Land Use Development Simulation Systems

Using Cellular Automata Model to Simulate the Impact of Urban Growth Policy on Environment in Danshuei district, Taiwan

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OUTLINE

- Research Background and Purpose
- Cellular Automata，CA
- Introduction of Study area- Danshuei district
- Data Processing and Land Use/Cover Identification
- Simulation Achievement of Urban Growth Model and Environmental Impacts
- Discussion, Conclusion and Recommendation

Research Purpose

Increasing demands of economic growth accelerate the rate of over development of land resources. Inappropriate urban sprawl and unsuitable configuration of land use destructively impact the ecological environment and worsen natural/man-made disasters .

- Danshuei is a good case showing how to balance among urban development, natural resource protection, and disaster management.
- This study applies CA model to simulate urban growth models and environmental impacts using different growing scenarios.
- Find out main driving forces of urban growth.
- Evaluate the effectiveness of land use policy.

Cellular Automata，CA

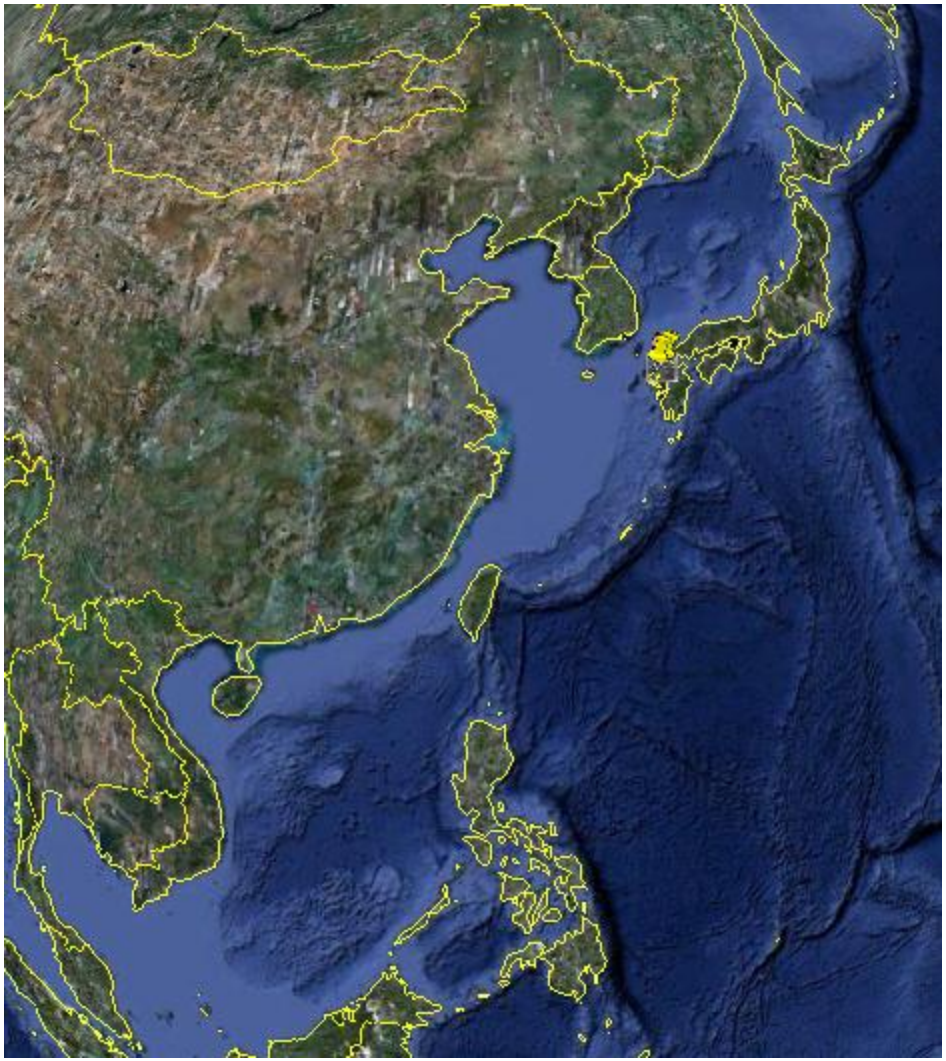
- CA, which is a raster-based model, considers spatial organization in terms of evolution and provides another point of view to spatial evolution.
- The status of each cell is decided by rule of status of transformation. Its mathematical form is defined in equation

$$S_{ij}^{t+1} = F(S_{ij}^{t}, \Omega_{ij}^{t})$$

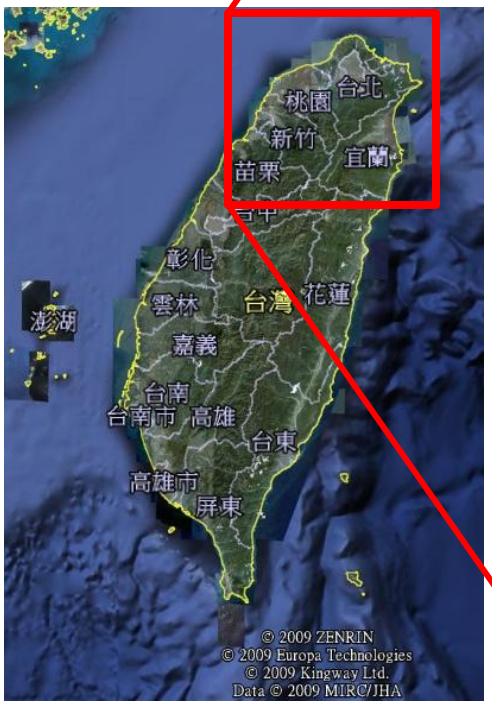
- NetLogo is adopted in this study because it can simulate and dynamically display the spatial changes of urban growth.

(NetLogo simulation software was developed by Northwest University , US . This system is widely applied to medical science, biology, environment and education; NetLogo was used to simulate the dissemination mode and situation of epidemic SARS)

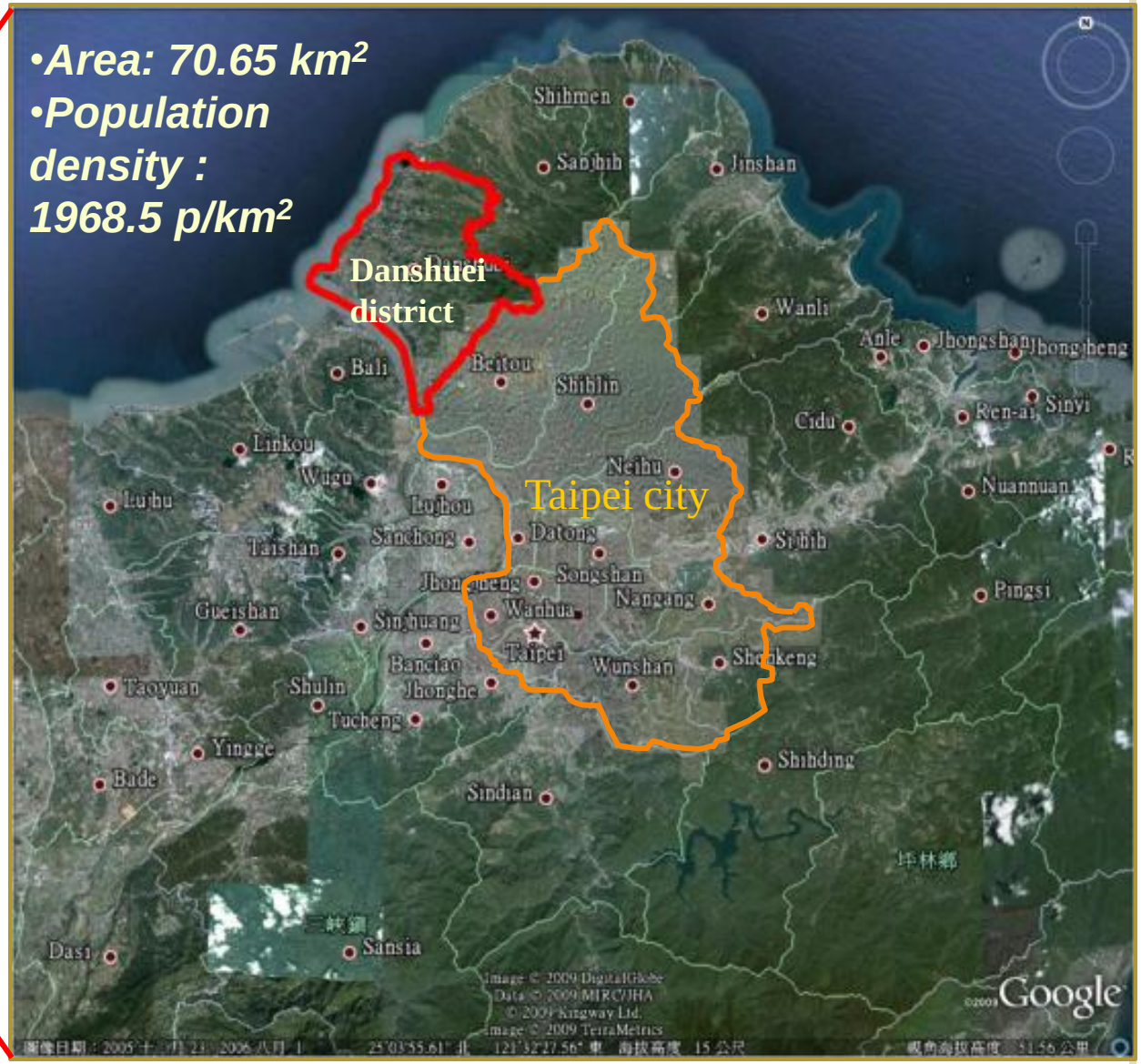
LOCATION OF TAIWAN



Location of Danshuei Township

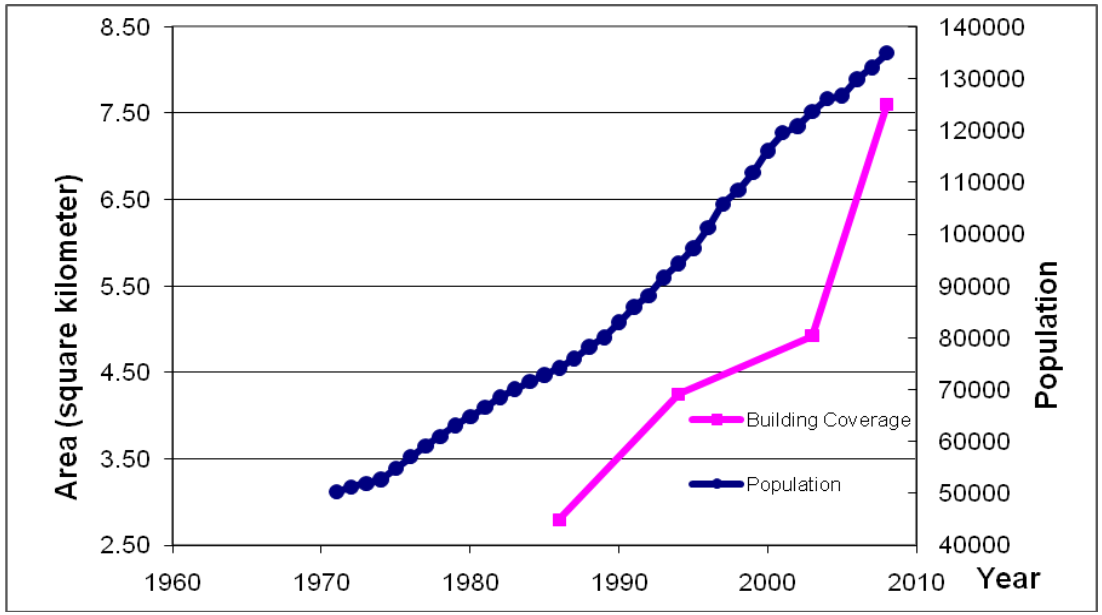


- *Area: 70.65 km²*
- *Population density : 1968.5 p/km²*



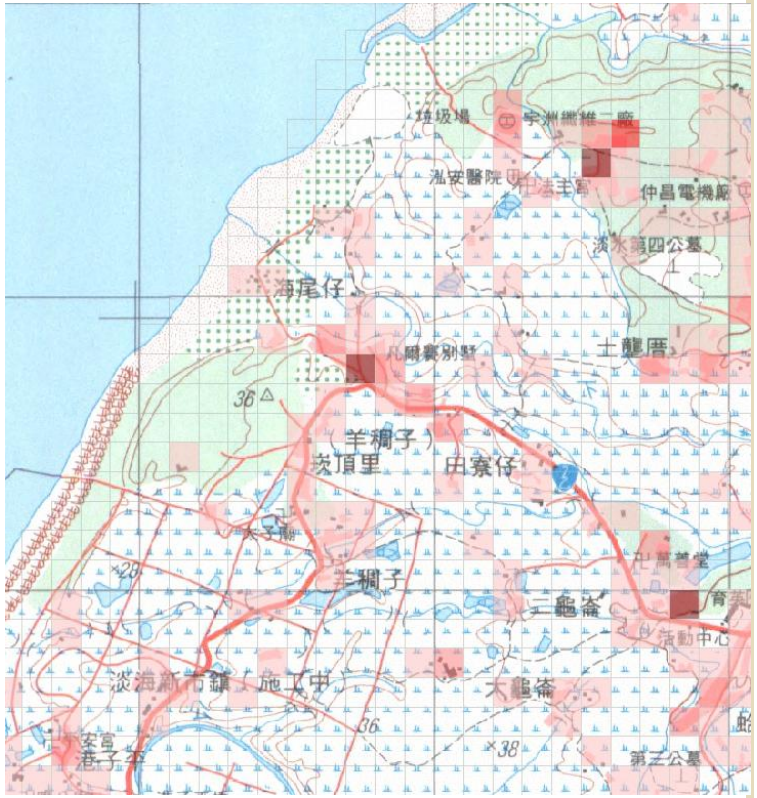
URBAN DEVELOPMENT PROCESS OF DANSHUEI

- Taipei Metropolitan area has attracted enormous immigrants from the southern parts of Taiwan, since 1895 when Taipei city became the political and financial center of Taiwan.
- The **population growth** of Danshuei district has increased by **87.30%** from 1986 to 2009 reaching 139,073.
- The **building coverage** has also been significantly increased by 1.7 times from 2.8 km^2 to 7.6 km^2 during 1986 to 2009 .



Data Processing and Land Use/Cover Identification

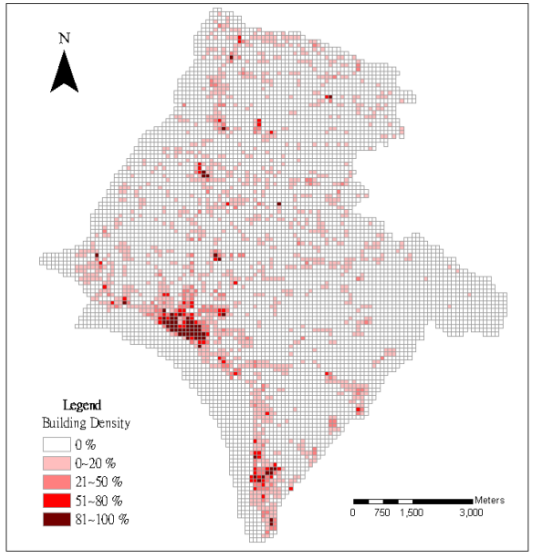
- **Official topographic maps** of 1985, 1993 and 2001 and **National Land Use Survey data** of 2008 were basic inputs to acquire the land use data.
- These maps were scanned to digital files, overlaid with 100 by 100 meters square grid in GIS software. (whereas Danshuei occupied 7211 cells)
- Classified terrain features into **9** categories comprising built-up, infrastructure, road, agricultural land, forest, grassland, barren land, wetland and water land.



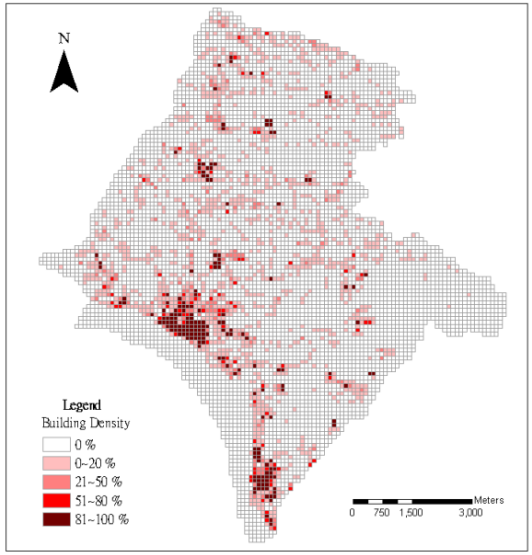
The coverage contains five levels from **0-4**, respectively presents 0%, 1~20% (10%), 21~50% (35%), 51~80% (65%) and 81~100% (90%). Legend presents as from lighter red to darker red.

Building Coverage Change over Time

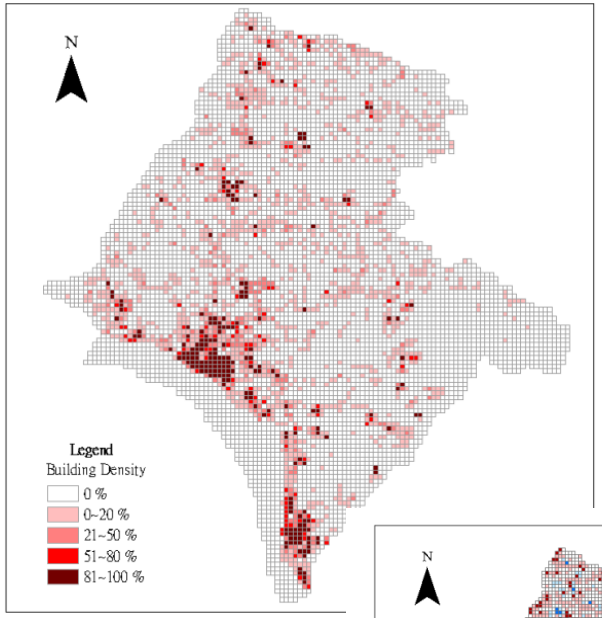
Year 1986

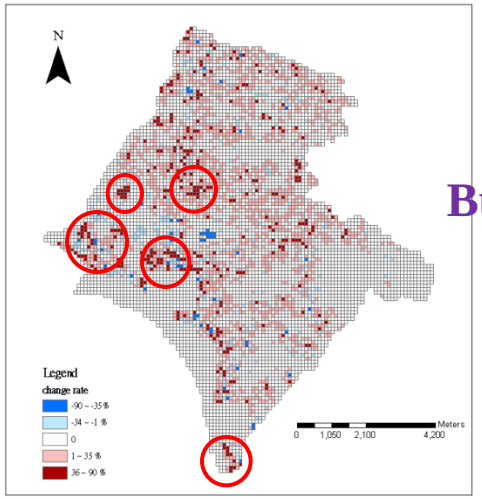


Year 1994

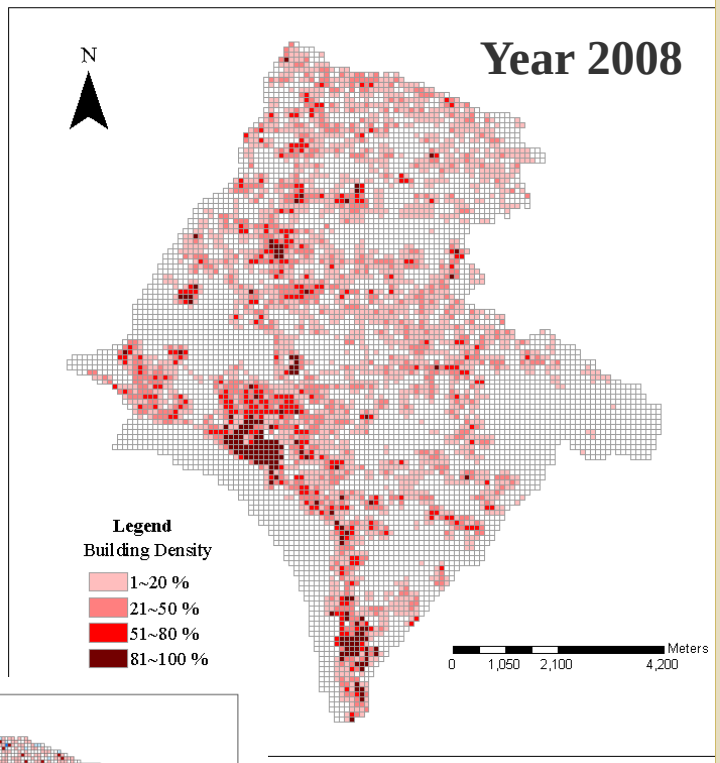


Year 2003





Year 2008



Building coverage change ratio between 2003 and 2008

PARAMETERS SET IN NETLOGO

- NetLogo example: An-ken case
- Starting points (seeds):

  Original settlements recorded by historical literatures
- Growth Rule

  1. **Slope**: considers a seed cell to seek the nearest unoccupied neighbor cell with the lowest slope
  2. **Neighbor effect**: considers the summation of building coverage of nine cells, which are the seed cell and the eight neighboring cells.
  3. **Road gravity**: considers the distance from each cell to the nearest cell with road.
- Policy Restricted Condition

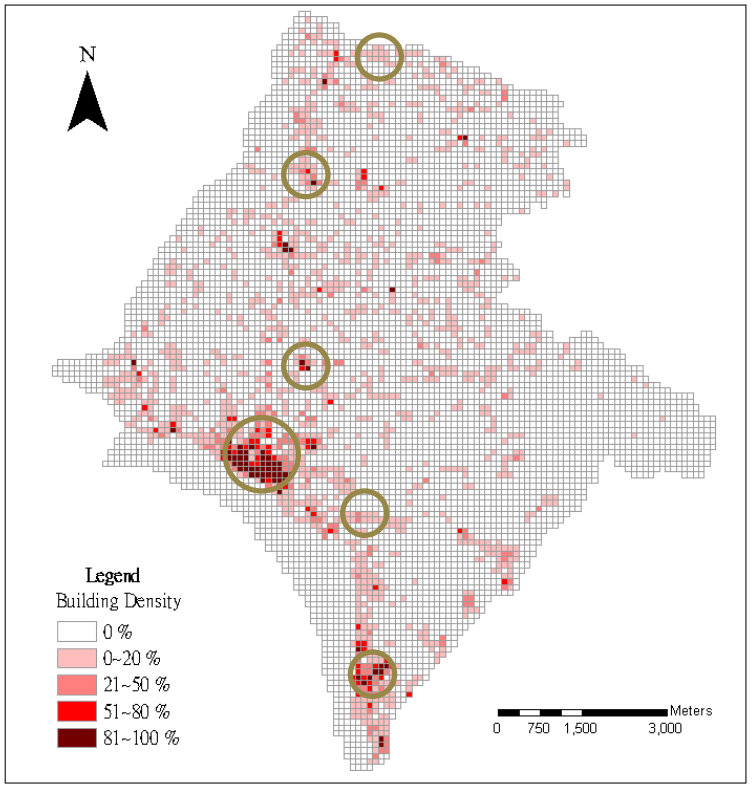
  1. None
  2. Land use control-"**moderate protection**" and "**restricted protection**"
- Environmental Impacts

  Agricultural and Forest resources
- Validation

  1. The actual growth in 2008 of Danshuei district is used to compare with the simulated urban development form.
  2. The model accuracy is assessed based on three parameters: **predicted accuracy rate, over-predicted rate and less-predicted rate**.

URBAN GROWTH SCENARIO SETTING

Six of starting points



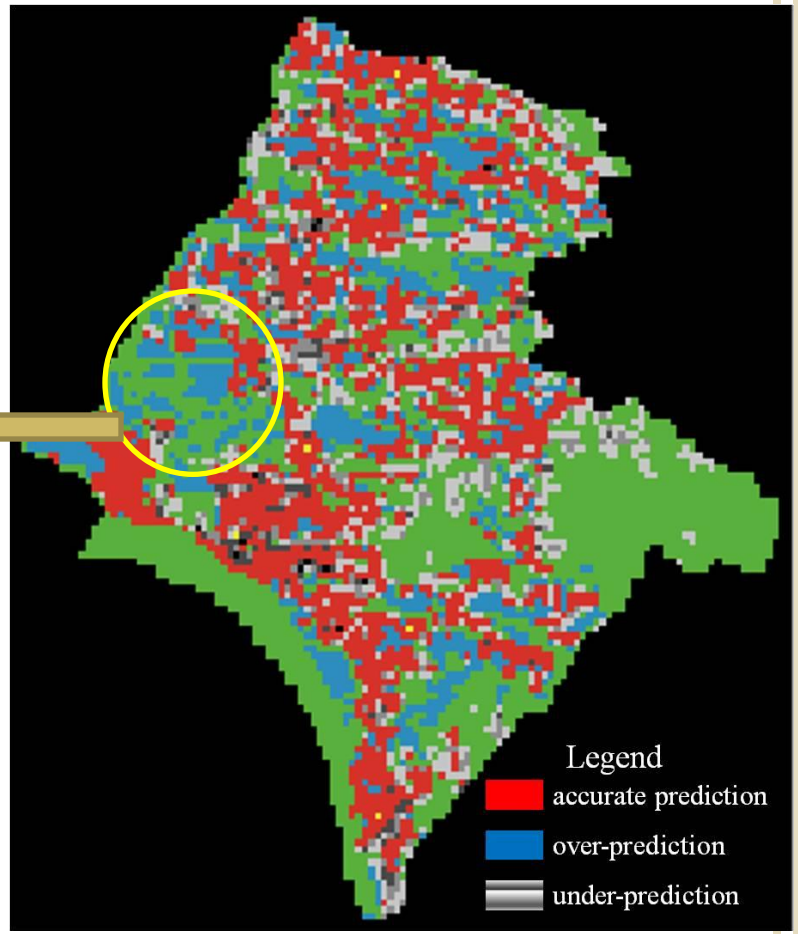
six original settlements of Pepo-frau aboriginal residents recorded by historical literatures

Parameters	Growth Coefficients	Growth Scenarios			
		1	2	3	4
Starting points		six	six	six	six
Growth rules	Slope	▲	▲	▲	▲
	Neighbor effect		▲		
	Road gravity		▲		
Policy Restricted Condition	Non	▲			
	Managed growth with **moderate protection**			▲	
	Managed growth with **restricted protection**				▲

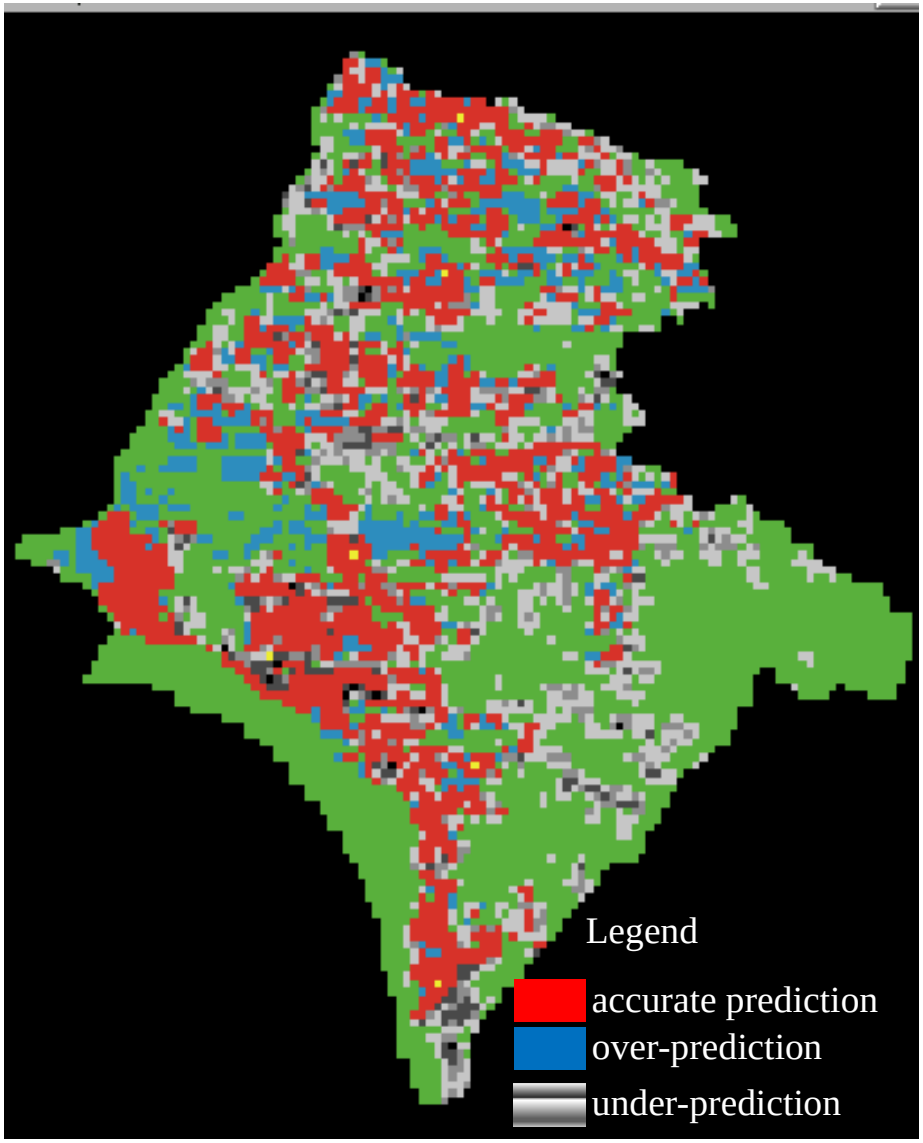
Simulation Result : Simulation Result 1

- Scenario 1 only considers coefficient of slope. Non of Policy Restricted Control.
- the predicted accuracy rate reaches 59.43% and the over-predicted rate reaches 33.59%.
- Forest and agriculture loss rates reach 27.12% and 38.78% respectively. (the loss rate of agricultural and forest areas are calculated based on the data of 1986.

The area circled in yellow could not be regarded as over-prediction as it will be developed in future.

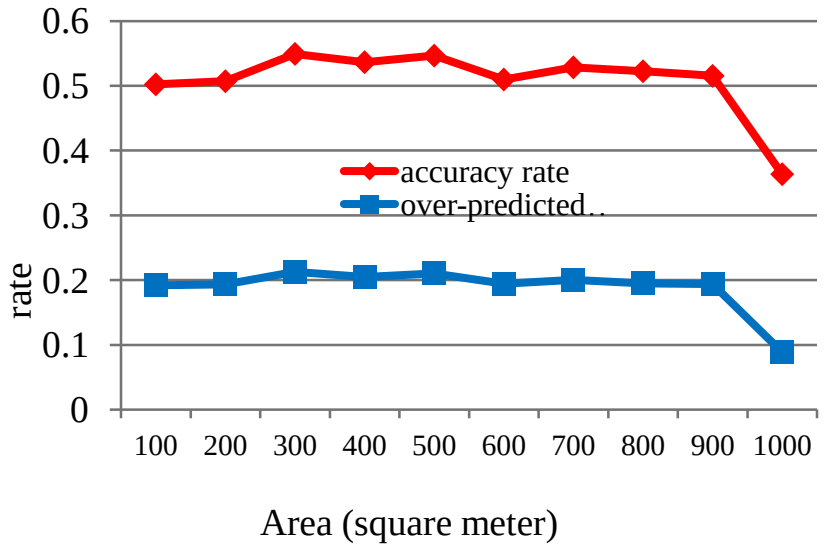


Simulation Result : Simulation Result 2 _(1)



- Scenario 2 considers slope, neighbor effect (200 m^2) , road gravity (500m) simultaneously.
- Although the predicted accuracy rate goes slightly down to 51.23% from 59.43%, the over-predicted rate is also down to 18.74% from 33.59% comparing to Scenario1.

SIMULATION RESULT : SIMULATION RESULT 2 _(2)

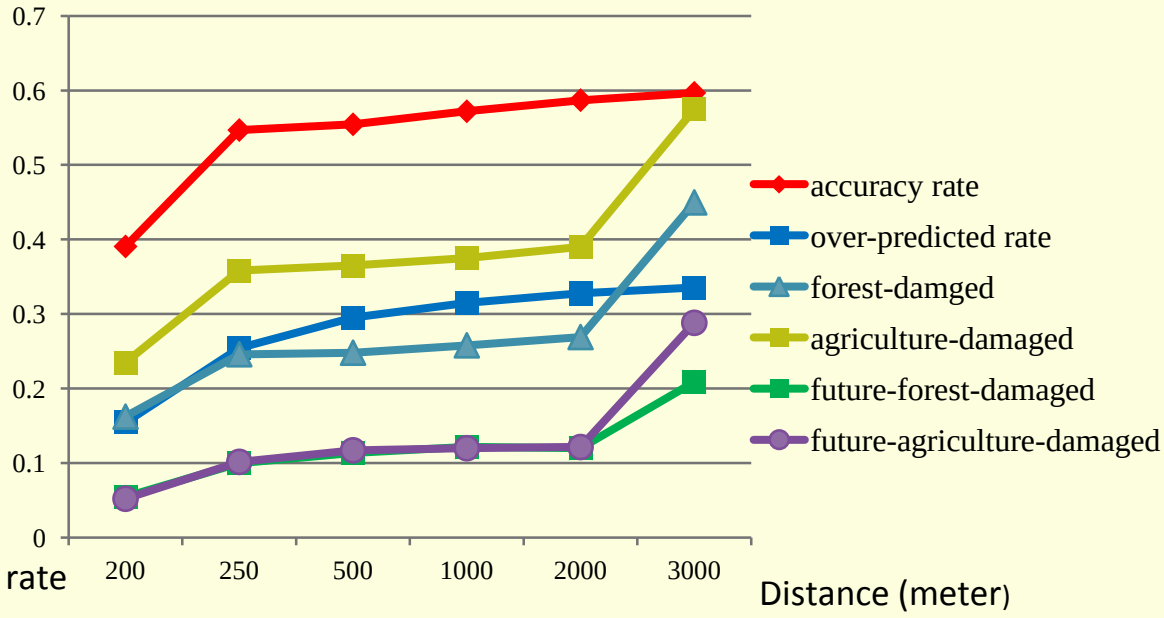


Considers slope and neighbor effect:

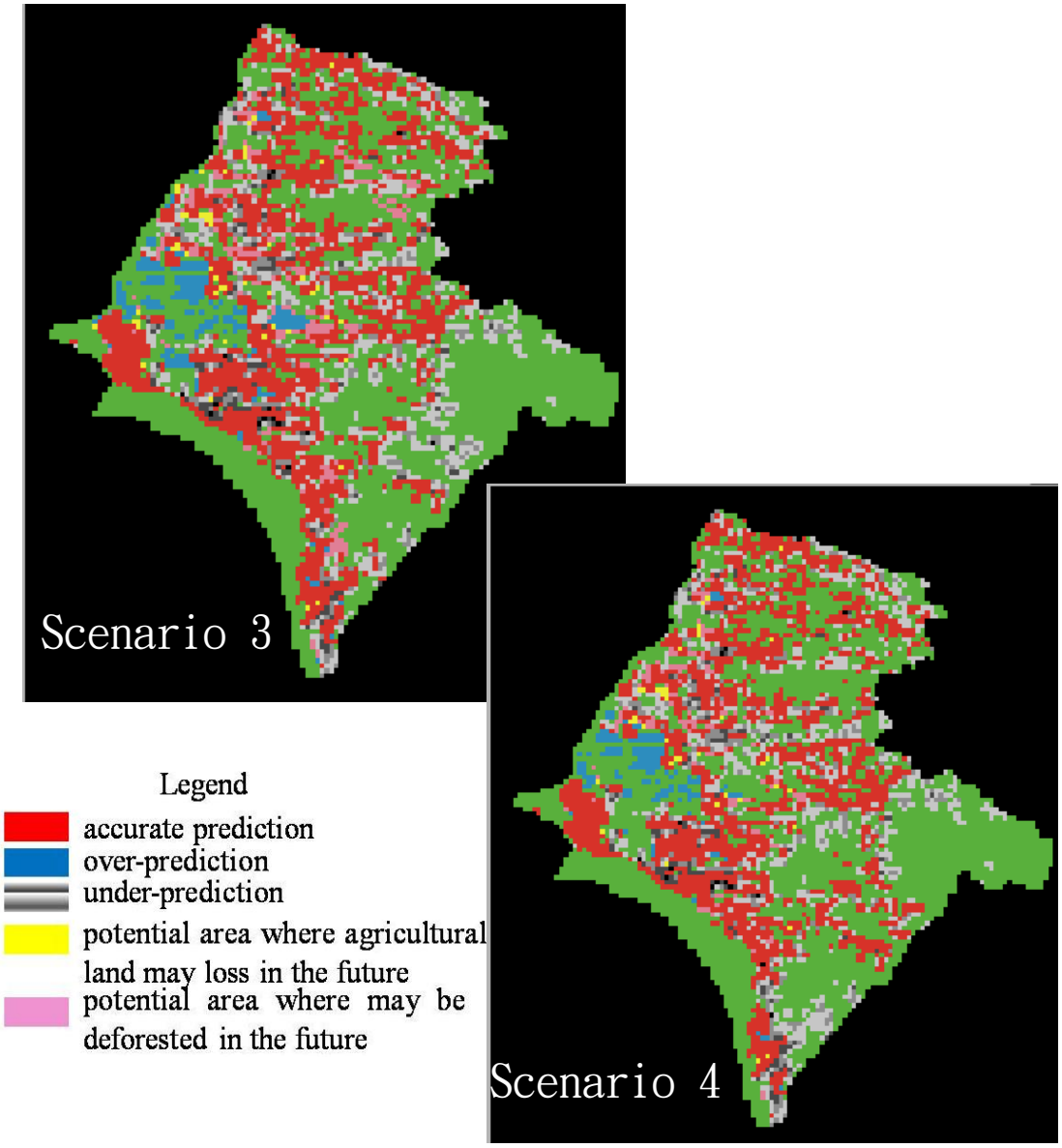
- when the value is equal or greater than 1,000, the predicted accuracy rate reduces significantly from 50% to 37%.
- Based on this observation, it is suggested that the urban development in Danshuei district would spread over an area instead of concentrated at a particular place.

Considers slope and road gravity:

- the urban development in Danshuei district tends to occur at a place which is 250m or above away from a road system.
- The loss rate of natural resources is noticeable when the distance between new urban development and a road system is greater than 2000m.



SIMULATION RESULT : SCENARIO 3 AND 4



Excluded Element From Development		
Element	**Scenario 3**	**Scenario 4**
	moderate protection	**restricted protection**
Agriculture District of Urban Planning		X
General Agricultural Zone		X
Special Agricultural Zone	X	X
Recreational area		X
General forest district		X
Urban parks		X
National Parks	X	X
Slop land conservation zone	X	X
Wetland	X	X
River District	X	X

Comparison of Simulation Results

- Comparing scenario 3 with scenario 1 suggests that the environmental restriction policy can reduce the forest loss rate by 9.2% and the agricultural land loss rate of 8.03%.
- As in scenario 4, the reduction for forest loss rate and agricultural land loss rate is 11.17% and 9.33% respectively.

	Scenario 1	Scenario 2-1	Scenario 3	Scenario 4
Accuracy rate	0.5943	0.5123	0.5943	0.5943
Over-predicted rate*	0.3359	0.1874	0.3359	0.3359
Forest-damaged rate	0.2712	0.3274	0.2712	0.2712
Agriculture-damaged rate	0.3878	0.4656	0.3878	0.3878
Future damaged rate of forest **	0.1341	0.1168	0.0421	0.0224
Future damaged rate of agriculture**	0.1247	0.1611	0.0444	0.0314

* over-predicted areas may indicate that the places have a high potential to be urbanized in the future.

** assumes that over-predicted areas are feasible to be urbanized, then predicts forest and agriculture loss rates.

Discussion and Conclusion

- From Scenario Slope factor is the influential driving force to urban growth model, comparing to neighbor effect and road gravity. More driving forces inputted would not increase the correct prediction rate.
- Over-predicted areas may indicate that the places have a high potential to be urbanized in the future, where should be controlled or protected carefully.
- Scenarios of environmental impact analyses show that restricted zoning control (Scenario 4) could have considerable preservation of forest and agriculture land in the future.
- Protection policy strategies assumed in Scenario 3 and 4 could be further applied as Performance measurement/ indicators of land use control.

RECOMMENDATION

Three major aspects will be addressed and further investigated in this urban growth modeling study:

(1) model calibration: more historical images/data will be collected to undergo a detailed calibration as well as to improve the model capability in modeling urban transformation process.

(2)investigation of other driving forces/growth rules:

- urban density and other social factors will be included in future simulation models.
- Combination of the strategies of development constraints will be considered.

(3)methods for accuracy assessment: further assessment methods such as Kappa, fuzzy Kappa statistic and other index will be examined in future research.

Gaps to be Connected

(1) Up-scaling the LUCC simulation model
    (1) Manpower / software engineers or AI machines
(2) Integrating climate change and land use policy simulation models in various levels
(3) Ontologies of urban planners and computer scientists

Thank you for your Attentions