H-3.2.3 Development of the land use/change dataset of Thailand

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Abstract The case study aims to illustrate the applications of GSIM simulation model in the projection of land use changing pattern from a current year up to the year 2050. Four regions of Thailand are utilized to illustrate the cases. The applications concern on two land use scenarios. The reference scenario is the ongoing land use policy represented entirely by the past performance of land use interaction. The alternative scenario represents the otherwise assumed policy options. The latter is formulated to illustrate some particular land categories that largely represent the regional land use specialty. The application process concerns on the formation of changing rate and changing pattern of land use in the future. The socioeconomic driving forces gear the projections of those two policy scenarios. The simulation results show the differences of changing pattern by scenarios.

Key words: land use/cover change, scenario, modeling, projection

1. Introduction

Land use/cover change simulation model, GKSIM, is one of the promising tools by its simplicity in handling with sophisticated land use interaction. The model mechanism enables to forecast the land use change subject to one homogenous area, country or region. To apply the model into lower hierarchical level, there is a certain limitation when the model regards a particular region as an individual base, and its still lacks of linkage mechanism among each individual. Naturally, there is a similarity and a difference in land use and socioeconomic drive forces among the lower hierarchical regions. To illustrate the land use/cover change through GKSIM in lower area-base, particular land use scenarios in accordance with particular regions are introduced. The formulation of land use scenarios is worthwhile to compare the development policy options that affect the land use/cover change in the future. This paper concerns on the formulation of regional land use scenarios in accord with particular development policy and illustrates the affects of development policy scenarios to the pattern of land use/cover change in the future. Four regions of Thailand are utilized to illustrate the cases.

2. Regional Scenarios and Policy Options

Thailand can be formally divided into four regions, the North, the Northeast, the Central and the South. In this study, land use is categorized into 5 types, namely, forest, paddy land, agricultural land (excluding paddy land), residential land and unclassified land. Each region has a certain similarity in land use. In sum, the forest land has been tremendously depleted in parallel with the tremendously increment of cultivated land. Residential land has increased continuously in accord with the continuously increase urbanization. The differences of land use pattern by region pose on paddy land and unclassified land since varieties of pattern are envisaged. The degrees of land use interaction are different region by region.

i. Scenario Formulation

Under Thailand's development planning, the national plan is made subject to five year term. The plan in a longer period is not available. Thus, the long-term scenario here is quite arbitrary. The purpose in setting up particular land use scenarios and policy options is only to illustrate the results of land use simulation model. To avoid the complexity of the simulation, the scenario is formulated as simple as possible. Besides, it has to be easily understood on a rationale behind the scenario. Two options of scenario are adopted. In GKSIM mechanism, the land use interaction in the past plays major role to forecast the future pattern. Therefore, *the first land use scenario*, so called here, *reference scenario* has to be relied totally upon the past performance of land use interaction. Here, the business as usual scenario is simulated in GKSIM forecasting. To formulate *the second scenario*, so called here, *alternative scenario*, there are two main options; the first concerns on the rate of change (increase or decrease) in a particular land use, and the second concerns on the pattern of change (increase or decrease) subject to the times. For example, when a policy maker emphasizes on forest conservation policy in a particular region and targets to stop the conversion of forest land in specific year, the rate of decline in forest land from the beginning year of simulation can be determined.

Furthermore, the pattern of change subject to a targeted year has to be determined. There are at least three changing patterns. In the decreasing land use pattern for example. Firstly, the decreasing rate is bigger decline in the beginning year and smaller decline in the later year, secondly is the opposite way, and thirdly is the flat rate of decline which means that annual decreasing rate is the same over the period of simulation. Besides, the meaning of targeted year is that if it is the year 2050, there will be no further forest depletion after the year 2050. Another example is when the policy makers design to expand the paddy land, aiming to raise the rural economy. They may design either the year the amount of paddy land shares certain percentage in total land use, or determine the rate of annually increase and the pattern of increasing rate as such. The different policy options from current situation is regarded as the alternative scenario.

To be more simplicity, only one or two categories of land use in one scenario is sufficient to illustrate the cases. In the real world, the changing pattern of land use may be apparent in various fashions. As described earlier, the arbitrary options of increasing (decreasing) figures and pattern of changes in the scenarios here are only employed to illustrate the cases.

ii. Regional Development Scenarios

a. Thailand Policies in Major Land Use

In major land use, there are only few policies are clearly envisaged. One of a clear scenario in macroscopic planning is the forest land that has been targeted at 25 percent of the total. In other major categories, the scenarios are apparent in the form of policies and measures subject to mid-term planning, a five-year national plan. In forest land, the results from simple linear regression model, $Y = a + b X + e$, (Y = forest land, X = time variable:year, a, b = parameter and e = error term) indicated that during the year 1978-1993 the forest land of the country has decreased in an average about 1.615 mil. rai per annum. The North has sharply declined about 782 thousand rai per annum (see Table 1). The total forest land of the nation at the year 1993 was only 26.02 percent of total forest land. The national policy goal of at least 25 percent forest land is, therefore, hardly met due to the problem of illegal logging. To be more realistic, in case the policy maker has set a new arbitrarily goal at 22 percent of national reserved forest at the year 2050.

In rice production, there is no longer policy to be the world number one rice exporter due to weakening competitiveness in rice production of Thailand. The current policy is to keep the amount of 5 mil. tons of rice export, and to have sufficient supply of rice for local consumption. About 60 mil. rai of total paddy land, 15 mil. rai is a long term reduction target. The policy measure to reduce the paddy land has been executed since the seventh national plan (the period of 1992-1996), aiming at the inappropriate cultivation of paddy by unsuitable soil condition, upland rice cultivation, and critical environmental degradation. A variety of crops have been introduced in the replacement of paddy land. In parallel the policy to increase productivity of rice farming in paddy land suitable for rice farming has continuously emphasized through the increment of appropriated technology and crop intensification. In the meanwhile, another kind of problems has been apparent. The misuse problem by urban sprawl has resulted a continuously loss of superior paddy land in central region. Currently, there is no clear policy measure on misuse of land in suburb areas. In agricultural land other than paddy, the major policy places on crop diversification from few conventional crops to more value added crops, and productivity upgrading through a variety of technology improvement. A clear target in long term planning is available only in a few conventional crop e.g., para-rubber.

Table 1 Regression Results of Forest Land Depletion by Regions

Region	R square	Coef. (X)	Std. Error	t-statistic (X)
Country	0.970	-1,615.28	75.339	-21.440
North	0.992	- 782.12	20.300	-38.529
Northeast	0.943	- 372.15	24.431	-24.431
Central	0.832	- 260.82	31.354	-31.354
South	0.991	- 197.65	5.156	-38.333

b. Regional Land Use Scenarios

The North

The northern region of Thailand has been prescribed by its abundant natural resources, especially tropical forest resource. It contains several major watershed forest of the country. In 1993, forest land composed of 44.35 percent of total land of the region, dropped from 55.96 percent from the year 1978. There are two scenarios on forest land; firstly, go on with the current policy measure. The alternative scenario is the arbitrarily decreasing rate of forest land to meet the minimum target of 22 percent of forest land of the nation. The year 2050 is targeted of no more forest depletion. The calculation has been made to obtain the annual rate of forest depletion in the national level. This annual depletion rate reconciles for all regions. The result of calculation is 0.25 percent per annum at the beginning year of simulation. The empirical results of recent forest depletion during the year 1978-1993 show a pattern of bigger-to-smaller decreasing rate in all regions. The simulation here then adopts such a pattern. It should be remarked that when the annual decreasing rate of forest and the bigger-to-smaller declining pattern are adopted at the North, the other three regions will automatically adopt the same depletion rate and the pattern as their pre-determined option of forest land scenario.

The Northeast

The northeastern region is considered as the poorest region with infertile soil and vulnerability weather condition. Rice is a major crop for both self-consumption and commercial. In 1993, paddy land shared about 35.82 percent of total area of the region. It shared 38.5 percent of the nation's rice produces. Total annual production in the past has been fluctuated in the range of 5.8 to

8.2 mil. tons. Rice productivity during the 1993/1994 crop year was 262 kg per rai (1 rai=1,600 m^2), about 86 kg lower than the national average. While other regions have been envisaged a declining pattern of paddy land, the northeast's paddy land remains stagnant. During the year 1978-1993, the average rate of increase is about 0.3 percent per annum. Two simple policy scenarios on paddy land are formulated, either the policy to follow the same fashion as occurred in the past, or the policy to prevail the productivity upgrading as the alternative. The policy on productivity upgrading will guarantee the maximum amount of rice produces ever produced by the region, at 8.2 mil. tons of paddy. Regarding to the current average consumption of paddy in the Northeast, this amount will also guarantee more than sufficient supply for the consumption of 23.26 mil. (forecasted) population of the region at the year 2050.

Table 2 Rice Productivity of Thailand and the Northeast

Region	R square	Coef. (X)	Std. Error	t-statistic (X)
Country	0.871	5.579	0.878	6.357
Northeast	0.750	6.690	1.579	4.238

In the current agricultural development policy of the region, the productivity upgrading in rice cultivation has highly been prioritized. However, since such a policy has no clear long term target, then, the national average of 348 kg per rai at the year 1993 is set as the arbitrarily alternative goal for the Northeast at the year 2050. In regression results of productivity upgrading during the year 1984-1993 show that the Northeast has a little higher than the country's average (Table 2, note: X is time variable). The increment pattern of productivity in both the Northeast and the country are apparent in a bigger-to-smaller rate. Here, the pattern as such is adopted in the simulation of the Northeast.

The Central

The Central is the most developed region of them all. Farming scheme is relatively high diversification and intensification. Paddy land has drastically been declined with the replacement of industrial and urbanization and other agriculture beyond paddy. In the year 1993, the paddy land constituted of 18.68 percent of total area of the region, dropped from the share of 26.10 percent in the year 1978. Most of the cultivated areas are low land has still been the major area for rice production of the nation by its advantages in irrigated facilities and soil fertility. At moment, there is no planning control measure to slow down the losses of prime paddy land. The regression results of paddy land depletion show that during the year 1986-1993 an average of 318,473 rai per annum of paddy land has been replaced to other land use (Table 3). The pattern of depletion is apparent in a fashion of bigger to smaller. Here, two scenarios are formulated, one scenario places on the case of land use change follows the pattern as occurred in the past. Alternative scenario is arbitrary that the policy maker set a conservative policy to stop the paddy land conversion at the year 2010. In the alternative scenario, the most recent annual depletion rate of 1.5 percent is employed as the beginning year of simulation.

Table 3 Paddy land reduction of the Central

R square	Coef. (X)	Std. Error	t-statistic (X)
0.969	-318.473	16.467	-19.340

The South

Para-rubber trees dominantly cover the farmland in the South. The production in the South alone shares about 90 percent of total para-rubber produces of the nation. In the year 1993, para-rubber area of 9 mil. rai covered about 85 percent of total agricultural land of the South (excluding paddy) and constituted 90 percent of total para-rubber area of the nation. In the

Table 4 Para-Rubber Productivity of the South

R square	Coef. (X)	Std. Error	t-statistic (X)
0.993	12.418	0.378	32.823

South, the acreage of para-rubber has increased about 1.6 percent average annually. The productivity of had also raised from 113 kg per rai in the year 1986 to 200 kg per rai in the year in the average rate of 12 percent per annum (Table 4). The national policy to improve the productivity of para-rubber has been prevailed since past three decades and it will prevail up to the year 2010, in the rate of 200,000 rai per year all over the country. In the South, the expansion to meet the target is hardly possible due to its constraint on topographical characteristics. Moreover, the small amount of arable land and the coming shortage of labor force for rubber harvesting will limit the expansion.

From the overwhelmingly acreage in total farmland of the region, para-rubber land is rationale to be employed as a proximity of agricultural land beyond paddy land. Reference scenario is the ongoing land use. The alternative scenario is to increase of cultivated land slower than the past. The alternative scenario means that the productivity will increase faster than the past, to offset the slower acreage expansion. The increasing rate of 15 percent per annum of productivity upgrading at the beginning year is set arbitrarily. The bigger-to-smaller pattern of increasing rate is adopted. This increasing fashion in simulation resembles the empirical result of bigger to smaller fashion of yield per rai during the year 1986-1993.

c. Land Use Scenarios

From the regional policies as mentioned, the scenarios of four regions can be summarized in Table 5. It is remarked that the forest policy to reserve at least 22 percent of forest in total land of the nation affects to all regions.

Table 5 Land Use Scenarios of the Regions

Regions	Policy Scenarios	Land Use Change Scenarios
North	- Forest conservation	Follows the past land use interaction Decreasing rate of 0.25 % in forest land, bigger-smaller Pattern to become zero (0) up to the year 2050
Northeast	Increasing paddy land productivity	Follows the past land use interaction Productivity increases bigger-smaller pattern to meet the current national average at the year 2050
Central	- Paddy land conservation	Follows the past land use interaction Decreasing rate of 1.5 % in paddy land, bigger-smaller pattern of decreasing to become zero (0) at the year 2010
South	Increasing para-rubber productivity	Follows the past land use interaction Productivity increase in the rate of 15 % per annum, bigger- smaller pattern of increase up to the year 2050

3. Dataset in GKSIM modeling

Land Use Dataset

In 5 land use categories mentioned earlier, the land use dataset at regional level is available in the period of the year 1978 to 1993. In most land use categories can be clarified by their individual characteristics except for the unclassified categories. The unclassified land use is derived from the sum of various micro land uses e.g., transport and other infrastructure, river, pond, lake, unusable land and others. Therefore, the changing pattern of various micro land use types can hardly be explained by a single and oversimplified major land use category.

Dataset in Socioeconomic Driving Forces

The socioeconomic driving forces to explain the way of land use change subject to a time span are the Gross Regional Product (GRP) and the population. To avoid the problem of auto-correlation in simulation modeling, only these two variables are employed. The model assumes that these driving forces have governed the changes of land use subject to the times. The observed data are also available at the same period as land use dataset. The long term and official projection of socioeconomic driving forces is limited. In population, the official projection by regions from National Statistical Office of Thailand (NSO) is available subject to the year 2020. In this study, the projection subject to the year 2050 conducted referring to the trend of NSO's population project. Under official projection of the year 1993-2020, the increasing rate has been declining subject to the time span. Therefore, to resemble such a population trajectory, the population in all regions will be almost stagnant (or zero growth population) at the year 2050.

The GRP of each region is projected in regard with the growth performance of the regions in recent years. To carry out the projection in coincide with national planning system, the projection is made subject to five-year term. GRP's projection is quite arbitrary. It is assumed that a rapid growth experience in the past decades is no longer apparent. During current plan period, the gross domestic product is assumed to increase in an average rate of 3.5 percent per annum, instead of 6 percent as officially projection earlier. The recovery period is assumed to occur during the planning period of the tenth national plan (the year of 2002-2006). Next, the annual increasing rate of increase has diminished from the period of 2007-2011 up to the year 2050.

4. Simulation Modeling

GKSIM Model

The detail explanation of the GKSIM modeling can be found in Gong (1997). Here, only the main characteristics of the model are explained. The structure and mechanism of GKSIM are as follows,

$$x_{i,t+1} = b_i - \Delta_i q_i \left(\frac{b_i - x_{i,t}}{\Delta_i} \right)^{s_i w_{i,t} d_t}$$

$$\sum_{i=1}^{m} x_{i,t+1} = A$$

$$w_{i,t} = \frac{u_i + \sum_{j=1}^{n} \{ |c_{ij,t}| + c_{ij,t} \}}{u_i + \sum_{j=1}^{n} \{ |c_{ij,t}| - c_{ij,t} \}}$$

Where, m: number of the all categories studied,

$x_{i,t}$: land use area of ith category at time t, $i = 1, 2, \cdots, m$

b_i: the maximum value of land use area of ith category

$\Delta_i = b_i - a_i$, a_i are the minimum value of land use area of ith category

$0 < q_i \leq 1$, $s_i > 0$: parameters being determined statistically

A: =*constant*, is the total area of studied region, $d_t > 0$: *coefficient used to hold Equation (3)*

$c_{ij,t} = Ia_{ij} x_j Se_{ij,t}$, Ia_{ij} is the quantified interaction between x_i and x_j, $Se_{ij,t}$ is the quantified influences of socioeconomic factors and particular policies on Ia_{ij} at time t, $i, j = 1, 2, \cdots, m$. u_i :any positive real number, usually being 1. Because $0 \leq (b_i - x_{i,t})/\Delta_i \leq 1$, $s_i w_{i,t} d_t > 0$ and $q_i \leq 1$, we have $a_i \leq x_{i,t+1} \leq b_i$. In addition, if rewriting Equation (3) as

$$\ln\frac{b_i - x_{i,t+1}}{\Delta_i} = \ln q_i + (w_{i,t} d_t \ln\frac{b_i - x_{i,t}}{\Delta_i}) s_i$$

The parameters q_i and s_i can be determined by the least square method, and the model can be tested statistically.

Model Application

In application has two parts. First part deals with the so-called *form matrix* (function $f_{ij}(p_{t-1}, p_t) g_{ij}(e_{t-1}, e_t)$ in GKSIM) to determine the way the population and GRP influences the land use change. This is very important step because the projection of land use pattern come from three basic terms, the correlation coefficient (obtained from land use interaction matrix, so-called *base matrix*) multiply with function $f_{ij}(p_{t-1}, p_t) g_{ij}(e_{t-1}, e_t)$ and with the land area of particular land use. After setting the form matrix which the least error, the *reference land use scenarios* can be obtained since GKSIM adopt the correlation in base matrix (referring the past land use interaction) and then project future land use through the multiplication of projected driving forces (referring form matrix) and land area. The model simulates the land use interaction from the observed dataset (period of 1978-1993). Thus, the model simply assumes that the changing pattern of land use is entirely governed by the trajectory of driving forces and the past performance of land use interaction. The second part deals with the *alternative scenario.* The rate of change is set at the beginning year and the pattern of increase (or decrease) subject to the targeted year is calculated from the formula as follows.

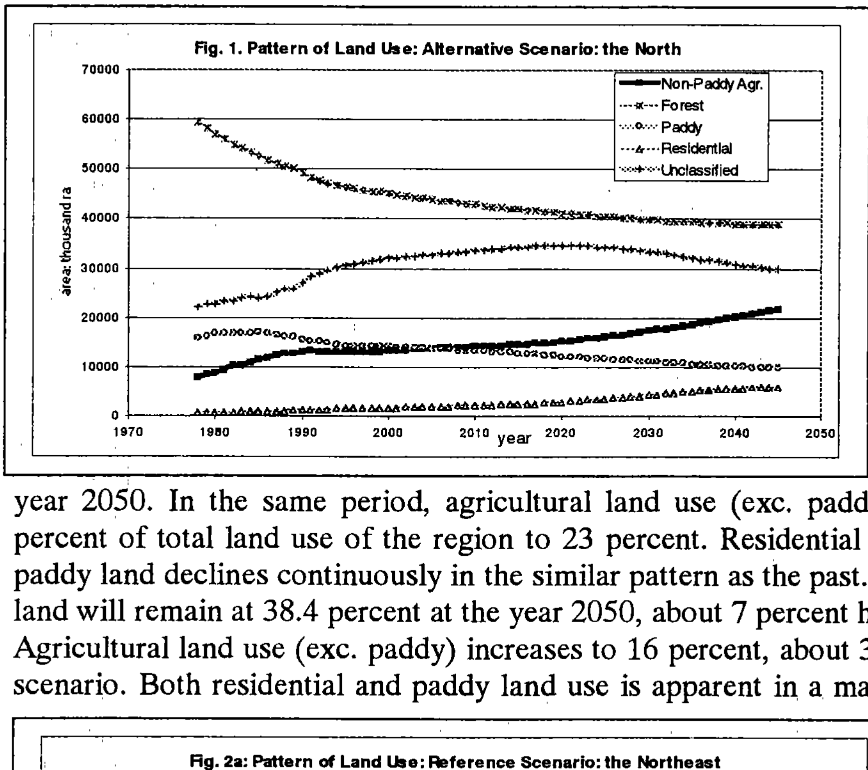
$$h_{ij,t} = k1_{ij}\left\{1 \pm \left(\frac{t - t_0}{t_{d_{ij}} - t_0}\right)^{k2_{ij}}\right\}$$

where, $k1_{ij} > 0$ is the initial value $h_{ij,t}$ gets at initial time, that is, $h_{ij,t} = k1_{ij}$ when $t = t_0$. $k2_{ij} > 0$ and the sign $\pm$ determine the way $h_{ij,t}$ changes after the initial time. If sign - is used, $h_{ij,t}$ becomes monotonous decreasing function of t, and $t_{d_{ij}}$ is the time when interaction, if sign + is used, on the other hand, $h_{ij,t}$ becomes a monotonous increasing function of t, and $t_{d_{ij}}$ is the time when $h_{ij,t}$ is considered to become two times of its initial value, that is, when $t = t_{d_{ij}}$, $h_{ij,t} = 2k1_{ij}$.

Thus, the pattern of change per annum subject to the time (year) can be determined by the amount and the sign $\pm$ of k_1 and k_2. The formula allows to designating either the rate of increase (or decrease) at the beginning year of simulation or the year the running is terminated.

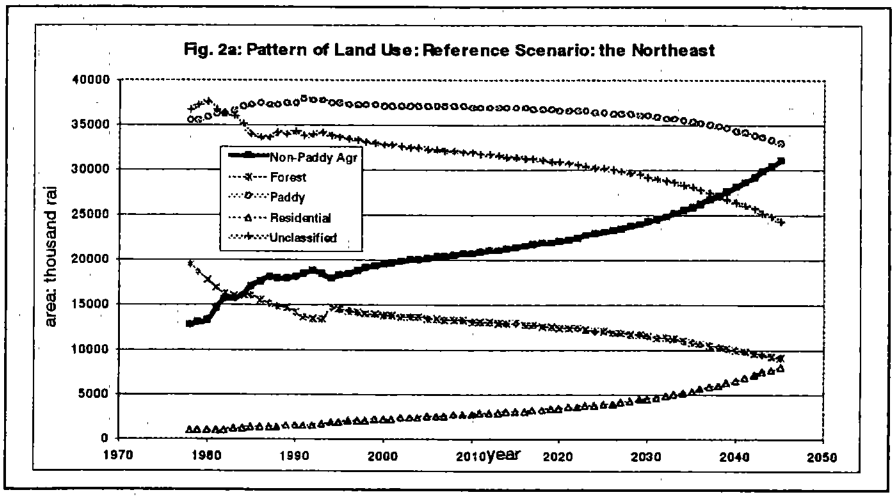
From above formula, the calculation of alternative land use scenario is conducted outside GKSIM. After the first step calculation is made, the results will be taken to reconcile the land use pattern in GKSIM. From the alternative scenarios in Table 5, the forest land of each region has been calculated at the first step by the pre-determined condition of 22 percent forest land at the year 2050. In the Northeast, maintaining the amount of 8.2 mil. tons and the minimum paddy land at the year 2050 can be computed targeting at the alternative goal of yield per acreage, 348 kg per rai, so the productivity rate at the beginning year can be obtained. The Central case is quite simple. The depletion rate of paddy land is set as zero at the year 2010 and the declining rate at the beginning year is 1.5 percent per annum. In the South, the increasing rate of 15 percent per annum at the beginning year is applied with the bigger-to-smaller rate of productivity upgrading.

5. Simulation Results



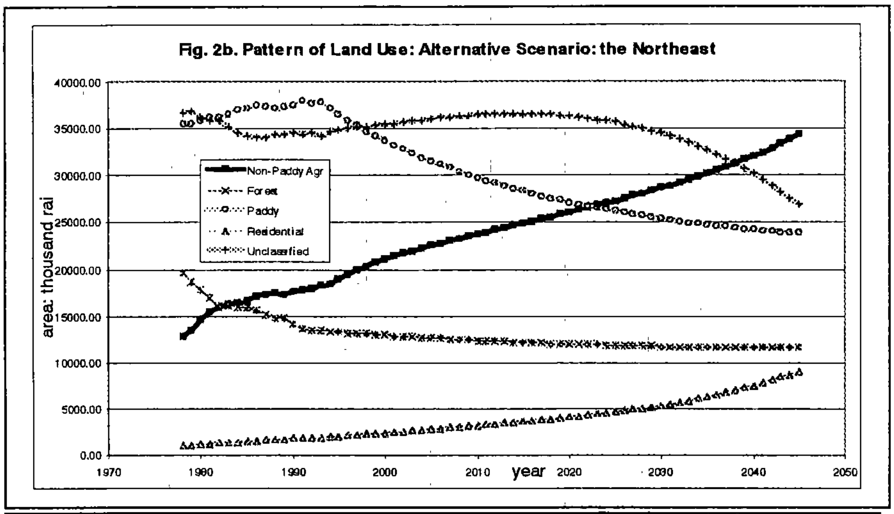
The North

In the Fig 1, the observed land use pattern during the year 1978-1993 is depicted, following by the projection of land use change up to the year 2050. The reference land use scenario shows a decrease trend of forest up to 2050. In the 44 percent of forest in total land at the year 1993, about 31.4 percent will be remained at the year 2050. In the same period, agricultural land use (exc. paddy land) has increased from 12.8 percent of total land use of the region to 23 percent. Residential land use has increased while the paddy land declines continuously in the similar pattern as the past. In the alternative scenario, forest land will remain at 38.4 percent at the year 2050, about 7 percent higher than the reference scenario. Agricultural land use (exc. paddy) increases to 16 percent, about 3.2 percent less than the reference scenario. Both residential and paddy land use is apparent in a marginal change from the reference scenario. This would indicate that most forest is converted to agricultural land. Due to similar patterns of two scenarios are obtained, then only the land use pattern of alternative scenario is shown.

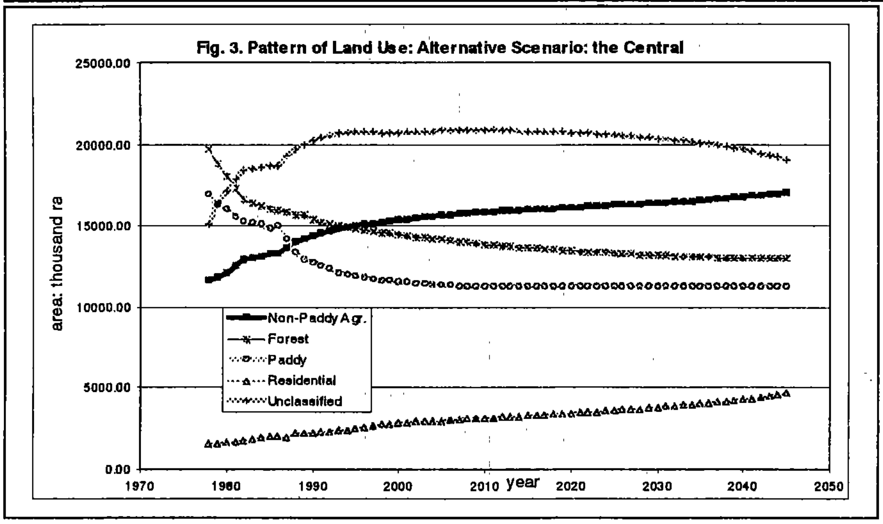


The Northeast

Reference scenario shows a stagnant pattern of paddy from the beginning years of simulation, and paddy land turn a little drop at the later years (Fig. 2a).

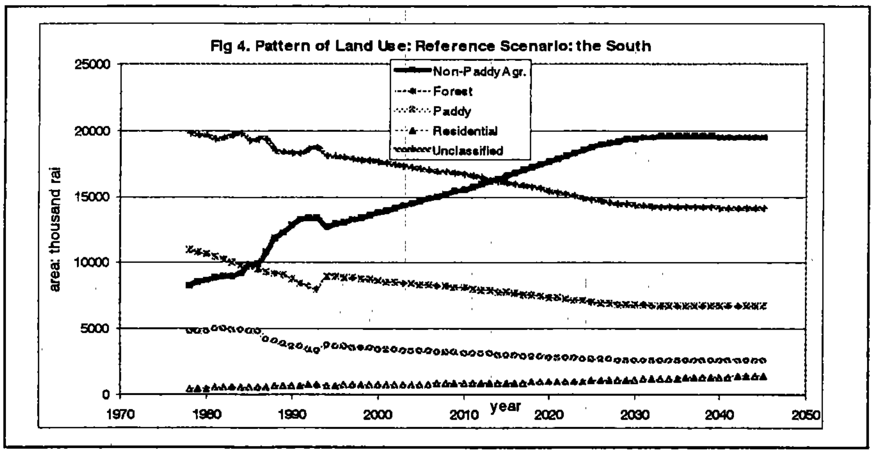


Surprisingly, the projected result is contrast to the pattern in the period of 1980s since paddy land had increased and has stagnated during 1990s. Agricultural land (exc. paddy) has increased continuously. It is seen that lower projected amount than observed data is obtained. Besides, forest land has steadily dropped with a higher projected amount than observed data. In alternative scenario (Fig. 2b), the drastically drop of paddy land as to offset productivity upgrading policy is envisaged. At the year 2050, the amount of paddy land is 22.3 percent of total land use, drops from 37 percent in the year 1993. Forest land has gradually declined and its constitutes about 10 percent of total land use of the region at the year 2050. The drastically dropped of paddy is replaced mainly by agricultural land beyond paddy.



The Central

In the reference scenario, paddy land has declined continuously to constitute about 13.5 percent of total land use at the year 2050, dropped from 18.7 percent at the year 1993. In the same period, forest land has also dropped in parallel with paddy land and constituted about 15.6 percent of total land use, dropped from 23 percent. Agricultural land (exc. paddy) has drastically increased in parallel with residential land. In the alternative scenario, very simple results are obtained when the paddy land stops conversion at the year 2010. Forest land has depleted



in a lesser degree than reference scenario to meet the least amount of national forest. Fig. 3 illustrates the land use pattern of the alternative scenario of the Central.

The South

Fig. 4 illustrates the case of reference scenario where agricultural land (exc. paddy) has tremendously increased to hit double amount at the year 2020. This pattern would largely be governed by a tremendously increase of agricultural land during the year period of 1978-1993. From Fig. 4, the projection of agricultural land exc. paddy is however, lower than the past trend. Forest land has been depleted continuously, so as paddy land. Both categories obtain a higher projected amount than observed data. Residential land has gradually increased subject to a time. In the alternative scenario, the similar land use changing patterns to the reference one are obtained, except for agricultural land (exc. paddy) which has increased in slower rate comparing to the reference one. This result indicates the effect from the policy to prevail the productivity upgrading in rubber plantation to offset the strong expansion of cultivated land. Besides, forest land has depleted in a lesser degree than the reference scenario, as to meet the pre-conditioned forest land of the nation. The figure of alternative scenario is not depicted due to the space limit of the report.

6. Discussions

GKSIM enables to project the pattern of land use change in the future under the limited number of variables of time series dataset. The modeling structure and its mechanism is simple, making ease to be employed to illustrate the trend of land use change at a designated time. Nevertheless, similarly to other simulation models, the projected results usually contain the error terms. Table 6 shows the percentage of differences between projected and observed amount at the year 1993. In some land use categories of particular regions, more than 10 percent differences are resulted. The degree of incurred differences at the beginning year could largely be appreciated at the ended year. The error suppression in the model is not simple task, since the error terms are derived from two components. The first component is the sign ± and the amount of correlation coefficients in base matrix. Despite the sign ± is correct the error suppression is not guaranteed. The second component is the error terms from the construction of form matrix. The amount of correlation is determined in form matrix construction. The relevant form matrix can not easily be obtained reasoned from an abundant combination of matrix derived from the 10! (factorial) combinations of $f_{ij}(p_{t-1},p_t)g_{ij}(e_{t-1},e_t)$ in 5 land use categories. In certain region, for example the North case, the error terms are comparatively lower than other regions. This might be reasoned from its simpler pattern of land use change in the observed dataset comparing to others.

Table 6 Differences between Projected and Observed

Land Use	North	Northeast	Central	South
Forest	4.23	11.53	-11.67	10.53
Non Paddy Ag.	-1.12	-5.55	4.74	-7.90
Paddy	-5.26	-4.32	4.20	3.74
Residential	0.35	1.73	-1.64	-0.70
Unclassified	1.80	-3.39	4.37	-5.67

Moreover, the statistical results of simulation from the log formula in GKSIM do not well coincidence with the erratic projection of particular land uses. Table 7

Table 7 Statistical results of Simulation: Northeast

Land Use	R^2	Intercept	Coef.	Std. Err
Forest	0.984	-0.150	0.715	0.018
Non Paddy Ag	0.983	-0.076	0.705	0.007
Paddy	0.949	-0.474	0.395	0.007
Residential	0.994	-0.012	0.951	0.002
Unclassified	0.933	-0.392	0.591	0.015

shows the vital statistical results from the simulation on the case of Northeast. The results indicate a high explanatory power when highly R^2 and low standard error are obtained in all land use categories. Referring Fig. 2a. and Table 6, the projection on forest land is higher than observed dataset. Meanwhile, the lower projections are clearly envisaged in agricultural land (exc. paddy) and paddy land. This problem may be derived from the independent computation of regression results subject to a single land use category, despite the erratic differences come from the interaction of all land use categories.

7. Concluding Remarks

Despite a certain erratic problem in the applications of GKSIM on the cases of Thailand, the overall performance of land use projection is relatively high with a simple framework and modeling mechanism to tackling with a comprehensive land use interaction. Nevertheless, the model will increase its promising level at least when the problems discussed earlier are solved.

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