

Mix-cell Cellular Automata V1.0 (MCCA) User's Manual

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Consultation

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Abstract

When used for landuse change modeling, Cellular Automata (CA) traditionally assume each cell to be of one landuse type at each time step, ignoring the mixed landuse structures that are often found in land units. Mixed cells, composed of cover proportions of multiple landuse types, can better express the continuous changes of land use, and provide a new perspective for modeling the spatio-temporal dynamics of mixed landuse structures.

Simulating landuse change with mixed cells is challenging because mixed-cell CAs are fundamentally different from conventional CAs. We presents the first attempt of developing a mixed-cell CA (MCCA). The structure of CA is re-designed based on mixed cells, including the representations of cell state, lattice, and neighborhood. The transition rules are automatically constructed by random-forest regression over historical data and a competition mechanism selects among multiple landuse types at the sub-cell scale. In addition, evaluation methods for both simulation accuracy and similarity of landuse structure are proposed for MCCA.

The MCCA represents a new breed of geospatial CA models for spatio-temporal dynamics of mixed landuse structures. Also, the MCCA provides a new approach to enable more dynamic mixed landuse modeling to move away from the analysis of static patterns.

One of the biggest advantages of mixed-cell CA models is the capability of simulating the quantitative and continuous changes of multiple landuse components inside cells, while pure-cell CA models can only simulate the qualitative and discrete change of landuse at the cell level. Therefore, mixed-cell CA models are able to simulate subtle changes in landuse structures caused by minor variations of socio-economic, eco-environmental and political driving factors, providing a detailed perspective for understanding landuse change process.

Also, the quantitative and continuous simulations generated by mixed-cell CA models that contain the information for landuse structure in each cell have the potential to help researchers more precisely evaluate the impacts of landuse change on many environment variables, such as air quality, the urban heat island, landscape connectivity, net primary production (NPP) lost, ecological service value, energy consumption and more. Mixed-cell CA models may better support space-time continuous analysis and the quantitative calculation of environment variables. In addition, mixed-cell CA models provide an enabling approach to the simulation of structural changes of mixed land use, as most previous studies focused on the measurement and static analysis of mixed landuse structures and ignored their dynamic evolution. The mixed-cell CA model can simulate the gradual change in land use structures and help the researchers understand how the multiple driving factors interact to generate the future distribution of mixed land use.

MCCA was developed purely in the C++ language. The parallel technology of MCCA software is from High-performance Spatial Computational Intelligence Lab @ China University of Geosciences (Wuhan) (<https://github.com/HPSCIL>). The Random forest technique in our model is from a powerful open source library called Alglib 3.9.2 (<http://www.alglib.net/>). The UI of the software is built using a famous open source library Qt 5 (<https://www.qt.io/download/>). This UI provides a real-time display of dynamic changes of land use in simulation process. Moreover, the using of open source library GDAL 2.0.2 (<http://www.gdal.org/>) allows our model to directly read and write raster data (.tif, .img, .txt files) that includes geographical coordinate information.

This user's manual is intended to provide users of MCCA a “quick start” on how to use the software. All of the necessary data and files for the tutorial have been provided and these can be used as templates for how to format your own files latter on.

1. Download and start MCCA

The latest version of MCCA software and the user's manual are provided at a download link (https://github.com/HPSCIL/Mixed_Cell_Cellular_Automata). Click the executable files “MCCA VX.0.exe” to start the software.

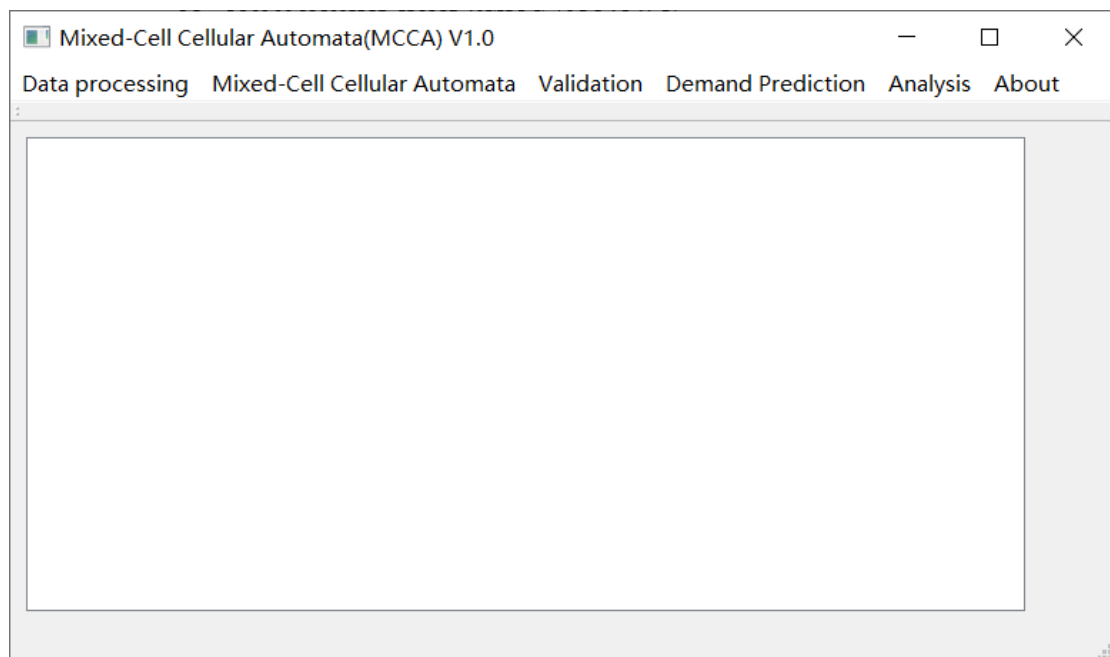


Fig. 1. Main interface of MCCA model.

The main interface is a brief image browser which provide dynamic display function for the simulation process.

2. Example data description

Tab. 1 List of test data

Category	Data	Filename	Description
Mixed Land use data	Land use structure data	Xianning_2000_landuse_1~7.tif	Each land use structure data has 7 layers, each layer represents the cover proportion of a land use type: Layer1: Cropland, Layer2: Woodland, Layer3: Glassland, Layer4: Waterbody, Layer5: Urban lan, Layer6: Rural Settlements, Layer7: Other
		Xianning_2005_landuse_1~7.tif	
		Xianning_2010_landuse_1~7.tif	
		Xianning_2015_landuse_1~7.tif	
Constraint data	Land use constraint	OpenWater.tif	Cover proportion of open water
Socioeconomic data	Population	population.tif	http://www.geodoi.ac.cn/WebCn/Default.aspx
	GDP	gdp2010.tif	
	Proximity to Town center	dst_town.tif	World Urbanization Prospects: The 2014 Revision, CD-ROM Edition
	Proximity to highway	dst_highway.tif	
	Proximity to arterial road	dst_arterialroad.tif	
	Proximity to primary road	dst_primaryroad.tif	OpenStreetMap (https://www.openstreetmap.org/)
	Proximity to secondary road	dst_secondaryroad.tif	
	Proximity to tertiary road	dst_tetriary.tif	
Climatic and environmental data	Proximity to high-speed railway stations	dst_highspeedrailwaystation.tif	http://lbsyun.baidu.com/
	Soil type	soiltype.tif	HWSD v 1.2 (http://westdc.westgis.ac.cn/data/844010ba-d359-4020-bf76-2b58806f9205)
	Annual Mean Temperature	annualTemperature.tif	WorldClim v2.0 (http://www.worldclim.org/)
	Annual Precipitation	annualPrecipitation.tif	
	DEM	DEM.tif	NASA SRTM1 v3.0
	Slope	slope.tif	

The test dataset are found in the **TestData** folder. Use this dataset to run example model or compared with your simulation results. In practical applications, more human-related and natural environment effects can be taken into consideration. The study region in this example is Xianning, located in south of Hubei province, central China. **Note that cover proportions of all land use components represent the landuse structure of a cell.**

3. User interfaces of MCCA model

The MCCA consist of two main parts, 1) Mining of quantitative transition rules and 2) Simulating dynamic of land use structures. Users are allowed to start corresponding module by selecting option from the “Mix-cell Cellular Automata Model” button’s pull-down menu on the main menu.

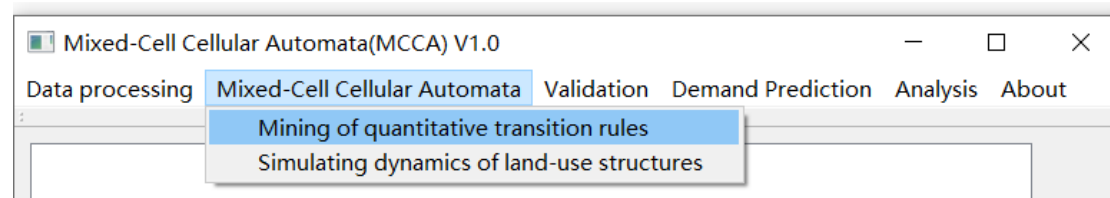


Fig. 2. Starting the ‘Mining of quantitative transition rules’ module.

3.1. Mining of quantitative transition rules

3.1.1. Start the module

Click the “Mining of quantitative transition rules” item to start the module that has the same name as the item. Then input the amount of land use type in your simulation, the amount of land use types in this experiment is 7. The amount of land use can not be less than 2 (e.g., urban land and non-urban land).

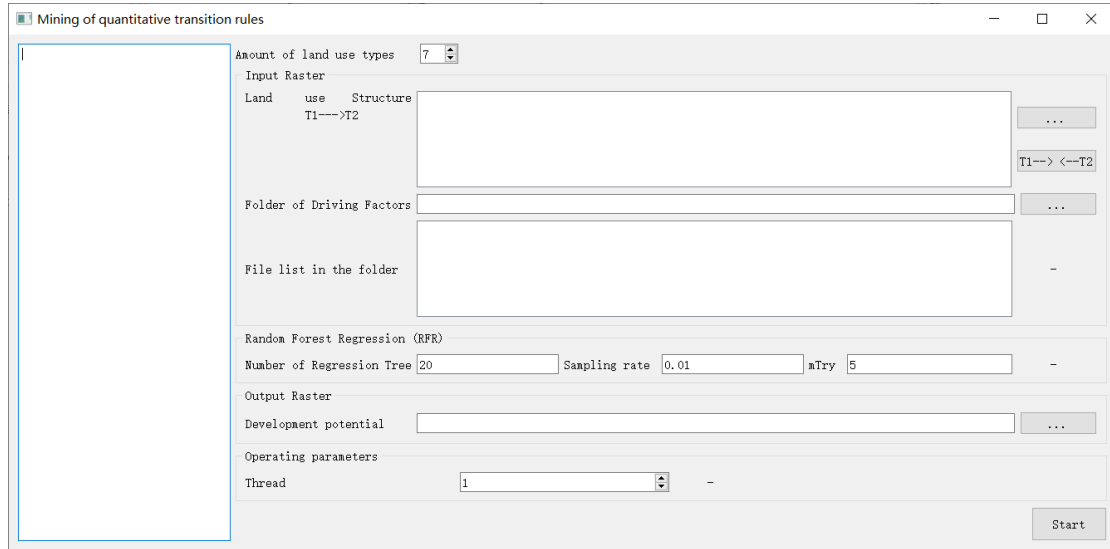



Fig. 3. UI of the ‘Mining of quantitative transition rules’ module.

3.1.2. Input land use data

Click the  button in the “**Land use Structure**” group box and select the two periods of land use data: ‘Xianning_2000_landuse’ and ‘Xianning_2010_landuse’ in the pop-up dialog. Note that in this experiment, 7 land use types mean 7 land use components in each land use structure data. You only need to select the first band of the two land use structure data (7 bands in total) in this step.

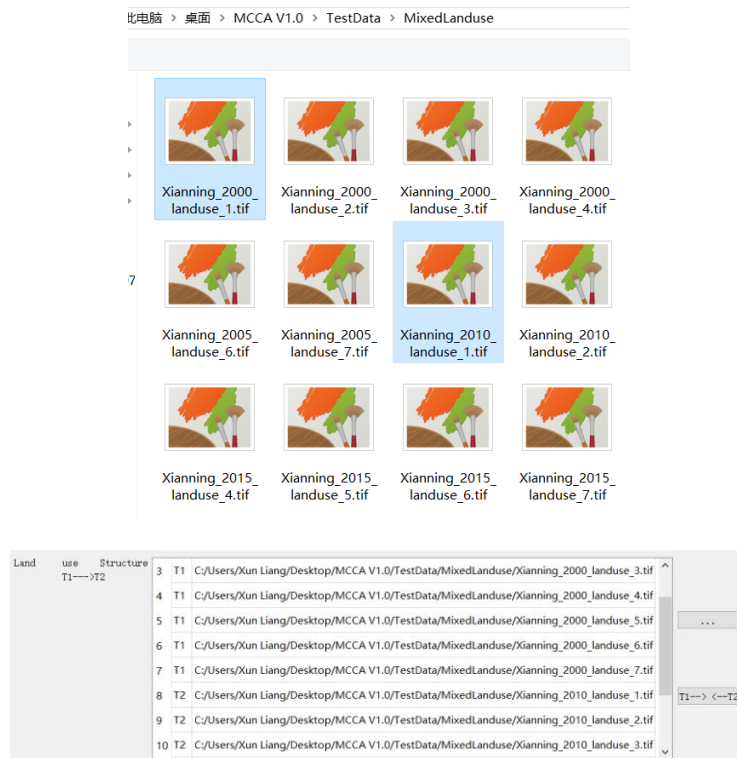
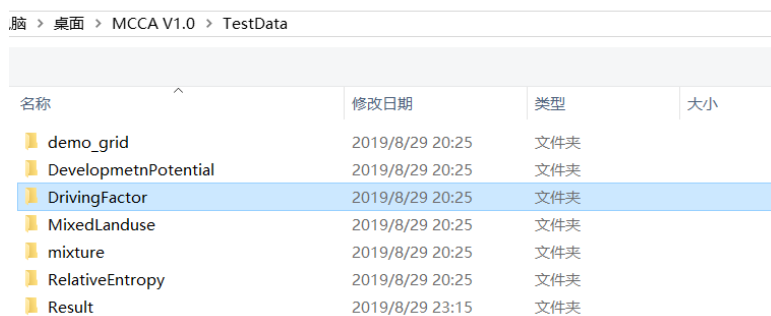


Fig. 4. Select two periods of land use structure data.

Please ensure that the latter land use structure data (e.g., T2, Xianning_2010_landuse) rank behind the early land use structure data (e.g., T1, Xianning_2000_landuse). The users can click the button to transpose their sort.

3.1.3. Input driving factors

Click the button in the “Folder of driving factors” group box and select the folder of driving factors in the pop-up dialog. The MCCA software would automatically load the “tiff” File in the folder. Our example data provide 14 driving factors for example run of MCCA model.



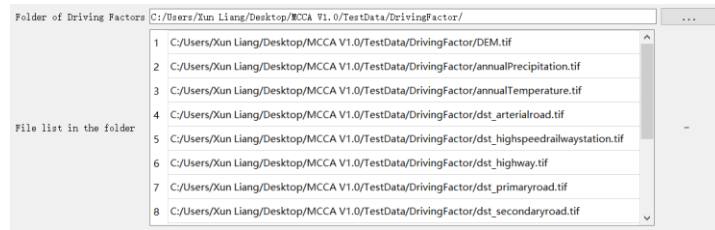



Fig. 5. Input all the driving factors by selecting one folder.

3.1.4. Setting the training parameters and output path

Users are allowed to set the parameters of **Random Forest Regression (RFR)**. Sampling rate is set to 0.01 by default, it means about one percent of pixels is selected for training. The number of regression tree is set to 20 in this experiment. mTry means the feature number used to train the RFR model. The max feature number is 14 in this experiment, equal to the number of driving factors. Then, click the  button in the “**Output Raster**” group box and input the save path of change probability in the pop-up dialog. The generated change probability is named “result_changeProbability.tif”. The users can increase the number of parallel internal threads to accelerate the running speed.

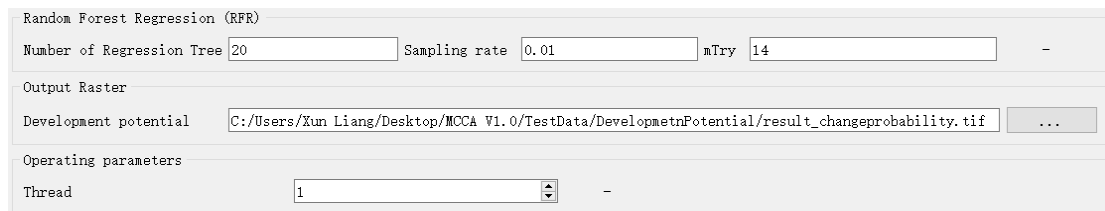
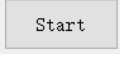


Fig. 6. Determining the training parameters and output path of the RFR.

3.1.5. Running program and examine the result

Once the setup mentioned above has completed, click the button  for running the module. There will come out a message box as below when the model process run is complete.

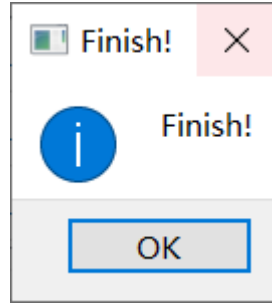


Fig. 7. A message that shows the program run successfully.

The text box at the left of the user interface will output the training velocity and accuracies of the RFRs for each land use components. Three accuracies indicators are the RMSE and OOB-RMSE for each land use type.

```
Train data, please wait...
save accuracy record...

Type 0
make df-trees success = 1
RMSE = 0.0216804
OOB RMSE = 0.0607237
Run time: 1.203

Type 1
make df-trees success = 1
RMSE = 0.0129695
OOB RMSE = 0.0379129
Run time: 1.094

Type 2
make df-trees success = 1
RMSE = 0.0100302
OOB RMSE = 0.0311892
Run time: 1.14

Type 3
make df-trees success = 1
RMSE = 0.0316778
OOB RMSE = 0.0891605
Run time: 1.86

Type 4
make df-trees success = 1
RMSE = 0.0382262
OOB RMSE = 0.10084
Run time: 1.156

Type 5
make df-trees success = 1
RMSE = 0.00857385
OOB RMSE = 0.0270509
Run time: 1.547

Type 6
make df-trees success = 1
RMSE = 0.00356475
OOB RMSE = 0.0143077
Run time: 1.515
```

Fig. 8. Accuracy for each land use type.

Then the program generate 7 change probability for each land use type.

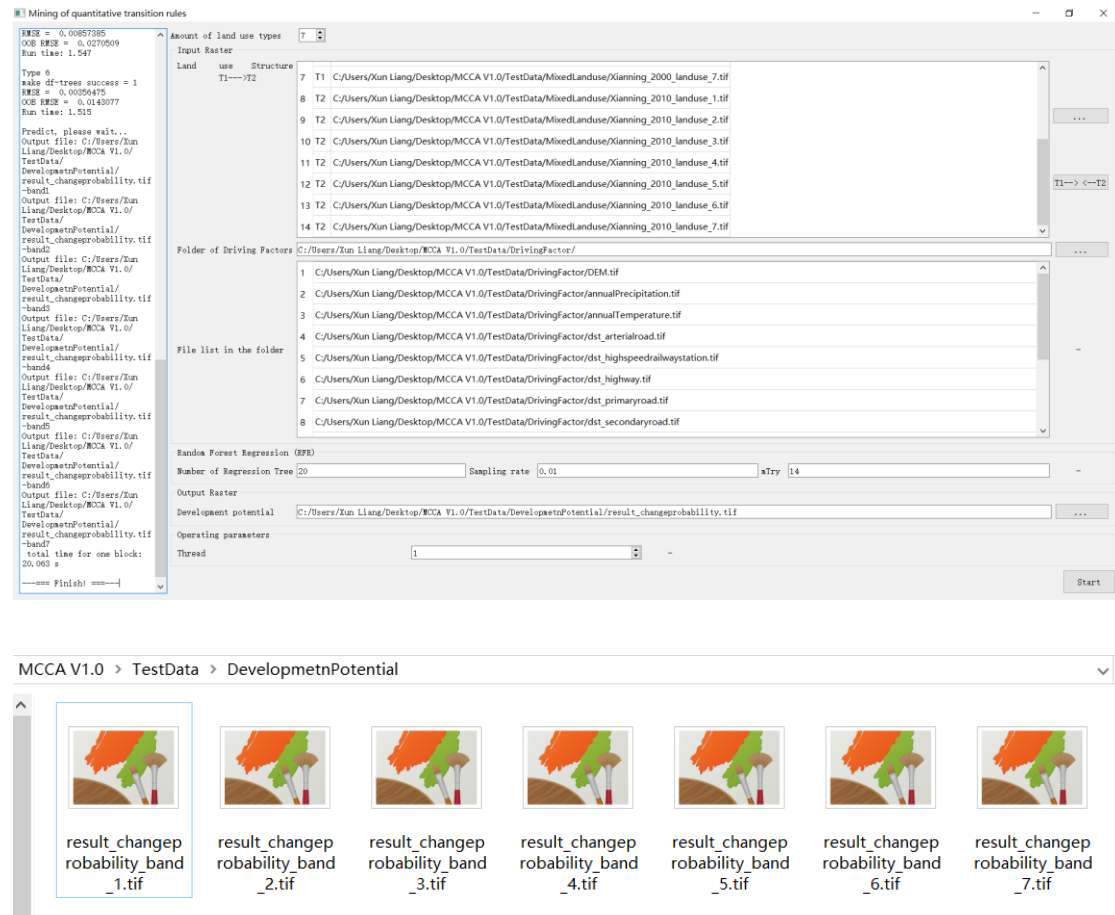


Fig. 9. Output of the ‘Mining of quantitative transition rules’ module.

3.2. Simulating dynamics of land use structures

3.2.1. Start the module

Click the “**Simulating dynamics of land use structures**” item to start the simulation module. Then input the amount of land use type in your simulation, the **amount of land use types** in this experiment is 7. The users can increase the number of parallel internal **threads** to accelerate the running speed. The **neighborhood** effect of MCCA is set to 3 in this experiment.

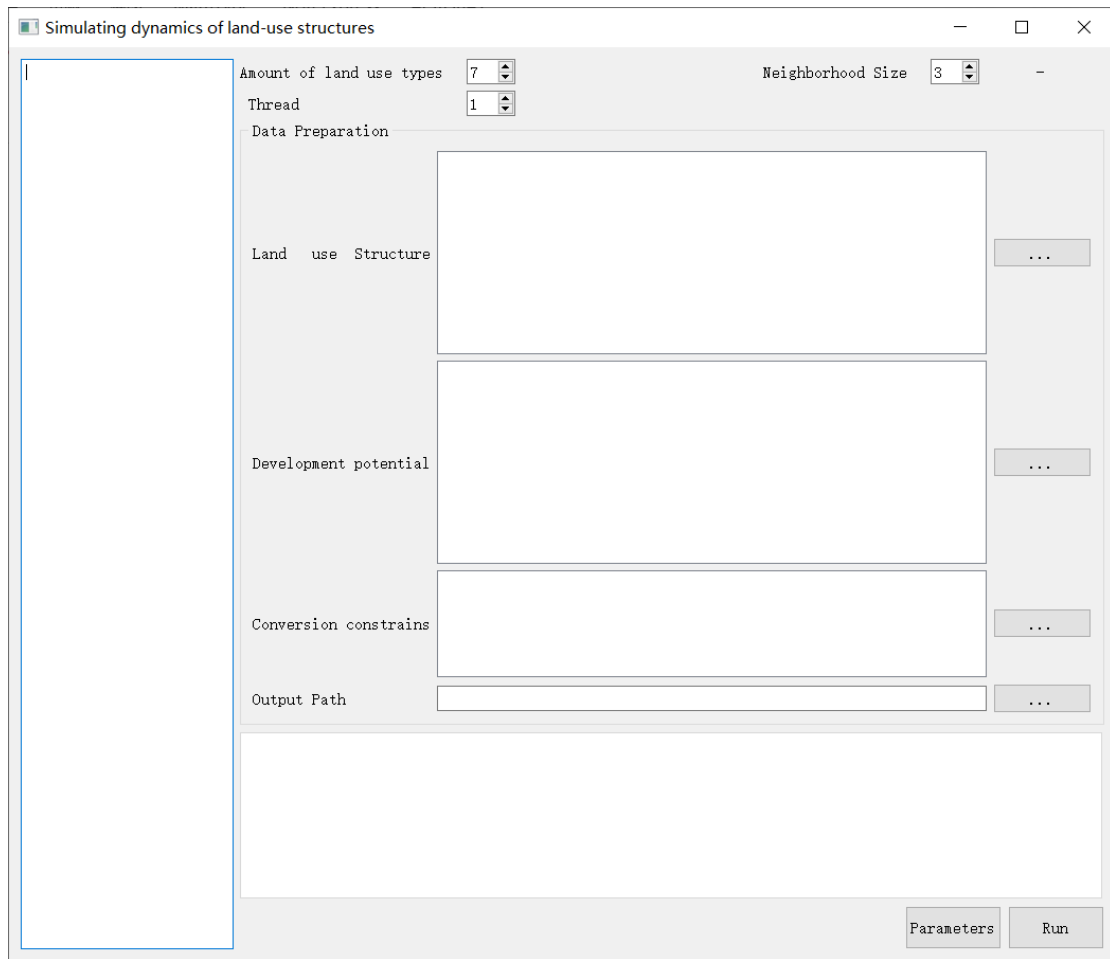
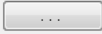


Fig. 10. The UI of ‘Simulating dynamics of land use structures’ module.

3.2.2. Input land use data

Click the  button in the “**Land Use Structure**” group box and select the start year land use data “Xianning_2010_landuse_1.tif” in the pop-up dialog. The program will automatically load all the 7 band of land use structure data.

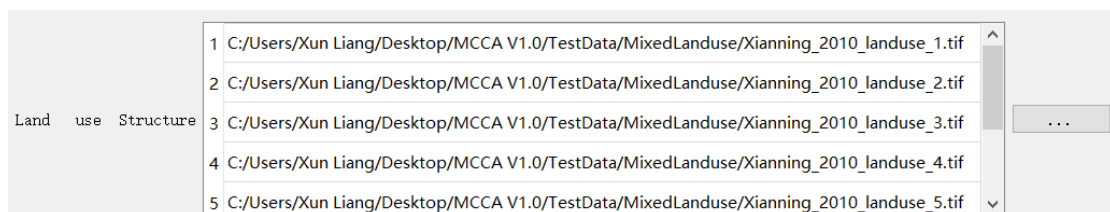


Fig. 11. Select the land use structure data at start year.

3.2.3. Input change probability data

Input the change probability file output from the ‘Mining of quantitative transition rules’ module in the “**Development Potential**” group box.

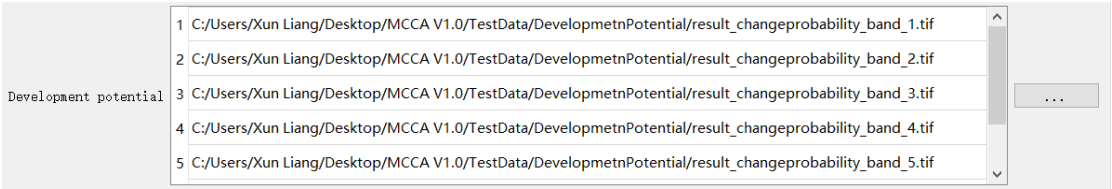


Fig. 12. Select the change probability data.

3.2.4. The constraint of open water (Spatial policies)

We assume that open water (a sub-category of waterbody) is not allowed to be converted to other land use components. Therefore, a distribution map of the cover proportion of open water was used to provide the minimum quantity of waterbody of each cell, which means that the cover proportion of waterbody within each cell is not less than the cover proportion of open water. Meanwhile, the mutual conversions between other pairs of landuse components are allowed in these cells.

Then we input the land use cover proportion of open water layer in the “**Conversion constraints**” group box. The second parameter is used to specific the land use type that the open water is about to restrain. In this experiment, the open water is used to constrain change of water body, and the code of water body is 4. Thus the parameter is set to 4.

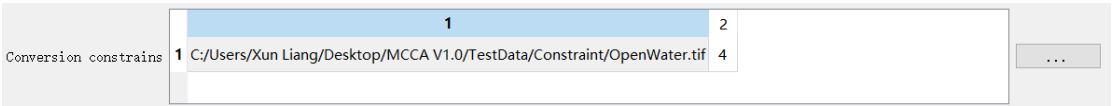


Fig. 12. Select the change probability data.

3.2.5. Set the path of saving simulation result

Input the save path of simulation result in the “**Output path**” group box.



Fig. 13. Select the output path.

3.2.6. Setting the simulation parameters

Simulation parameters include the land use demands, transition matrix and step size. The land use demands are parameters of our model, which need to be firstly set according to the actual situation of study region. So users need to firstly use external model to determine the land use demands of future scenario. **For our example run, the time span of the land use change simulation is from 2010 to 2015, so the land use demands are set to be the same as the actual area of various land use types in 2015.** We also provide a simple tool for calculating the historical land demand and predict the future land demand (section 3.4). We will introduce this module in the following section.

The model will stop when the allocated area equal the demanded area for all land use types. In the tab widget, the second row “Future Amounts” in the “Land Demand” page is for inputting the future land use demand of each land use type. The initial pixel number will be automatically loaded after running the program. You can also input the cover proportion of each land use type in predicted year as what figure 13 shows.

Step Size	Transtion Matrix	Land Demands					
	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7
Start Amounts	0	0	0	0	0	0	0
Future Amounts 1	0.350175	0.416448	0.0531915	0.123057	0.0305599	0.0215888	0.00497983

Fig. 13. Input the future land use demand.

Then, switch the tab widget to the “**Transition Matrix**” page. The columns of this matrix indicate the current land use types, and the rows indicate the future land use types. A value of 1 means the conversion is allowed while a value of 0 indicates that the conversion is not possible. A **Transition Matrix** is a collection of a series of prior knowledge of experimenter about study area. An example of cost matrix is provided below:

Step Size	Transtion Matrix	Land Demands					
	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7
Type 1	1	1	1	1	1	1	0
Type 2	1	1	1	0	1	1	0
Type 3	1	1	1	0	1	1	0
Type 4	1	0	0	1	1	1	0
Type 5	0	0	0	0	1	0	0
Type 6	0	0	0	0	1	1	0
Type 7	1	1	1	1	1	1	1

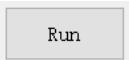
Fig. 14. Transition Matrix.

And in the “**Step Size**” page, users need to set the Step Size of different land use types, because the neighborhood effects may be different for different land use types in a study region. The step size for each land use type is determined according to expert knowledge and a series of model tests, ranging from 0-1. At this example, we set the parameter as below:

Step Size	Transtion Matrix	Land Demands					
	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7
Step Size	1	1	1	1	1	1	1

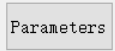
Fig. 15. Step Size, the value of 1 for each land use type is recommended.

3.2.7. Running the multiple CA allocation model

Finally, click button  to start the simulation. The information of each iteration is showed on the left of the interface of ‘Simulating dynamics of land use structures’ module. Also, the MCCA is able to show the process of land use change dynamically, including the spatial change, change in value and change curve of each land use type on the main interface.

The visualization panel allowed the users to zoom in and observe the land use dynamics of local regions. The users can choose any land use type to show on the visualization panel by activating the corresponding radio buttons on the right. The horizontal axis of the dynamic chart is the number of iteration, and the vertical axis represents the product of the cover proportion and amount of cell.

The model will stop and save the simulation result in 2015 when the allocated area equal the demanded area for all land use types. The MCCA software will save all the parameters to two configuration files: “SCAparameters.tmp” in the ‘Parameterfile’ folder. The module will loads the parameters that are recorded in the configuration files

when click the  button, which is convenient for the user to use to repeat their experiments.

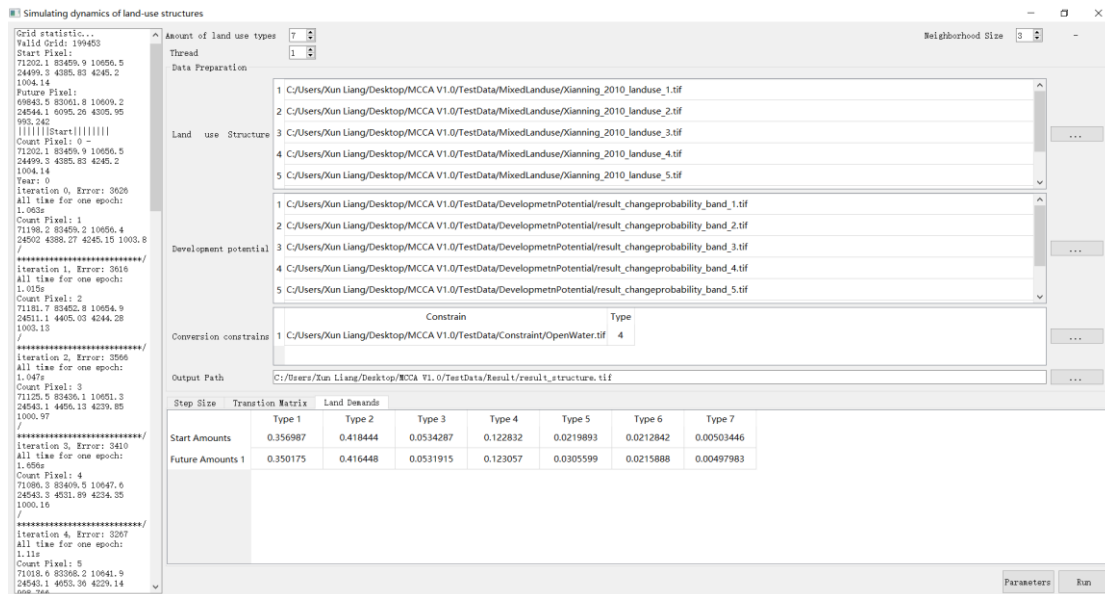


Fig. 17. The dynamic information of each iteration is show on left.

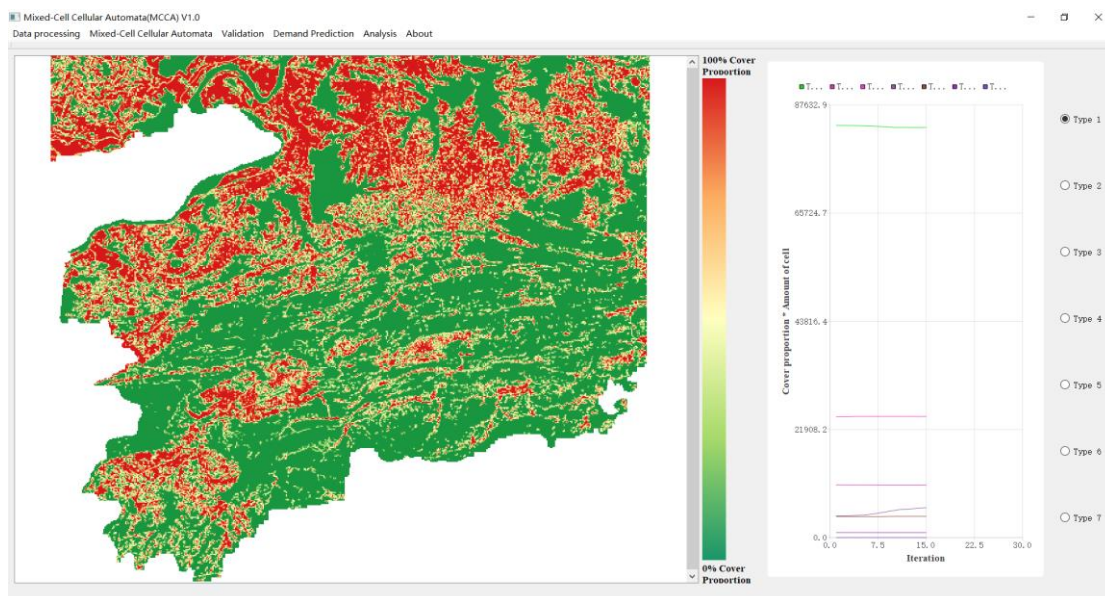


Fig. 17. The dynamic display of the simulation process on the main interface.

3.3. Accuracy validation of simulation

MCCA provides a sub-pixel confusion matrix (SCM) statistic tool for calculate the kappa coefficient for land use structure data for the conventional confusion matrix is not available for evaluating the simulation result of mixed-cell land use data. And a Relative Entropy (RE) statistic tool for measuring the similarity between simulation land use structure and actual land use structure.

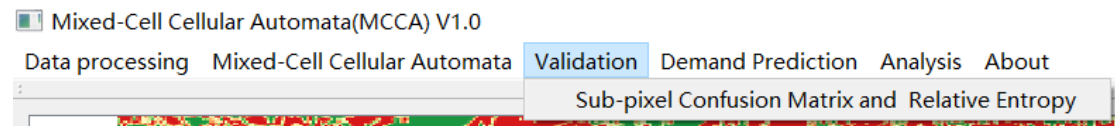


Fig. 18. Activate the validation module.

3.3.1. Load data

Input the amount of land use type in your simulation, the amount of land use types in this experiment is 7. Click the button in the “**Ground Truth**” row, select the start year land use data “Xianning_2015_landuse_1.tif” in the pop-up dialog. The program will automatically load all the 7 band of the land use structure data. Then click the button in the “**Simulation Result**” row to input the simulated land use structure data ‘result_structureSimulation_1_Type_1.tif’.

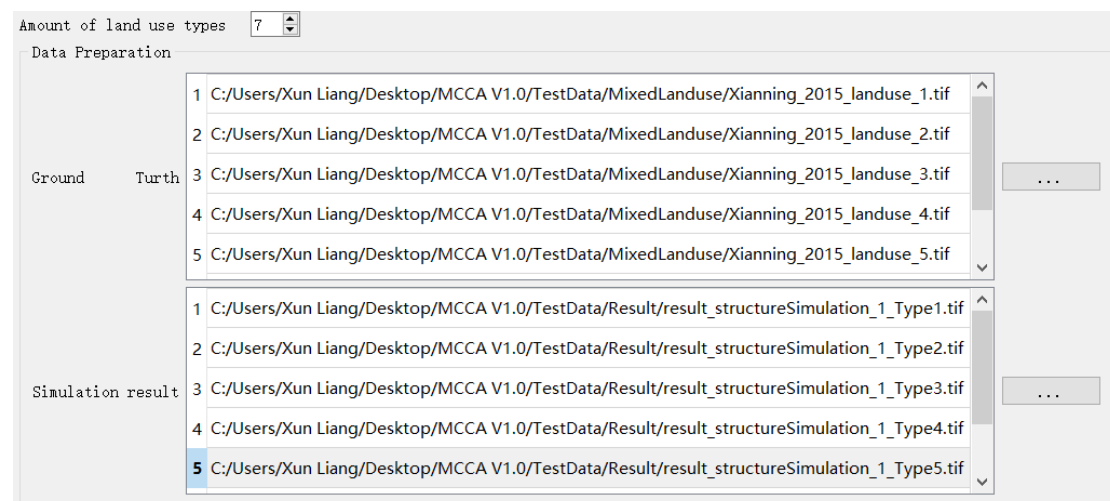
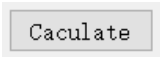
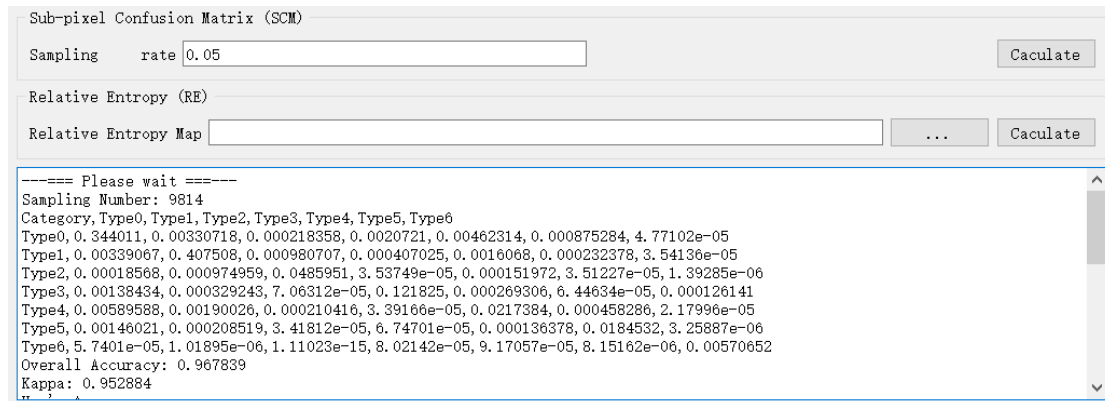



Fig. 19. Input the actual and simulation land use structure data.

3.3.2. SCM statistic tool


Set the sampling rate to 5%. Click the  button to start calculating Kappa coefficient. A message box will pop up when the program completes the calculation. The results include Kappa coefficient, overall accuracy and sub-pixel confusion matrix, which will be saved in a file named “SCM.csv” in the folder ‘Parameterfile’.



Sub-pixel Confusion Matrix (SCM)

Sampling rate 

Relative Entropy (RE)

Relative Entropy Map ... 

```


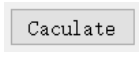
===== Please wait =====
Sampling Number: 9814
Category, Type0, Type1, Type2, Type3, Type4, Type5, Type6
Type0, 0.344011, 0.00330718, 0.000218358, 0.0020721, 0.00462314, 0.000875284, 4.77102e-05
Type1, 0.00339067, 0.407508, 0.000980707, 0.000407025, 0.0016068, 0.000232378, 3.54136e-05
Type2, 0.00018568, 0.000974959, 0.0485951, 3.53749e-05, 0.000151972, 3.51227e-05, 1.39285e-06
Type3, 0.00138434, 0.000329243, 7.06312e-05, 0.121825, 0.000269306, 6.44634e-05, 0.000126141
Type4, 0.00589588, 0.00190026, 0.000210416, 3.39166e-05, 0.0217384, 0.000458286, 2.17996e-05
Type5, 0.00146021, 0.000208519, 3.41812e-05, 6.74701e-05, 0.000136378, 0.0184532, 3.25887e-06
Type6, 5.7401e-05, 1.01895e-06, 1.11023e-15, 8.02142e-05, 9.17057e-05, 8.15162e-06, 0.00570652
Overall Accuracy: 0.967839
Kappa: 0.952884

```

Fig. 20. Sub-pixel confusion matrix, Kappa coefficient and overall accuracy.

3.3.3. Relative Entropy statistic tool

We computed the Relative Entropy (RE) as an indicator to evaluate the similarity of landuse structure, which can represent the information decay of the simulation process. When the actual and simulated landuse structures of mixed cell i are identical, RE is 0. A larger RE value indicates a greater difference between the actual and simulated landuse structure. After the REs for all cells are calculated, the mean RE of the whole region is calculated as the measurement of similarity of landuse structure at the regional level.

Click the  button in the “**Relative Entropy Map**” row, and choose a path for the calculation of relative entropy map. Click the  button to start calculating RE. A message box will pop up when the program completes the calculation. The similarity between simulation structure and actual structure of on cell are showed in image “RE.tif”.

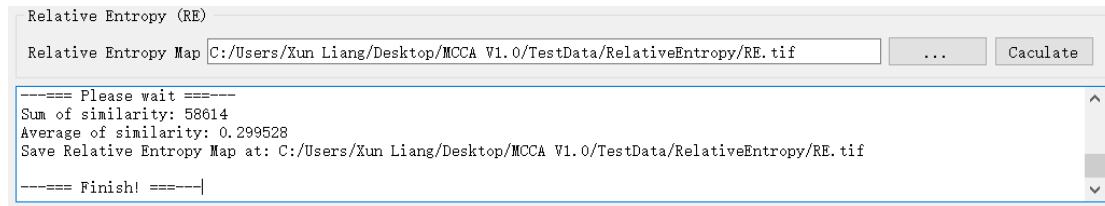


Fig. 21. Output the mean Relative Entropy of the region and Relative Entropy on each cell.

3.4. Projecting future landuse demands

3.4.1. Starting the land use demand projection module

Future land use demands can be determined by many method, such as using expert experience, linear regression, Markov chains, the system dynamics model, or an integrated assessment model. This software provide linear regression method. This experiment projects the future landuse demands based on the historical data of 2000, 2005, 2010 and 2015. Click the “Linear regression” item to start the simulation module.

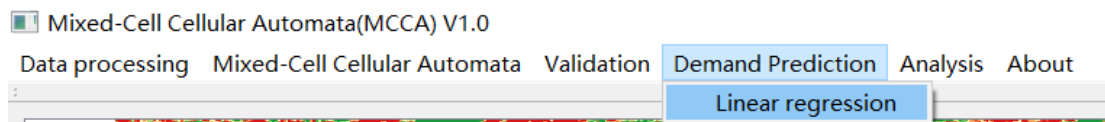



Fig. 22. Activating the land use demand projection module.

Then input the amount of land use type in the simulation, the amount of land use types in this experiment is 7. Set the predict year amount as 20. Then the module will predict the future land use demand from 2015 to 2035 (2015+20).

3.4.2. Input historical land use structure data

Click the  button, select the historical land use structure data in 2000, 2005, 2010 and 2015. The users only need to select the first band of the four land use structure data in this step. The MCCA software would automatically load the other bands of these land use structure data.

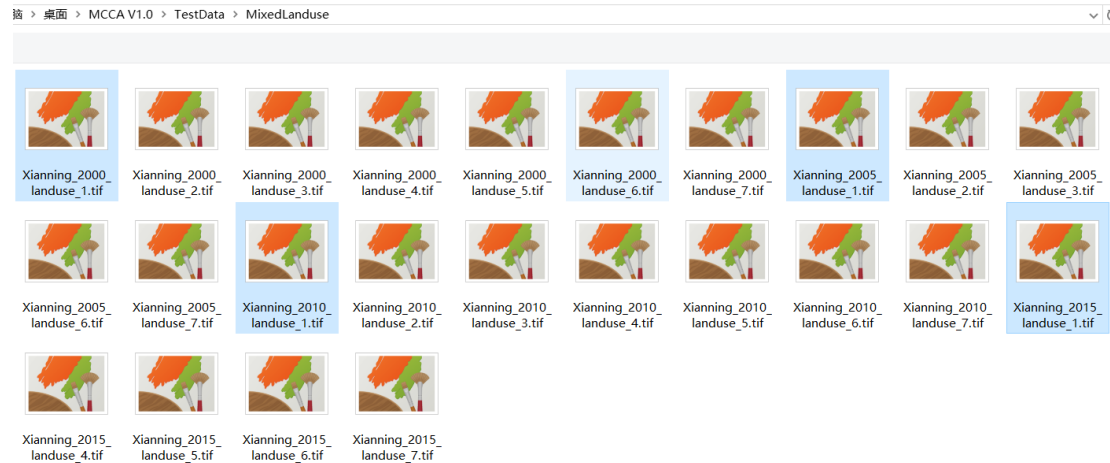


Fig. 23. Select the historical land use structure data.

What's more, the program can automatically read the year on the filename. The users can also manually input the year to the 'Year' column on the chart of data.

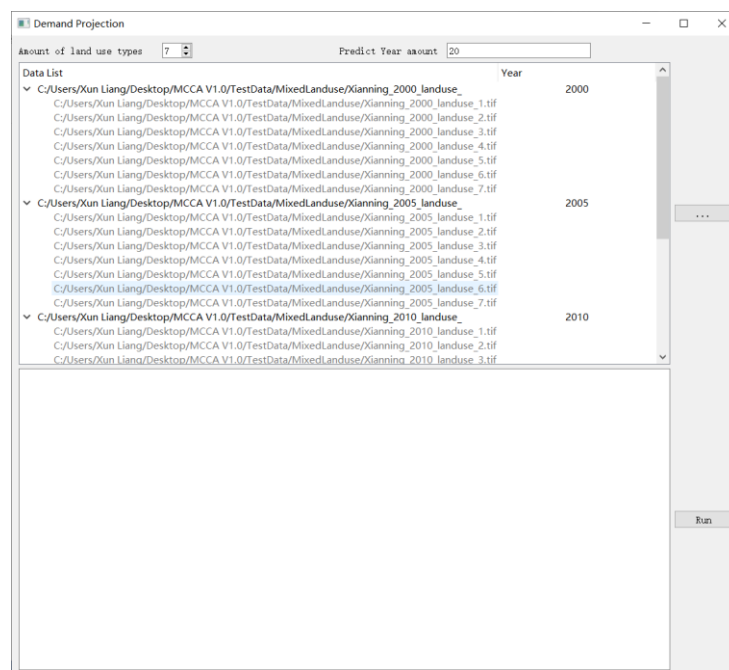



Fig. 24. Inputting the historical land use structure data to the Demand projection module.

3.4.3. Running linear regression and predicting future demands

Click the  button to start calculating future land use demand. A message box will pop up when the program completes the calculation. The results will be showed on the interface and saved in a file named "PredictDemand.csv" in the folder 'Parameterfile'. Noted that this module also can be used to obtain historical land use cover proportions for model validation (section 3.2.6)

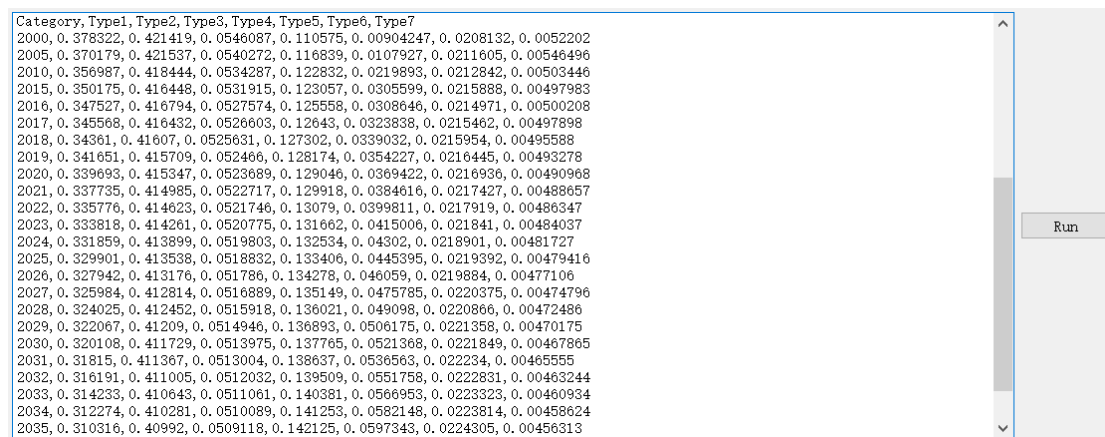


Fig. 24. Running the linear regression and predicting future land use demands.

3.5. Simulating future land use structure from 2015 to 2035

3.5.1. Obtain change probability form 2010 to 2015

Repeat the same procedures in section 3.1 using historical land use structure data: ‘Xianning_2010_landuse’ and ‘Xianning_2015_landuse’ in the ‘MixedLanduse’ folder. Then obtain the change probability form 2010 to 2015.

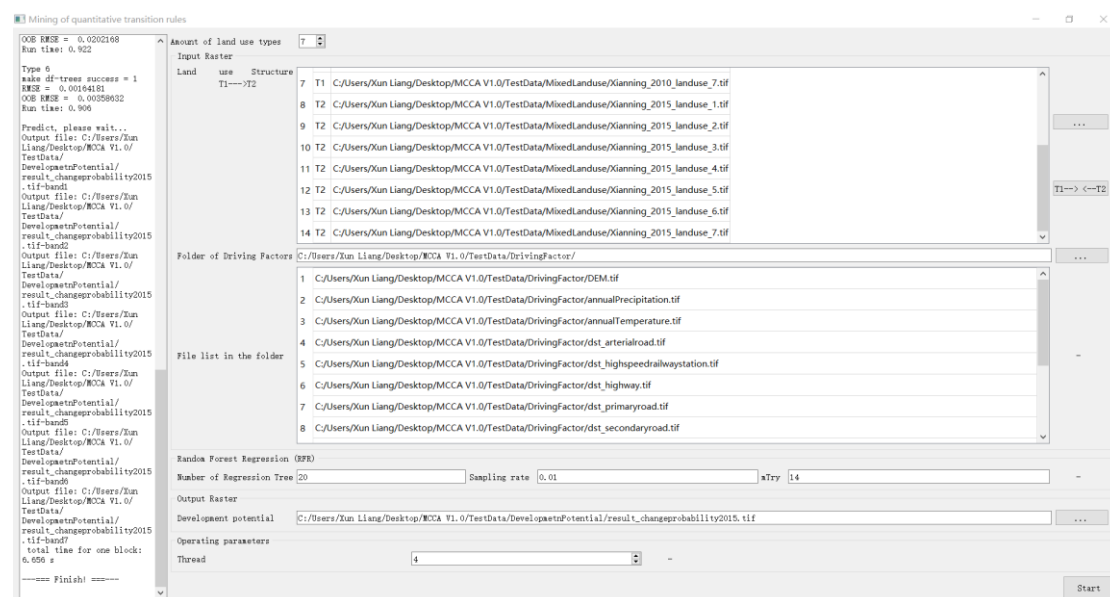


Fig.25. Running the ‘Mining of quantitative transition rules’ module for future simulation.

3.5.2. Simulating land use structure change from 2015 to 2035

Repeat the same procedures in section 3.2 using historical land use structure data: ‘Xianning_2015_landuse’ in the ‘MixedLanduse’ folder. And the change probability exported by ‘Mining of quantitative transition rules’ module in section 3.5.2. Import the predicted land use demands in 2035, which have been obtain at section 3.4.3. Other simulation parameters that have been well calibrated keep the same as validation process (section 3.2).

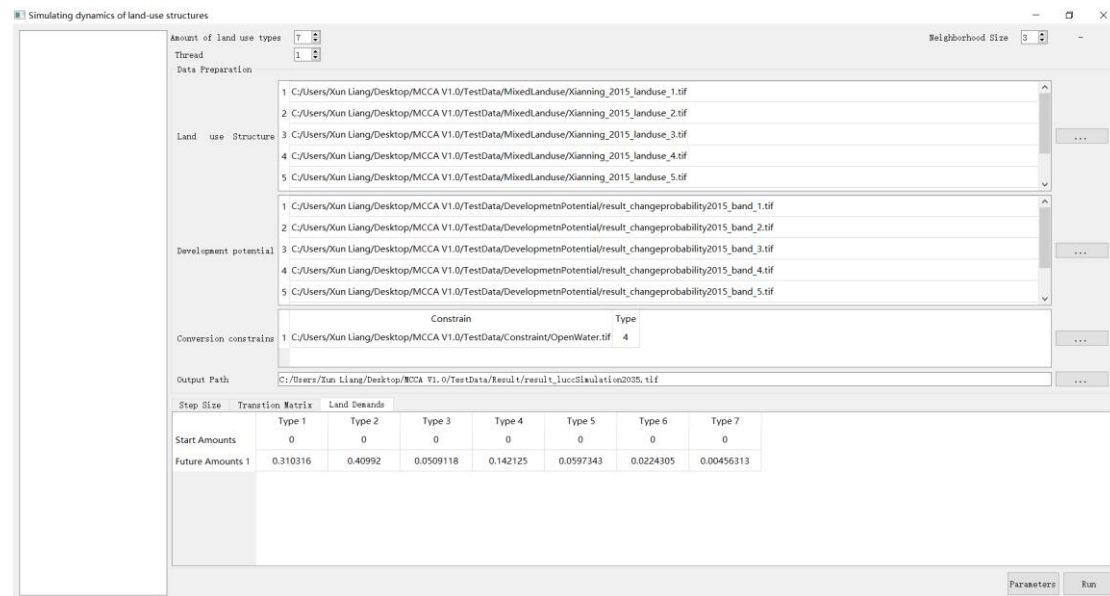




Fig. 26. Parameter setting for simulation from 2015 to 2035.

The MCCA software will save all the parameters to two configuration files: “SCAparameters.tmp” in the ‘Parameterfile’ folder. The module will loads the parameters that are recorded in the configuration files when click the  button, which is convenient for the users to repeat their experiments. Finally, click the  button to generate simulation result of land use structure in 2035.

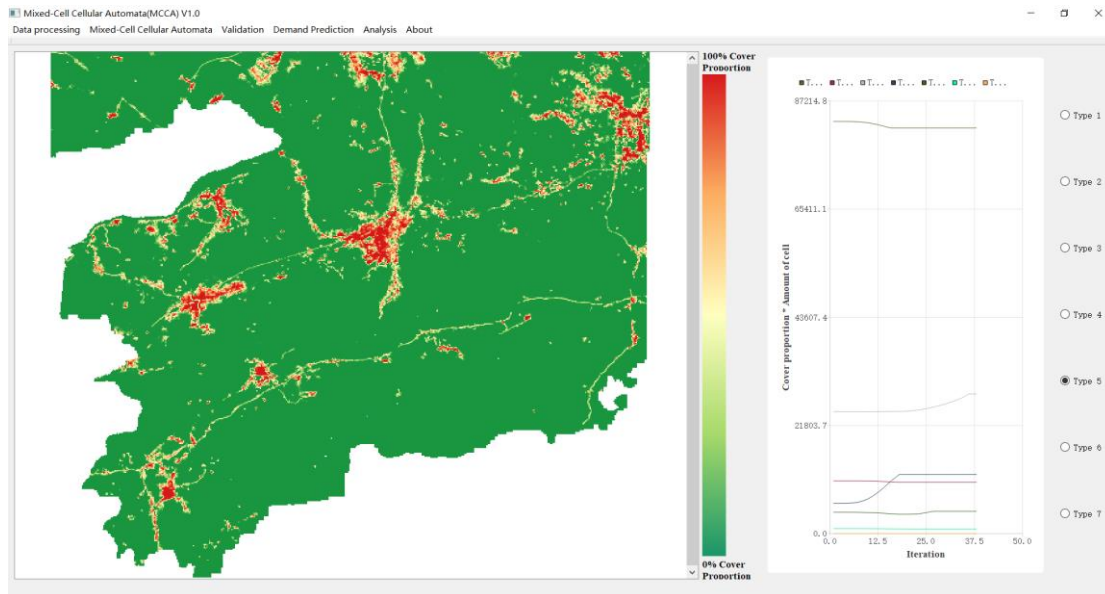


Fig. 27. Dynamic display of the simulation from 2015 to 2035.

3.6. Calculation of landuse mix

The mixture of land use components in land units is closely related to the socioeconomic activities, environmental functions and landscape amenities, and is very important for regional sustainable development. Different from pure-cell CA models, mixed cell CA models have the advantage of simulating the changes of landuse structure within individual cells. The cell-level mixture can be directly measured by their entropy according to the cover proportions of landuse components. A higher entropy means a higher degree of mixture or diversity of land use in an individual cell.

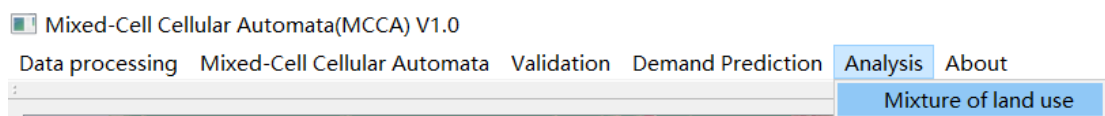


Fig. 28. Activating the ‘mixture of land use’ module.

3.6.1. Setting the input and output paths

Input the amount of land use type in your simulation, the amount of land use types in this experiment is 7. Click the button in the “**Land use structure**” row, select the simulation result in 2035 “result_luccSimulation2035Simulation_1_Type1.tif” in the pop-up dialog. The program will automatically load all the 7 band of the simulated land use structure data. Then click the button in the “**Output**” row to set the output path of the mixture image of land use.

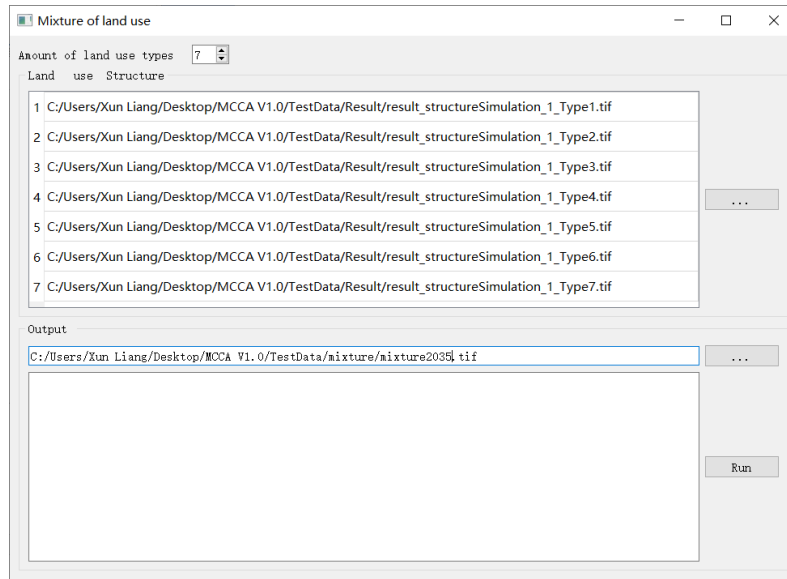



Fig. 29. Setting the input and output paths for ‘mixture of land use’ module.

3.6.2. Calculating the land use mixture of each cell

Click the  button to generate the predicted land use mixture of each cell in 2035.

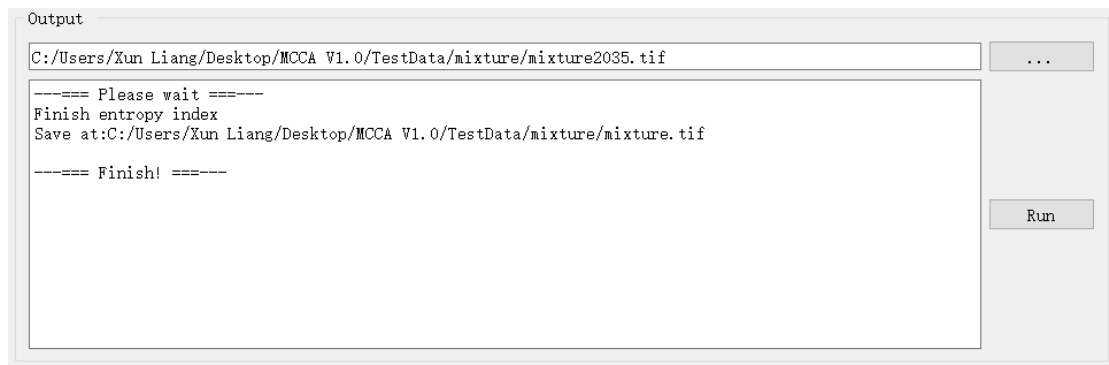


Fig. 30. Generating the image of land use mixture in 2035.

4. Preparing for historical land use structure data

In practical application, the mixed-cell landuse data can be obtained using at least four approaches: (1) remote sensing inversion method; (2) decomposition of mixed pixels; (3) extracting the land use mix structure from multi-source big data (e.g., social network data, taxi trajectories, points of interest) ; and (4) aggregating fine-resolution landuse data into coarse-resolution data. We used the fourth approach—the most convenient method to obtain the mixed-cell landuse data to illustrate the MCCA model.

To aggregate fine-resolution landuse data into coarse-resolution data and calculate the cover proportion of each land use type for each cell. The users first need to generate a fishnet for study region, just like the ‘demogrid’ in ‘demo_grid’ folder provided in our test data, and calculate the cover proportions with zonal statistics tool in ArcMap or QGIS.

However, the grids with area of each land use types should be converted to the raster format so that they can be as the input of MCCA software. The MCCA model provide two data processing tools to help users prepare the land use structure data of raster format.

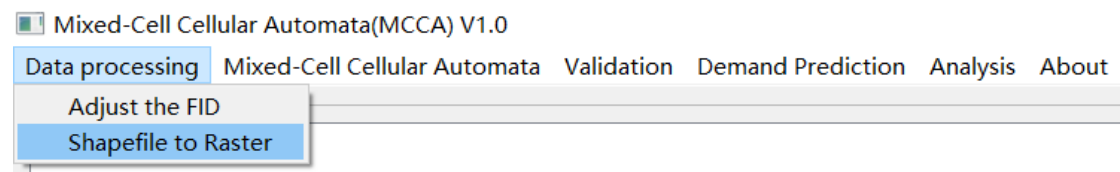


Fig. 31. Data processing tools for preparing the historial land use structure data.

We assume that the users have successfully obtained the area of each land use in each cell, by aggregating fine-resolution landuse data into coarse-resolution grid using zonal statistics tools in ArcMap or QGIS. However, the grid generated by ArcMap or QGIS with area information of multiple land use can’t be directly converted to the raster format. Because the FID (serial number) of ArcMap grid starts from the bottom left corner and increase from the bottom row to the top row, while the FID (serial number) of QGIS grid starts from the up left corner but increase from the left column to the right column. These two arrangement is inconsistent with the raster format data that start from the up left corner and increase from the top row to the bottom row.

So, the users can firstly applied the ‘Adjust the FID’ module to modify to fishnet grid.

4.1. Adjusting the FID for grid shapefile

Click the “**Ajusting the FID**” item to start the simulation module. Select the fishnet grid generated by the ArcMap or QGIS grid, and set the output path of adjusting fishnet grid.

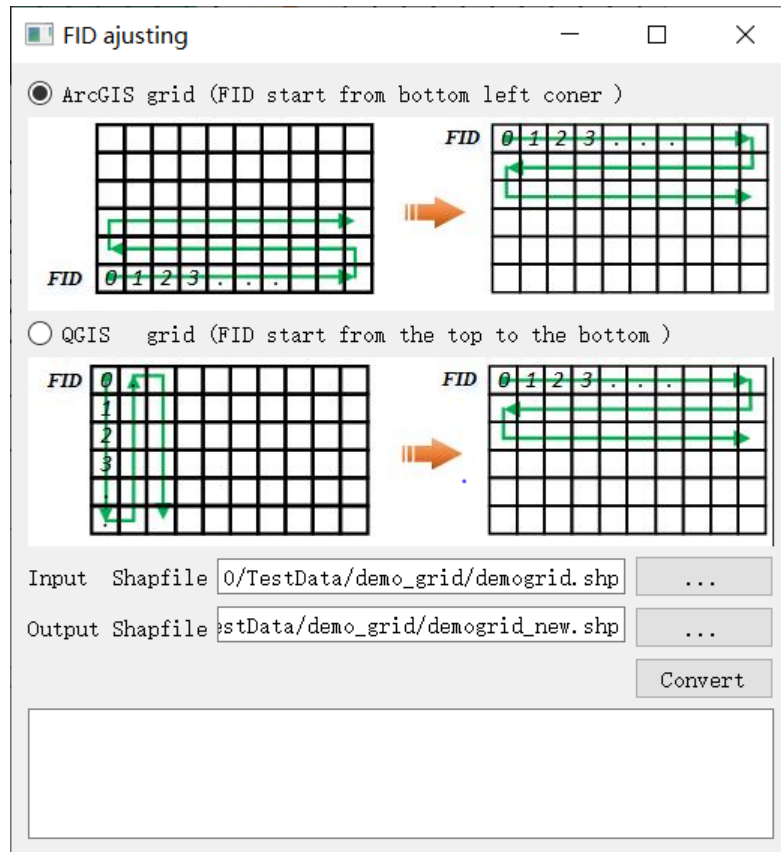
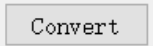


Fig. 32. The interface of ‘FID adjusting’ module.

Then click the  button to obtain the new fishnet grid. If the original grid is generated by QGIS, just choose the ‘QGIS’ radio button. There will come out a message box when the model process run is complete.

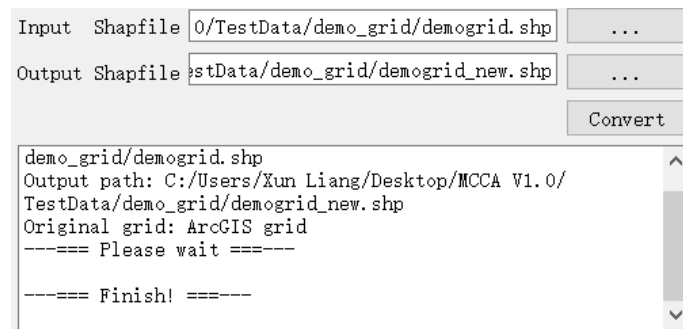


Fig. 33. Output information of ‘FID adjusting’ module.

4.2. Shapefile land use structure data to raster format

Click the “**Shapefile to Raster**” item to start the simulation module. Select the fishnet grid exported by the last step. We provide the four land use structure data in shapefile format: ‘Xianning_2000.shp’, ‘Xianning_2005.shp’, ‘Xianning_2010.shp’, ‘Xianning_2015.shp’, which have been already converted.

Select the four shapefile grid with land use area of each land use type on each cell, and choose an output folder.

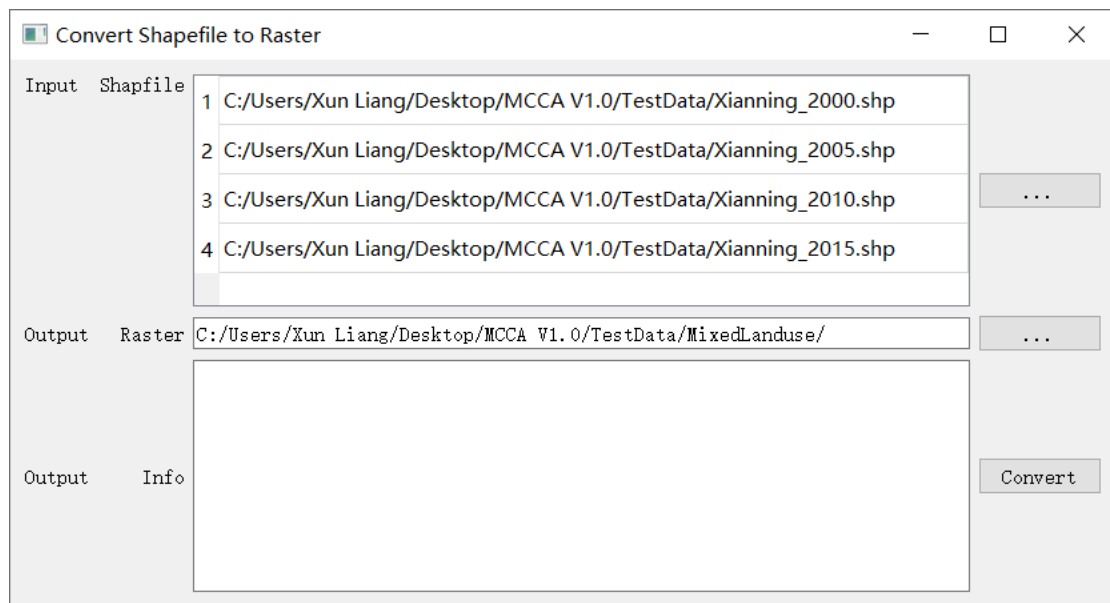
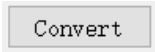


Fig. 34. The interface of ‘Convert Shapefile to Raster’ module.

Then click the  button to generate land use structure data of 7 layers. There will come out a message box when the model process run is complete. **Note that the program only identify the Fields in the shapefile with the format of ‘VALUE_X(1~7)’.**

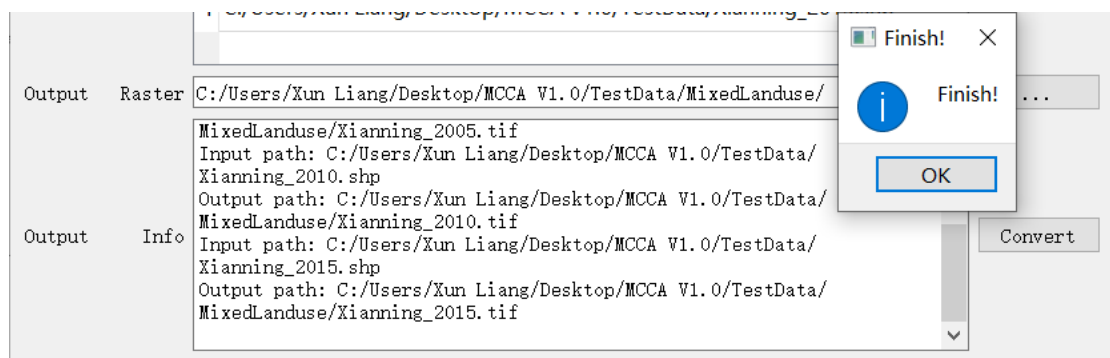


Fig. 35. Output information of ‘Convert Shapefile to Raster’ module.

5. Some notes in using MCCA model

- 1) The input land use structure data must be in 'double' format.
- 2) In the step of mining of quantitative transition rules, the coordinate or projection system must be supported by GDAL. We recommend the World Geodetic System (WGS 84). This step do not require the input image data have the same number of rows and columns. An integral alignment mechanism is available.
- 3) In the step of simulating dynamics of land use structures, the input image data need to have the same number of rows and columns, including the land use pattern, restricted area, and change probability data.
- 4) We strongly recommend the users do not include non-English character or sign in the file paths of PLUS model, including the spaces. The file names and folder names must begin with a letter, not a number.