete)		
	Input San	aples Path	
	1 D:/Experiment/CoCA/dwq-data/data/AuxiliaryVariableDatas/airpo	rt.tif	
	2 D:/Experiment/CoCA/dwq-data/data/AuxiliaryVariableDatas/city.t	if	
	3 D:/Experiment/CoCA/dwq-data/data/AuxiliaryVariableDatas/count	v.tif	
	4 D:/Experiment/CoCA/dwq-data/data/AuxiliaryVariableDatas/dem.	-	
	5 D/Experiment/CoCA/dwq-data/data/AuxiliaryVariableDatas/L1.tit		
	Mining method of overall development probability random forest Sampling rule O Uniform Sampling O Random Sampling	O Manual Sampling	<ul> <li>Stationary Sampling</li> </ul>
	Sampling Rate (1/1000)	300	•
	Sample file data (Polygon vector data)		
	Sample file data (Point data)		
	RF-based Params NN-based Params		
	Decision Trees Number	80	<b>•</b>
	Output Pg Path		
	D:/Experiment/CoCA/dwq-data/data/test/pg2.tif		
		Convert	

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: Land Use Data

D:/Experiment/CoCA/dwq-data/data/LanduseDatas/land2000-4.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.

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

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			
<ul> <li>Uniform Sampling</li> </ul>	O Random Sampling	O Manual Sampling	Stationary Sampling

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

RF-based Params	NN-based Params		
Decision Trees Nun	nber 80	30	

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

sche	_	Jse Default Symboliz Set S	<b>ation Plan</b> Symbolic Scheme		.Click on	the "S	et Syn	nbolic S	Scheme	e" button to
set	the	vector	land	parcel	symbols	in	the	popp	ed-up	interface
		Set Symb	olic Scheme		as show	wn be	low:			
		الله الم	and-use Scheme				-			
		Pro	perties of Land Use	Type (Double click to	change)					

	Land Use Code	NoData Option	Pixel Statistics	Name	Color
1	2	valid Data	34197	Type 2	
2	1	valid Data	12760	Type 1	
3	3	valid Data	6250	Type 3	
4	4	valid Data	4807	Type 4	

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:

Select the color of this label	×
Basic colors	+
Custom colors	Hue: 114 ⊕ Red: 85 ⊕ Sat: 114 ⊕ Green: 143 ⊕ Val: 143 ⊕ Blue: 79 ⊕ Alpha channel: 255 ⊕ HTML: #55824£ OK Cancel

Click the "OK" button  $\bigcirc K \bigcirc$ , 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

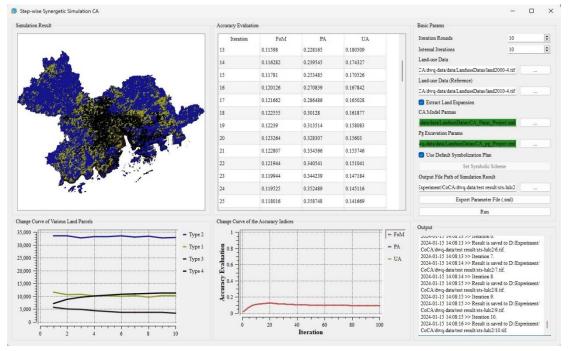
	Output File Path of Simulation Result	
in the popped-up dialog box		

Click	the	"Export	Parameter	File"	button
Expo	ort Parameter File (.	xml)	, to save and expo	ort all current	parameter
settings in XM	L file forma	t.			

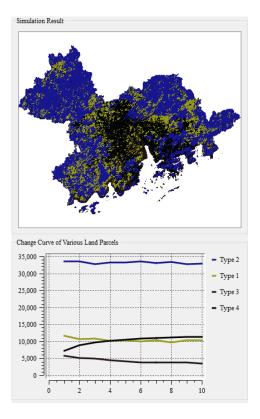
Finally,	click	the	"Run"	button	on	the	simulation	interface
	Run	1		, to a	utoma	atically	perform the	simulation

of urban land-population-economic changes.

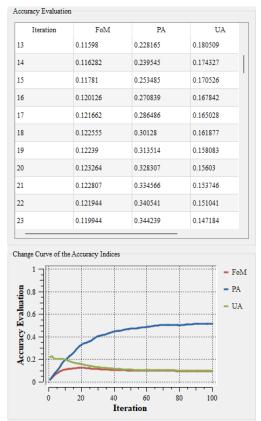
After the program finishes running, the system will display the final land use type map, accuracy evaluation indicators for each iteration, line graphs showing the changes in the number of land parcels for each type, and line graphs showing the changes in accuracy evaluation indicators, as shown in the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

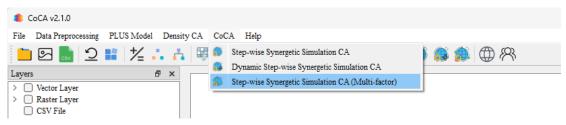


In addition, we provide a Log output interface for checking relevant outputs. The Log output interface for the urban land-population-economic change simulation module is shown in the following figure:

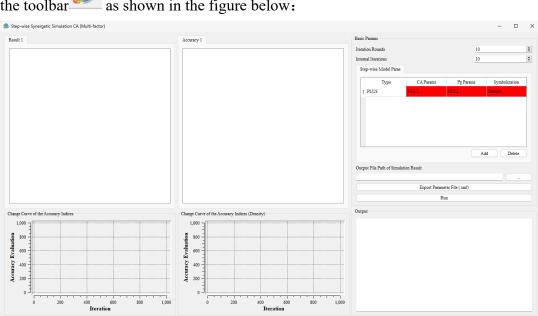
Dutput	
2024-01-13 14.08.13 // Iteration 0.	
2024-01-15 14:08:13 >> Result is saved to D:/Experiment	1
CoCA/dwq-data/test result/sts-lulc2/6.tif.	
2024-01-15 14:08:13 >> Iteration 7.	
2024-01-15 14:08:14 >> Result is saved to D:/Experiment	1
CoCA/dwq-data/test result/sts-lulc2/7.tif.	
2024-01-15 14:08:14 >> Iteration 8.	
2024-01-15 14:08:15 >> Result is saved to D:/Experiment	1
CoCA/dwq-data/test result/sts-lulc2/8.tif.	
2024-01-15 14:08:15 >> Iteration 9.	
2024-01-15 14:08:15 >> Result is saved to D:/Experiment	1
CoCA/dwq-data/test result/sts-lulc2/9.tif.	
2024-01-15 14:08:15 >> Iteration 10.	
2024-01-15 14:08:16 >> Result is saved to D:/Experiment	/ 1
CoCA/dwq-data/test result/sts-lulc2/10.tif.	1

## 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



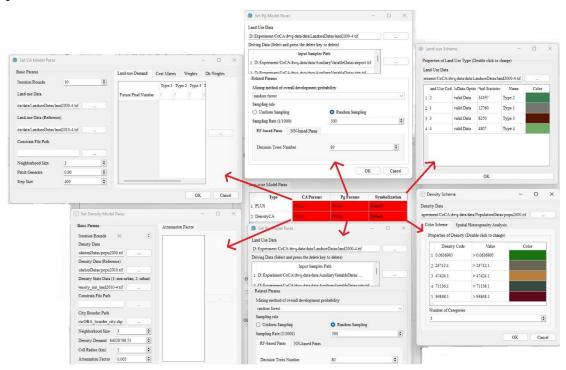
as shown in the figure below: the toolbar

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:

	Type	CA Params	Pg Params	Symbolization
1	PLUS	D:/Experiment/	D:/Experiment/	Default
2	DensityCA	D:/Experiment/	D:/Experiment/	Default
3	DensityCA	D:/Experiment/	D:/Experiment/	Default

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 4.2, and for symbolization, refer to section 4.3. For the DensityCA model, refer to section 5.2 for the CA parameter setting interface, section 6.1 for the Pg

parameter setting interface, and section 5.3 for symbolization.

 To facilitate future research, click the button in the "Output File Path of Simulation

 Result" feature
 ...

 , in the dialog box that appears, select the path to save the

 Simulation results.

 Output File Path of Simulation Result

 Click
 the

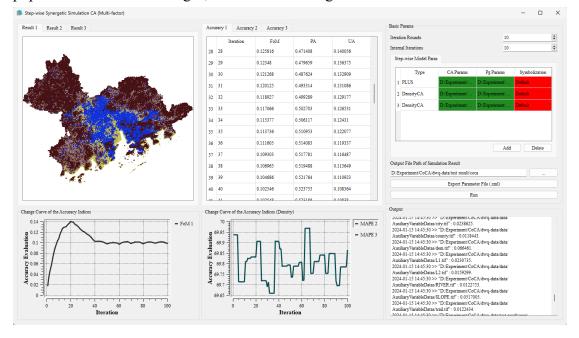
 "Export Parameter File (xml)

 , to save and export all the current parameter

settings in XML file format.

Finally,	in	the	simulation	interfa	ace, click	the "	Run"	button
		Run		to a	automatically	simulate	urban	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		
4 CoCA v2.1.0		
File Data Preprocessing PLUS Mo	Density CA CoCA Help	
늘 🖂 🔜 එ 🖬 🏄	📩 🚠 🐺 🕒 ( 🌐 Website and Update 🔰 🐼 🕍 🎒 🎆 🕌 🥋	
Layers	🗗 🗙 🕅 About Us	
> Vector Layer		

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.



We can also view information about the development team by clicking the "About Us" button on the toolbar  $\Re$ , as shown below:

#### 🛞 About Us



CoCA - Spatial Cooperation Development Platform Simulation for "Land-Population-Economy" based on Cellular Automaton Model Version 2.1.0

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#### CoCA v2.1.0 was developed by the following laboratory:

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# 8. Copyright Statement

CoCA v2.1.0: Spatial Cooperation Development Platform Simulation for "Land-Population-Economy" based on Cellular Automaton Model

CoCA v2.1.0 was developed by the following laboratory: UrbanComp Team for Location Intelligence and Urban Sensing, School of Geography and Information Engineering, China University of Geosciences, Wuhan, China.

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