

LanduseSim Methods: Land use class hierarchy for simulations of multiple land use growth

N A Pratomoatmojo¹

¹ Urban and Regional Planning Department, Institut Teknologi Sepuluh Nopember, Indonesia

*Corresponding Author: pratomoatmojo@urplan.its.ac.id or nursaktiadhi@gmail.com

Abstract. LanduseSim, as a land use change modelling software to predict the future of land use, has specific framework on spatial modelling process. Regarding to its process behind the simulation procedure, LanduseSim offers good flexibility so user able to adjust the process of land use change iteration by modify the order of land use class. As a consequences of its flexibility structure, understanding the hierarchy system of land use class for multiple land use growth becomes one of the most important knowledge. In this research, author would like to demonstrate a land use change simulation by changing the hierarchy of land use class and explains the different simulation output.

Keywords: *LanduseSim, Cellular Automata, Multiple land use*

1. Introduction

Cellular automata has proved as a robust method in predicting land use through spatial simulation and modelling process [1][2][11], not only for geography approach [7][9], it also powerful tool for urban planning process [2][3][4]. LanduseSim, a geographic information system tool for land use/ land cover (LULC) modelling and simulation, used cellular automata algorithm to predict the land use change. It has many features that able to assist urban planner in research or practicing in planning field [5]. Because of its flexibility, understanding the process of simulation procedure will impact to quality of the output simulation. Several different of result are generated by LanduseSim when the simulation used different order of land use class sequences on transition rules. The worst result of simulation may occurs, instead the best result can be achieved by better configuration on land use class hierarchy under land use change modelling by means of cellular automata.

Understanding about the hierarchy of land use class is vital when user do land use change modelling using LanduseSim. By using LanduseSim, user is able to control the simulation procedure in more specific process of iteration. The iteration process will be determined by number of time-steps, growth of land use, and land use class hierarchy. The simulation process will follow land use class sequence that has been set on transition rules file, however the different result can be expressed by different setting of land use class hierarchy. This paper will do a simple experiment with different type of hierarchy on land use class for cellular automata using LanduseSim. To provide a comprehensive approach for reader, the information about the result about all experiment results are recorded as well as explained in this paper.



2. Methods

In this study, a number of experiments are tested towards different implementation of land use class hierarchy using LanduseSim. LanduseSim uses cellular automata model to predict the land use change's distribution and this model starts from neighbourhood filtering on initial transition potential map for each land use. Cellular automata algorithm that used by LanduseSim is different with Markov-CA algorithm, in which Markov-CA generated by transition area for land use allocation that has been demonstrated by Pratomoatmojo [6], meanwhile in LanduseSim land use allocation will be processed sequentially following its sequences. In order to test the several different hierarchy of land use class for simulation, the module of *Transition Rules* is used. *Transition Rules* module is used to generate 6 (six) configuration of land use hierarchy that applied into two scenario of growth for the experiment purposes (Table 1). Each of transition rules is executed used LUCC_Module of cellular automata model in LanduseSim.

Table 1 shows several settings regarding the experiment that will be tested for land use change modelling using LanduseSim CA. Each of experiment will test the variation of land use iteration sequences where each of land use has been set its own land constraint, iteration and neighbourhood filter operation. Land constraint serves as constraint to development of land use so during the simulation process, the growth of land use will never convert its own land constraint. In this phase, the land constraint was determined by the author based on personal assumptions according to the case in general. Furthermore, each experiment will be tested with two land use development scenarios i.e. identical growth (scenario-1) and different growth (scenario-2). In scenario 1, selected land use growth (settlement, commercial, and fishpond) will increase by 100 hectares for each, meanwhile in scenario 2 the growth of those land uses is a half of the size of each type of land use.

Table 1. Experimental setting of land use class hierarchy

No	Land use order	Land Constraint	Iteration	Neighbourhood Filter
EXP-1	1st : Settlement (1)	Commercial	10 time-steps	3x3 Sum Operation
	2nd : Commercial (2)	-		
	3rd : Fishpond (3)	Settlement and Commercial		
EXP-2	1st : Settlement (1)	Commercial	10 time-steps	3x3 Sum Operation
	2nd : Fishpond (3)	Settlement and Commercial		
	3rd : Commercial (2)	-		
EXP-3	1st : Commercial (2)	-	10 time-steps	3x3 Sum Operation
	2nd : Settlement (1)	Commercial		
	3rd : Fishpond (3)	Settlement and Commercial		
EXP-4	1st : Commercial (2)	-	10 time-steps	3x3 Sum Operation
	2nd : Fishpond (3)	Settlement and Commercial		
	3rd : Settlement (1)	Commercial		
EXP-5	1st : Fishpond (3)	Settlement and Commercial	10 time-steps	3x3 Sum Operation
	2nd : Settlement (1)	Commercial		
	3rd : Commercial (2)	-		
EXP-6	1st : Fishpond (3)	Settlement and Commercial	10 time-steps	3x3 Sum Operation
	2nd : Commercial (2)	-		
	3rd : Settlement (1)	Commercial		

3. Data Collection

This section discusses about data creation for experimental purposes. Land use map on this research is a set of hypothetical data to provide appropriate explanation about the simulation process. The land use map consist of four classes i.e. settlement area (code-1), commercial area (code-2), fishpond (code-3) and paddy field (code-4). The suitability map or initial transition map for each land use class

was built by overlaying with weighting and scoring using of Multi Criteria Evaluation (MCE) technique [12]. This limited experiment uses transition map, which consist of distance to road network, distance to settlement, distance to fishpond, and distance to commercial area. All raster dataset were set to the uniform cell size 20 meter x 20 meter (400 meter square).

4. Result and Discussion

As explained in the data collection phase, the first process is hypothetical land use data preparation. In aggregate, the total area that is used in this experiment about 621 Ha, consists of settlements 211 Ha, commercial 54 Ha, Fishpond 159 Ha, and Paddy field 197 Ha. In addition to land use data, road network data is prepared as one of the data used for development of each land use transition map.

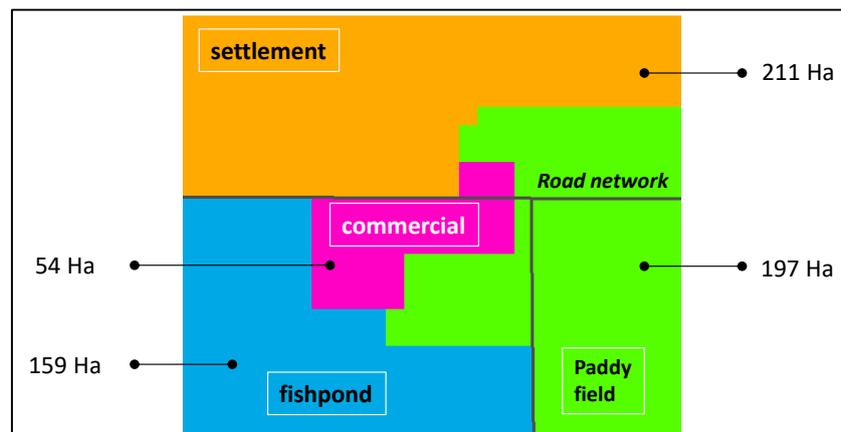


Figure 1. Initial map of land use class distribution (in cells)

Figure 1 provides an overview of the study region and its land use classification. The land use map used in this research is hypothetical data for experimental purpose. On the next step, transition map for each of land use class (i.e. settlement, commercial, fishpond) are created by using multi criteria evaluation (MCE) technique by taking into account hypothetical driving-factors for experimental purposes (Figure 2). Here, settlement driving-factors are consist of distance to settlement (0.4) and distance to road networks (0.6), commercial growth is influenced by distance to commercial area (0.4) and distance to road networks (0.6), and fishpond growth affected by distance to fishpond (0.6) and distance road networks (0.4). Before overlaying using MCE, each of distance factor is standardized into real number (0 – 1).

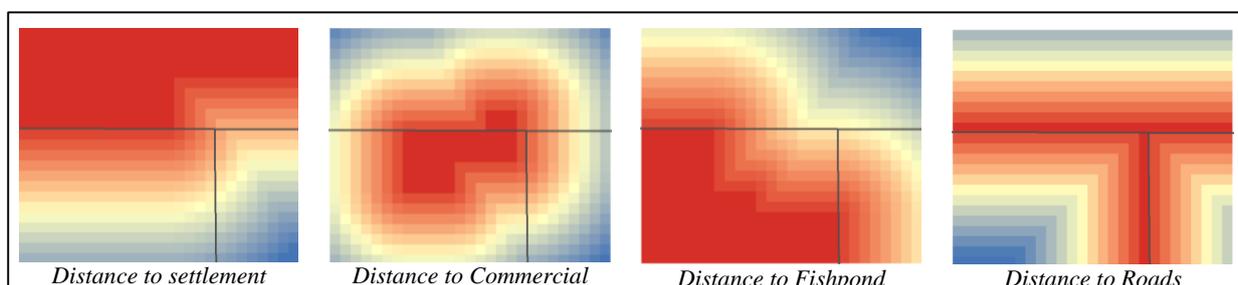


Figure 2. Spatial driving-factors included in this study

In this land use hierarchy experiment towards cellular automata model, neighbourhood filter 3x3 are used in conjunction with ten time-steps of iteration to produce ten years map series. Several transition rules will be tested in order to give output about all possibilities of land use change simulation result (Table 1). At this stage, each experiment is transformed into a transition rule which is then processed through the LUCC_CA Module on LanduseSim. This paper describes several findings

of simulation results related to the variation of land use patterns, variations of land use dynamics, and variations in the area of land use.

4.1. Variations of land use pattern

Due to differences of land use class order during simulation, the result may vary from one to another. This is caused by cellular automata processes each land use sequentially. Figure 3 shows the simulation results from one set of experiments (Table 1) with the similar growth (100 Ha) for each land use expected to grow (i.e. settlement, commercial, and fishpond). From these experiments expressed diverse results from one another in terms of land use patterns generated. Furthermore, it has been described by Table 2 which examines the similarities between experiments with one another. Highest value of similarity is shown by EXP1 with EXP2 (99.84%), and EXP4 with EXP6 (99.84%). As a conclusion, there is a resemblance to land use hierarchy 1-2-3 with 1-3-2, and 2-3-1 with 3,2,1.

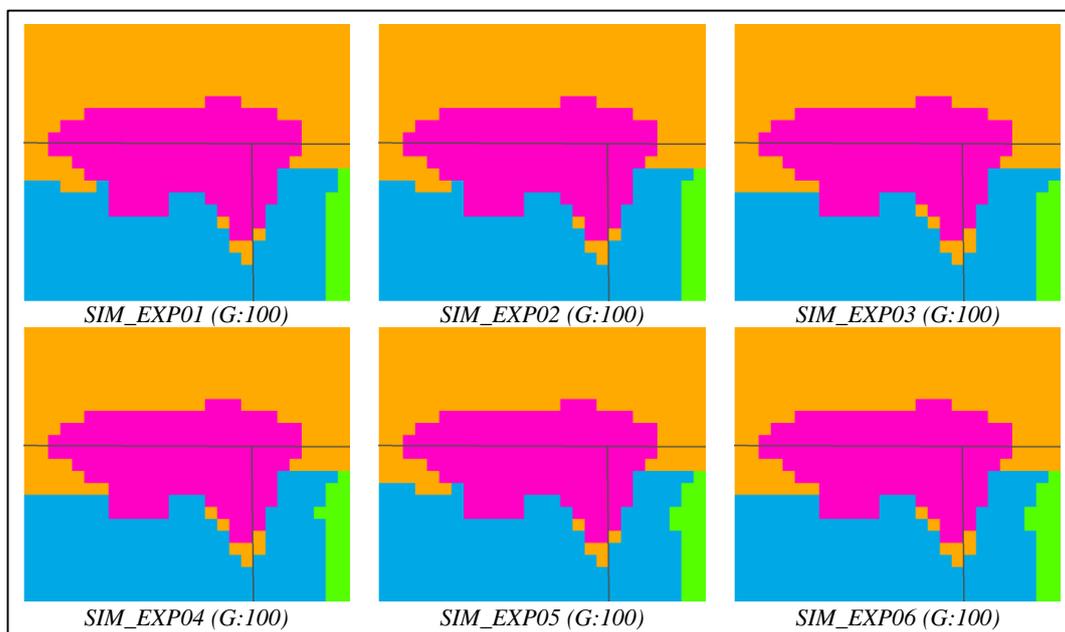


Figure 3. The Scenario-1 simulation result of land use pattern

Table 2. Pattern similarity by variation of land use class (Scenario-1/Growth 100 cells)

No	Output	Class Differences	Overall Pattern Similarity
1	1. SIM_EXP1 2. SIM_EXP2	3_4 : 1 Ha	99.84 percent
2	1. SIM_EXP1 2. SIM_EXP3	3_1 : 6 Ha 4_3 : 1 Ha	98.87 percent
3	1. SIM_EXP2 2. SIM_EXP3	3_1 : 6 Ha 4_3 : 2 Ha	98.71 percent
4	1. SIM_EXP2 2. SIM_EXP6	3_1 : 6 Ha 3_4 : 2 Ha	98.71 percent
5	1. SIM_EXP3 2. SIM_EXP5	1_3 : 6 Ha 3_4 : 4 Ha	98.39 percent
6	1. SIM_EXP4 2. SIM_EXP5	1_3 : 6 Ha 3_4 : 1 Ha	98.87 percent
7	1. SIM_EXP4 2. SIM_EXP6	3_4 : 1 Ha	99.84 percent

The scenario-2 implementation produces a relatively different output of land use change modelling (Figure 4). However, there are several experimental results of the same pattern of use i.e. EXP1 with EXP2, and EXP4 with EXP6. The two comparative pairs resulted in similarities in land use patterns about 100% (Table 3).

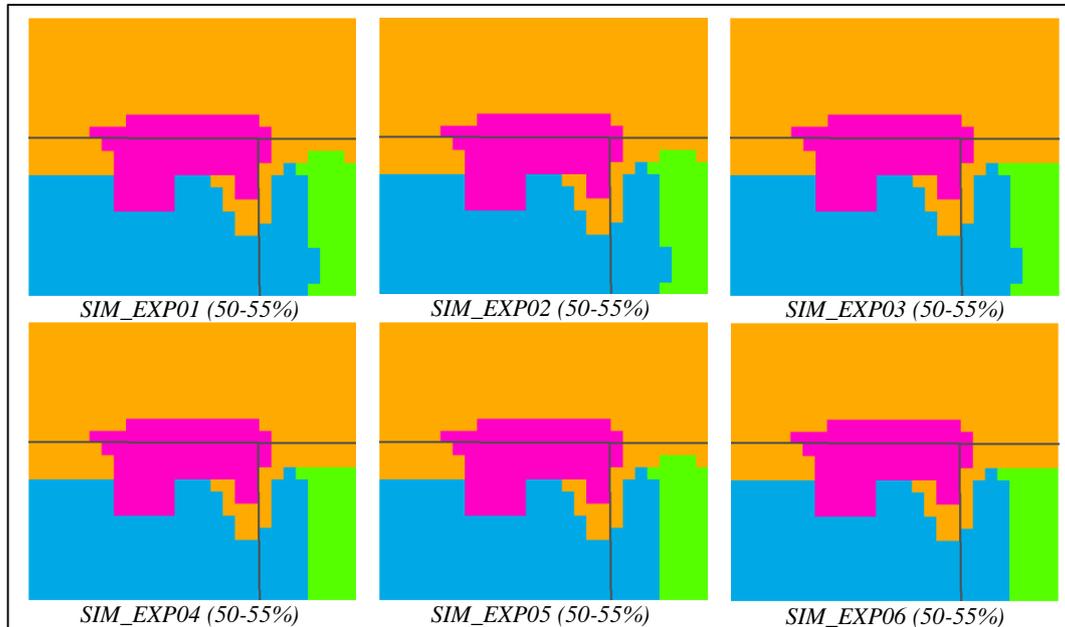


Figure 4. The Scenario-2 simulation result of land use pattern

Table 3. Pattern similarity by variation of land use class (Scenario-2/Growth 50-55%)

No	Output	Class Differences	Overall Pattern Similarity
1	1. SIM_EXP1 2. SIM_EXP2	-	100 percent
2	1. SIM_EXP1 2. SIM_EXP3	4_1 : 3 Ha	99.52 percent
3	1. SIM_EXP2 2. SIM_EXP3	4_1 : 3 Ha	99.52 percent
4	1. SIM_EXP2 2. SIM_EXP6	3_4 : 3 Ha 4_1 : 3 Ha	99.03 percent
5	1. SIM_EXP3 2. SIM_EXP5	1_4 : 3 Ha 3_4 : 3 Ha	99.03 percent
6	1. SIM_EXP4 2. SIM_EXP5	1_4 : 3 Ha	99.52 percent
7	1. SIM_EXP4 2. SIM_EXP6	-	100 percent

4.2. Variations of land use dynamic transition

Based on Figure 6 and Figure 8, both explain the dynamic of land use change simulation per each time-step of iteration. The Paddy field in Figure 5 is more suffering than Figure 7 because of higher rate of growth from three land use class (i.e. settlement, commercial and fishpond). It can be deduced that different growth on land use change simulation will generate different rate of conversion per period. Both of transition growth per year are described on Table 4 and Table 5.

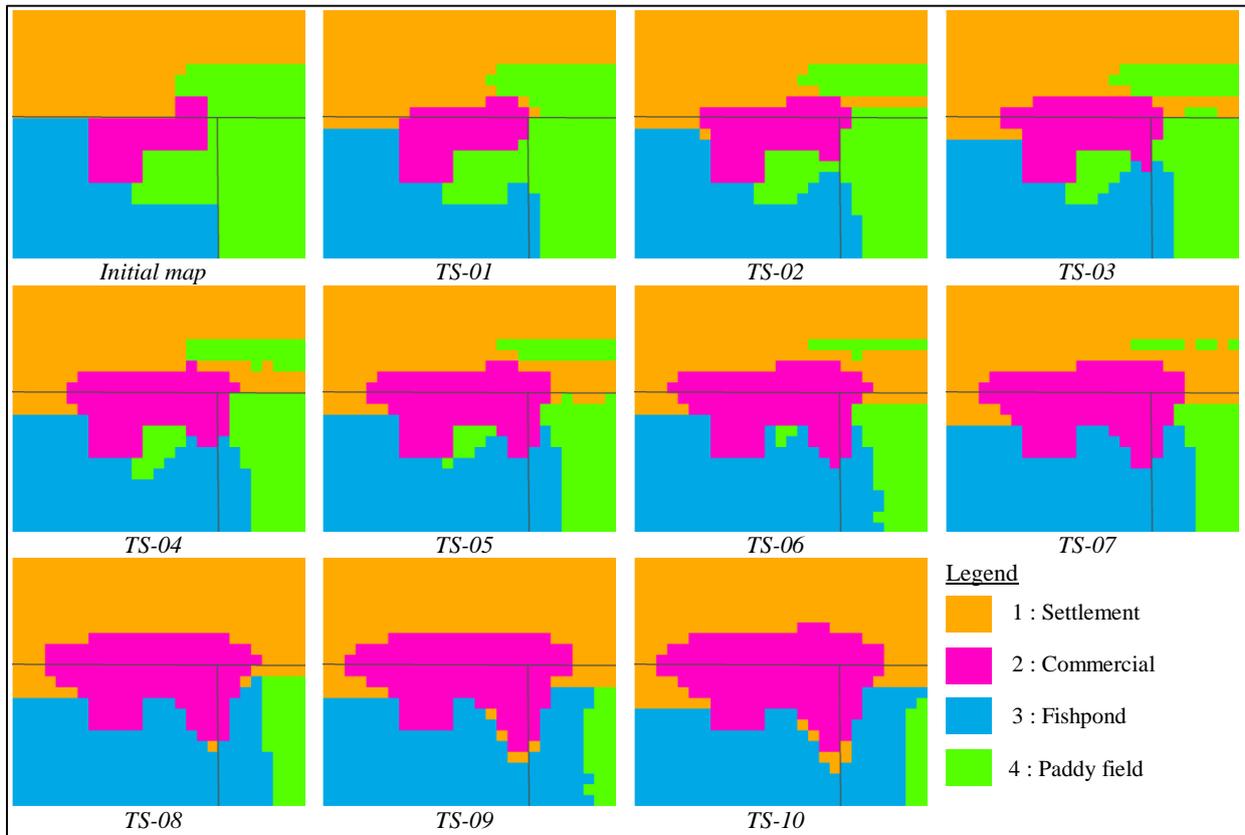


Figure 5. Ten iterations map series of EXP3 from the Scenario-1

Table 4. Growth per year (time-step) during ten years simulation (Scenario-1)

LU \ time-steps	Initial	TS-01	TS-02	TS-03	TS-04	TS-05	TS-06	TS-07	TS-08	TS-09	TS-10
settlement	211	214	218	220	224	228	231	236	238	241	244
commercial	54	64	74	84	94	104	114	124	134	144	154
fishpond	159	162	171	175	184	191	198	199	206	207	204
paddy field	197	181	158	142	119	98	78	62	43	29	19

unit in hectares

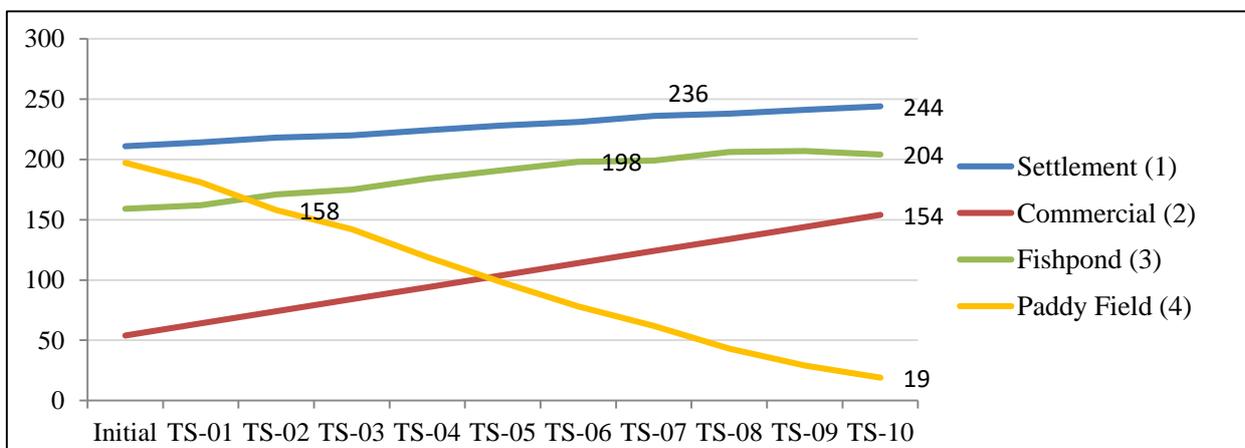


Figure 6. Land use change dynamic with experiment growth (Scenario-1)

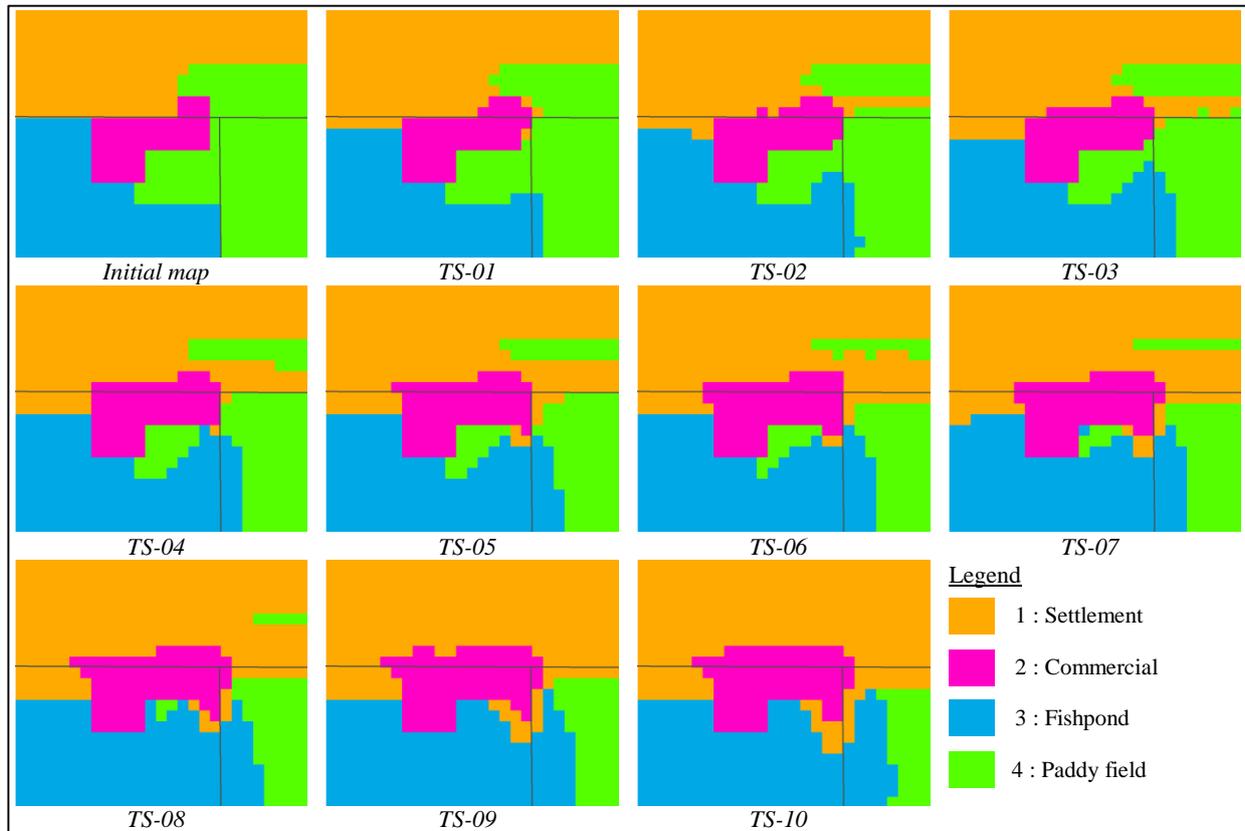


Figure 7. Ten iterations map series of EXP3 from the Scenario-2

Table 5. Growth per year (time-step) during ten years simulation (Scenario-2)

LU \ time-steps	Initial	TS-01	TS-02	TS-03	TS-04	TS-05	TS-06	TS-07	TS-08	TS-09	TS-10
settlement	211	221	229	237	246	254	262	270	278	286	294
commercial	54	57	60	63	66	69	72	75	78	81	84
fishpond	159	160	166	169	177	182	190	193	195	198	201
paddy field	197	183	166	152	132	116	97	83	70	56	42

unit in hectares

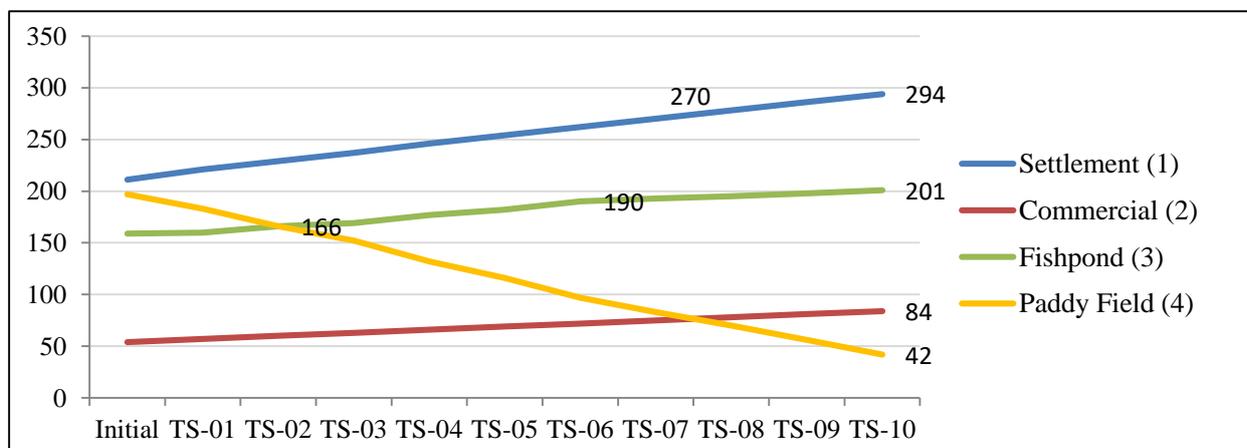


Figure 8. Land use change dynamic with experiment growth (Scenario-2)

4.3. Variations of land use extents

Based on the Table 6, it shows each of different on land use class sequence on transition rules will impact to different output result on land use change pattern.

Table 6. Experiment result of land use class order

Scenario-1: 100 Ha		EXP-1	EXP-2	EXP-3	EXP-4	EXP-5	EXP-6
		<i>1,2,3</i>	<i>1,3,2</i>	<i>2,1,3</i>	<i>2,3,1</i>	<i>3,1,2</i>	<i>3,2,1</i>
	1 : Settlement	238	238	244	244	238	244
100 Hectars	(%) <i>Expected</i>	76.527%	76.527%	78.457%	78.457%	76.527%	78.457%
	2 : Commercial	154	154	154	154	154	154
100 Hectars	(%) <i>Expected</i>	100%	100%	100%	100%	100%	100%
	3 : Fishpond	209	208	204	201	206	200
100 Hectars	(%) <i>Expected</i>	80.695%	80.309%	78.764%	77.606%	79.537%	77.220%
	4 : Paddy field	20	21	19	22	23	23
Growth-Rate (1,2,3)		85.741%	85.612%	85.740%	85.354%	85.355%	85.226%
Scenario-2: 50%-55%		EXP-1	EXP-2	EXP-3	EXP-4	EXP-5	EXP-6
		<i>1,2,3</i>	<i>1,3,2</i>	<i>2,1,3</i>	<i>2,3,1</i>	<i>3,1,2</i>	<i>3,2,1</i>
	1 : Settlement	291	291	294	294	291	294
52.1% (110 Ha)*	(%) <i>Expected</i>	90.654%	90.654%	91.589%	91.589%	90.654%	91.589%
	2 : Commercial	84	84	84	84	84	84
55.6% (30 Ha)*	(%) <i>Expected</i>	100%	100%	100%	100%	100%	100%
	3 : Fishpond	201	201	201	198	198	198
50.0% (80 Ha)*	(%) <i>Expected</i>	84.100%	84.100%	84.100%	82.845%	82.845%	82.845%
	4 : Paddy field	45	45	42	45	48	45
Growth-Rate (1,2,3)		91.585%	91.585%	91.896%	91.478%	91.166%	91.478%

* *adjusted to fit with time-step*

* *Expected in Ha*

Based on several experiment of land use change modelling with different hierarchy class on transition rules, it has generated diverse result on each running model. Author has tested about 12 experiments that were divided into two scenarios. The scenario-1 experiment used number of expected growth about 100 Ha for each land use class. The highest growth-rate shown by EXP-3 is about 85.74% using configuration of land use 2-1-3 (that generates 78.764%) get highest achievement growth of fishpond compare than others. Meanwhile, the third group of experiment run with different number of growth for each class of land use in the range of 50-55% from each class of land use i.e. 110 Ha for settlement, 30 Ha for commercial, and 80 Ha for fishpond land use.

On the scenario-2, three land use classes (settlement, commercial, and fishpond) out of four of land use class are expected to grow about 50 Ha for each. In the first experiment have been found there are two experiments, EXP-3 and EXP 4, have same expected area rate achievement about 92.915% from total of area after added the development result. On this case, the total area settlement is about 228 Ha, 1 Ha bigger compare than others. From the first experiment, the sequences simulation of land use class order of 2-1-3 and 2-3-1 both are the best configuration setting. The both of experiment draw conclusion that commercial area is the highest hierarchical class order due to its less possibility to be converted by others, and settlement would be more suitable to be placed thereafter. However, the scenario-1 and scenario-2 experiment reinforce the conclusion.

The experiment determines that the EXP-3 (2-1-3) is the best configuration of land use order on transition rules with the score about 91.896% ratios to the total expected area. Once again, in this case the configuration of 2-1-3 (commercial 1st, settlement 2nd, fishpond 3rd) proves the best solution for land use change modelling is put on the highest class land use hierarchy (has the lowest possibility to be converted) on the first iteration procedure, and followed by lower class until the class is easily converted.

5. Conclusion

Understanding about hierarchical order of land use change simulation procedure is essential and it should be understood well by researcher. Those experiments above are not deal with the spatial accuracy assessment, moreover it talks about the foundation of knowledge to do appropriate simulation in better result. Through this study, it can be inferred some related facts about the experiment.

First, based on variations of land use pattern, it is proved that the variation of land use hierarchy in the simulation process using LanduseSim-CA can produce different outputs although less likely to produce the similar output. The similarity level will be lower if more variety of land use is simulated and each of them has the potential to convert each other class. Second, It can be realized that different growth on land use change modelling by means of cellular automata will generate diverse rate of alteration per period of iteration. therefore, an understanding of how much the growth of a land use becomes important. Third, based on the simulation result that higher hierarchy of land use class should be placed above in LanduseSim's transition rules. If there are more than one of land use class and it's possible to convert each other, land use that less possible to be converted by other should be placed at the top of transition rules, and later on it could be followed by higher possibility of conversion by the others, and so on.

Mistake on assigning places of sequences growth for each land use class will lead to poor result in land use change model and its consequences to spatial accuracy assessment as well. Improving the understanding about the hierarchical order of land use class also can be reviewed through historical of land use change analysis for deep analysis process.

6. References

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