Modeling of Urban Land Use Changes: A Case Study of Communities Near Rajamangala University of Technology Thanyaburi

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ABSTRACT

This research has investigated the changes in land use of an area adjacent to a university over the past 30 years to predict the future use of land in the next 5 years (through to the year 2019). The study area is 2,000,000 m^2 (1000 × 2000 m) in size and is located on the east side of Rajamangala University of Technology Thanyaburi (RMUTT) in Thailand's Prathum Thani province. In this research, geographical data were collected and categorized into nine groups by land use types for four different time periods: 20-30 years ago, 10-20 years ago, 5-10 years and the present. This research has ceased at the 30-year mark because the university was first established in the area merely some 30 years ago. The nine land use types are: 1) agricultural area; 2) irrigation canal; 3) roads; 4) wasteland; 5) dormitory/apartment complex; 6) residential housing estate; 7) commercial area; 8) convenience store; and 9) other. The ArcGIS program was deployed to predict the future land use based on the 30-year geographical data. The findings indicate that the existence of the university has contributed to a constant influx of non-resident students and workers to the area and the subsequent sprawling residential housing projects and basic services. This necessitates the conversion of agricultural farmlands into other developments and thereby a steady decline of agricultural areas. The area also suffers from traffic jams, environmental degradation, and higher cost of living. Thus, the future planning and management of land use near or around a large educational institution must take into an account the subsequent rapid growth of the community in close proximity to the institution and its ramifications.

Keywords: GIS/ Urban growth simulation /Land use pattern/ Simulation
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1. INTRODUCTION

It is estimated that by the year 2030 metropolitan areas will be home to roughly 60% of the world's population. According to Glebova and Khabibrahmanova (2014), the migration of rural populations to large cities is one factor that contributes to overcrowding in the cities and other related problems, e.g., environmental degradation and low quality of life. The urban environmental problems directly affect dwellers of the metropolitan areas (Su et al., 2015). Since, the cities are centres of economic development where labour, resources, communications and other services are concentrated, private buildings and investments thus densely populate the urban areas. According to Aulia and Ismail (2013), the economic development could have both positive and negative impacts on societies and the environment.

Urban growth requires the construction of more basic infrastructure, e.g., utilities, transportation in response to the needs of the increasing number of dwellers. Furthermore, the urban growth increases commercial and industrial activities, and small traditional residential units are converted into large building complexes, e.g., large apartments and facilities that are more common in large cities. In addition, some spatial changes are attributed to the environment, such as natural disasters or the use of natural resources (Pilon et al., 1988; Muttitanon and Tripathi, 2005). The expansion of urban areas, if improperly implemented, thus results in the environmental degradation and pollution.

The collection of terrestrial data to analyse the spatial extent of growth, especially the development of areas around educational institutions, is an integral part of planning for effective future land use; and at the same time helps identify potentially serious problems. According to Hegazy and Kaloop (2015), a spatial analysis of growth would be of great benefit if it is proactively incorporated in both area management and the direction of future development. In addition, feasibility studies should be a vital part in the planning of urban area development projects to prevent or mitigate the environmental impacts caused by rapid urban development. In collecting terrestrial data, the geographic information system (GIS) is a useful tool for capturing the positional data for subsequent policy planning with regard to area development programs (Lee et al., 1998; Frenkel and Orenstein, 2012).

In particular, the use of GIS, by which various stakeholders can participate in the decision-making and setting the direction for future development (Hessel et al., 2009), is a most effective tool to assess environmental impacts at the community level (Shalaby and Tateishi, 2007). According to Malczewski (2004), GIS can be a useful tool for assessing the impacts of policies, planning, and programs associated with private investments and government infrastructure projects. Furthermore, Liu and

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Yang (2015) have established a GIS database that can be applied to evaluating and analysing future development trends in various community types.

2. METHODOLOGY

This empirical research has utilized the area mapping and field survey techniques. The study area is 2,000,000 m^2 (1000 x 2000 m) in size and located on the west side of Rajamangala University of Technology Thanyaburi (RMUTT). The north and east sides of the university are water reservoirs (monkey's cheeks) while the south side is situated the provincial government complex. The study area is partitioned according to a scale of 1:500, thus resulting in 4,230 grids with each grid measuring 20 x 20 m (Figure 1). In predicting the future land use, this research has utilized the quantitative forecasting method.

The reasons this current research has focused on this particular area are that it is adjacent to RMUTT, consistent with one of the research aims of examining changes in land use of the area near an educational institution; and that it has the highest population density. Besides, beyond the area under investigation are sparsely populated farmlands.

In the collection of geographical data, the area was first equally divided into zones A, B and C (Figure 1). Three 15-member teams were then recruited and trained prior to assignment to either zone to carry out the survey. Originally, at the behest of King Rama V, the study area was set aside for agricultural use. Thus, if a given grid or group of grids is not farmlands, e.g., a dormitory, housing estate, the surveyors would then inquire (or interview) the owner or local residents for the age of the construction and history of the land use. The information on the building age is useful in determining the changes in land use and the pace.

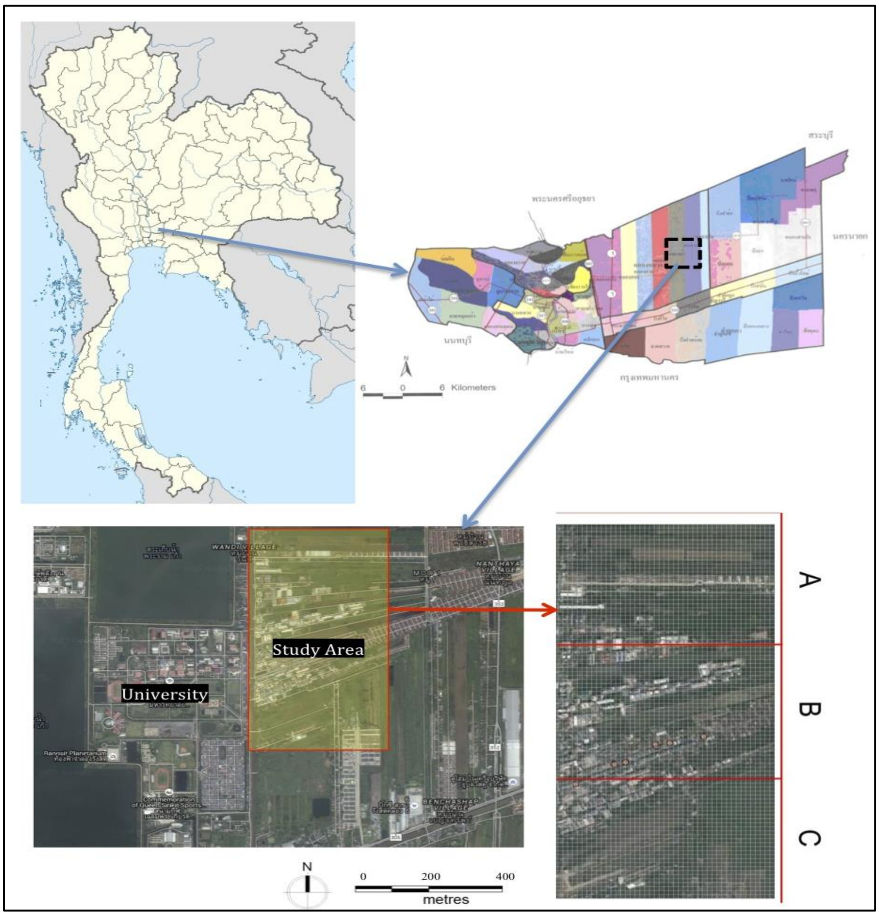

Figure 1. The country and locality maps of the study area and its surroundings

The collected data are as follows: 1) the specific localities and addresses; 2) the age of the construction and land use type, e.g., agricultural area, irrigation, dormitory/apartment complex, convenience store, etc.; and 3) the interview information with regard to the prior land use for non-agricultural uses.

The geographical data were then categorized into nine groups according to land use types for four different time periods: 20-30 years ago, 10-20 years ago, 5-10 years and the present. The reason this current research has ceased at the 30-year mark is that the university was first established in the area merely some 30 years ago. For the nine land use types, they are: 1) agricultural area; 2) irrigation canal; 3) roads; 4) wasteland; 5) dormitory/apartment complex; 6) residential housing estate; 7) commercial area; 8) convenience store; and 9) other.

3. RESULTS AND DISCUSSION

Figure 2 illustrates the land use types for the four different periods using the ArcGIS program based on the collected geographical survey/interview data. It could be observed that the changes in geography over the past 30 years are evident and radical. The use of land for residential purposes and basic infrastructure and services, e.g., roads, retail outlets, increased considerably at the expense of agricultural areas. In addition, the division of land and the layout of roads in a west-east straight-horizontal-line fashion indicate that the area was originally intended for agricultural use (Thanwiset, 2014). Interestingly, there are no north-south public secondary or tertiary access roads linking between the west-east thoroughfares due to various private ownerships of the land plots along different west-east roads.

In Figure 2, in the 20-30 years ago period, most areas were greeneries or agricultural areas, accounting for approximately 80% of the total area. Nevertheless, a mere 50% of the total area currently remains dedicated to agriculture. Based on the geographical survey data, the amount of green space is expected to decrease to 40% in the near future because of new construction in the area. In particular, new construction of residential housing projects, which subsequently results in new commercial buildings, convenience stores, and transportation routes, will significantly contribute to this decrease.

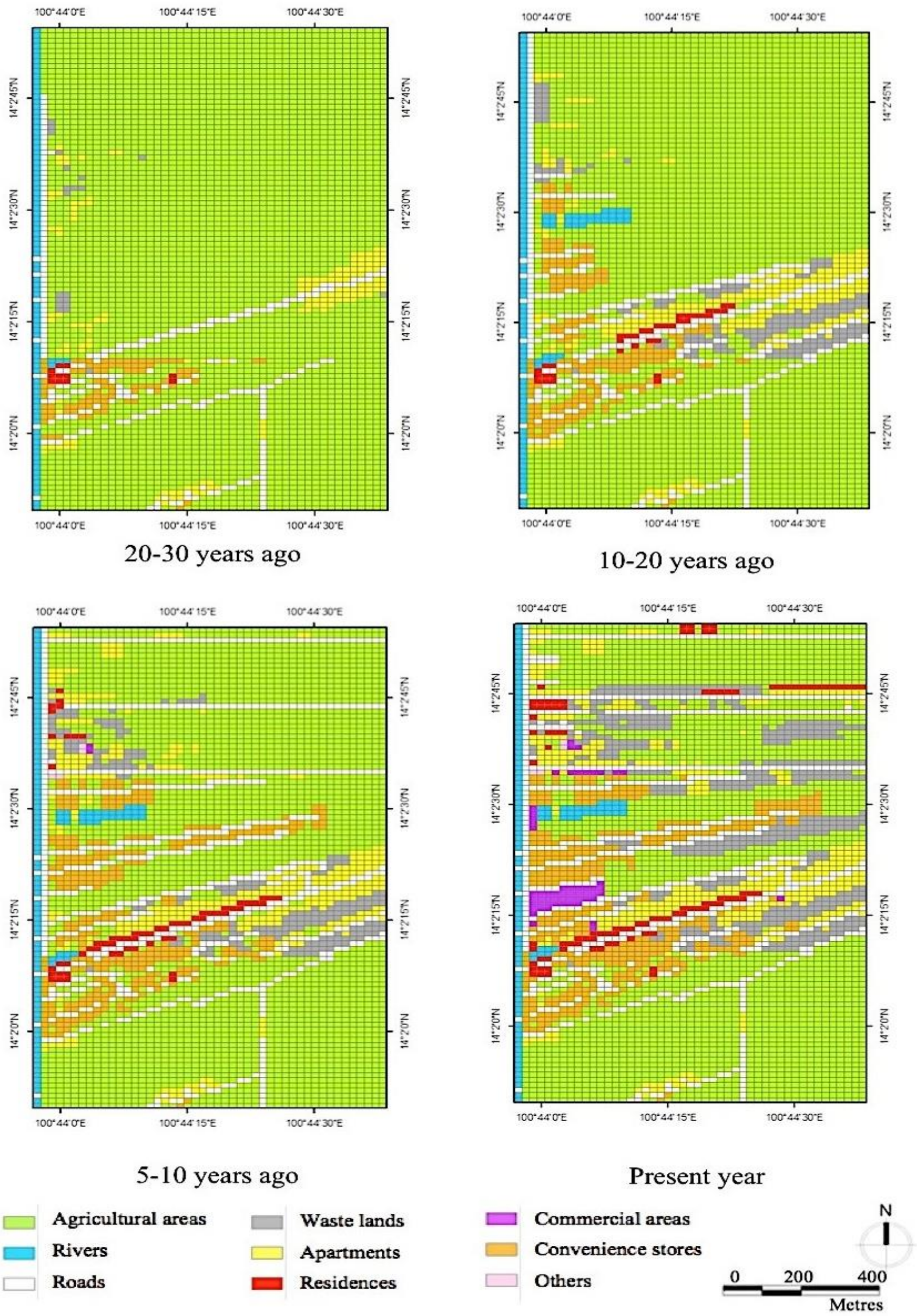

Figure 2. The average amount of operational waste per month over seven years

Table 1 tabulates the proportions in the percentage of land use by type during the past 30 years and the predicted future land use. In this research, the past geographical data were plotted to observe the trend, revealing a straight line. The trend line was determined using the two-point method, giving the following predictive equation:

$$\hat{Y} = Y_1 + b(X_i - X_1)$$

Where $\hat{Y}$ is the forecasting value and Y_1, Y_2 are the data at point 1 and 2. X_1, X_2 are the time at point 1 and 2 (A.D.). X_i is the time used to determine trend value (A.D.). b is the slope of the forecasting equation, where

$$b = \frac{Y_2 - Y_1}{X_2 - X_1}$$

The agricultural area $(X_1,Y_1) = (1989, 86.5)$ and $(X_2,Y_2) = (2014, 49.5)$

$$b = \frac{Y_2 - Y_1}{X_2 - X_1} = \frac{49.5 - 86.5}{2014 - 1989} = -1.48$$

Thus, the forecasting equation is:

$$\hat{Y} = 86.5 - 1.48\,(X_i - 1989)$$

Thus, to forecast the amount of land remaining for agricultural purposes over the next five years (through to 2019), the forecasting equation and the estimate are as follows:

$$\begin{aligned}\hat{Y} &= 86.5 - 1.48\,(2019 - 1989)\\ &= 86.5 - 44.4\\ &= 42.1\end{aligned}$$

Table 1. Proportions of land use types (in %) in the study area in the past and the predicted future land use

Land use	1984-1994	1994-2004	2004-2009	2014	2019	2024	Forecasting equation
Agricultural areas	86.5	72.7	62.2	49.5	42.1	34.7	Y= 86.5-1.48x
Irrigation canal	2.1	2.8	2.8	2.8	2.94	3.08	Y= 2.1+0.03x
Roads	5.4	8.9	13.7	15.4	17.4	19.4	Y= 5.4+0.40x
Waste lands	0.5	3.9	4.6	10.8	12.86	14.92	Y= 0.5+0.41x
Apartments	3.2	5.8	7.4	8.4	9.44	10.48	Y= 0.5+0.21x
Residences	2.1	5	7.8	9.5	10.98	12.46	Y= 2.1+0.30x
Commercial areas	0.2	0.8	1.4	2.2	2.6	3.0	Y= 0.2+0.08x
Convenience stores	0	0	0	1.3	1.56	1.82	Y= 0.05x
Other	0	0	0.1	0.1	0.12	0.14	Y= 0.004x

Figure 3 compares the proportions in the percentage of land use by type for the past three periods (20-30, 10-20, 5-10 years prior), the present and the future. As illustrated, the agricultural areas steadily decrease, while other forms of development continue to increase, particularly the residential housing estates, dormitories/apartments, roads and commercial areas. The wasteland area also increases, following the normal cycle of the land use conversion in which farmlands, i.e., land for agricultural purposes; are acquired by property developers and then left unutilized for a certain time period prior to development. The unutilized farmlands are naturally transformed into wilderness or wasteland. The wasteland is however anticipated to decrease once the development begins.

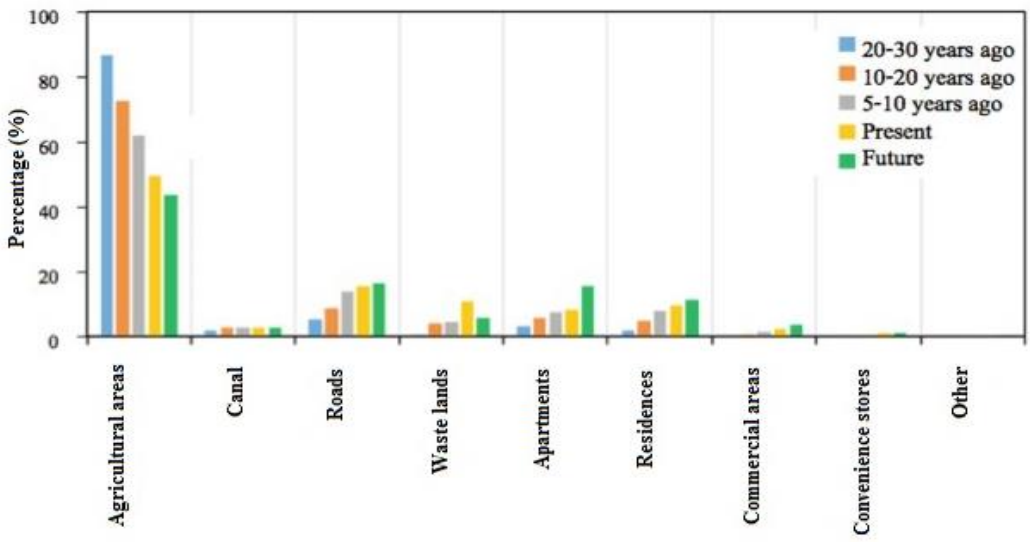

Figure 3. The proportions in percentage of land use by type for the past three periods, the present and the future

Figure 4 illustrates the trends of development and land use of the area under study. To predict the future use of land for the various land use types, this research has utilized the linear regression analysis: y = mx + c, where m is the and observation of the land-usage plans of the slope calculated from $(Y_2 - Y_1) / (X_2 - X_1)$. In addition, data from other previous studies, survey, landowners and government agencies involved in infrastructure development were used to predict the future land use.

Figure 5 depicts the simulated future land use of the area under investigation 5-10 years forward. It shows a significant decline in the agricultural areas with the largest negative slope (Y = 10.929x + 95.651), indicating the fastest change in land use. This is followed by, based on their respective slope values, the construction of roads, dormitory/apartments, residential housing estates, wastelands (tend to decrease in the future), commercial areas and buildings, and convenience stores. In addition, in Figure 5, based on the geographical data from the past 30 years to the present, the study area is limited in its ability to expand (grow) because the area's west side is confined to an irrigation canal (Figure 1). This results in a linear land allocation and transportation routing. The migration of non-residents into the area also contributes to the rise in the demand for housing, causing a linear expansion of tall buildings. Moreover, the study area is densely populated based on the number of populations per square metre, resulting in vertical expansion characterized by the construction of multi-storied residential buildings because of the limited space.

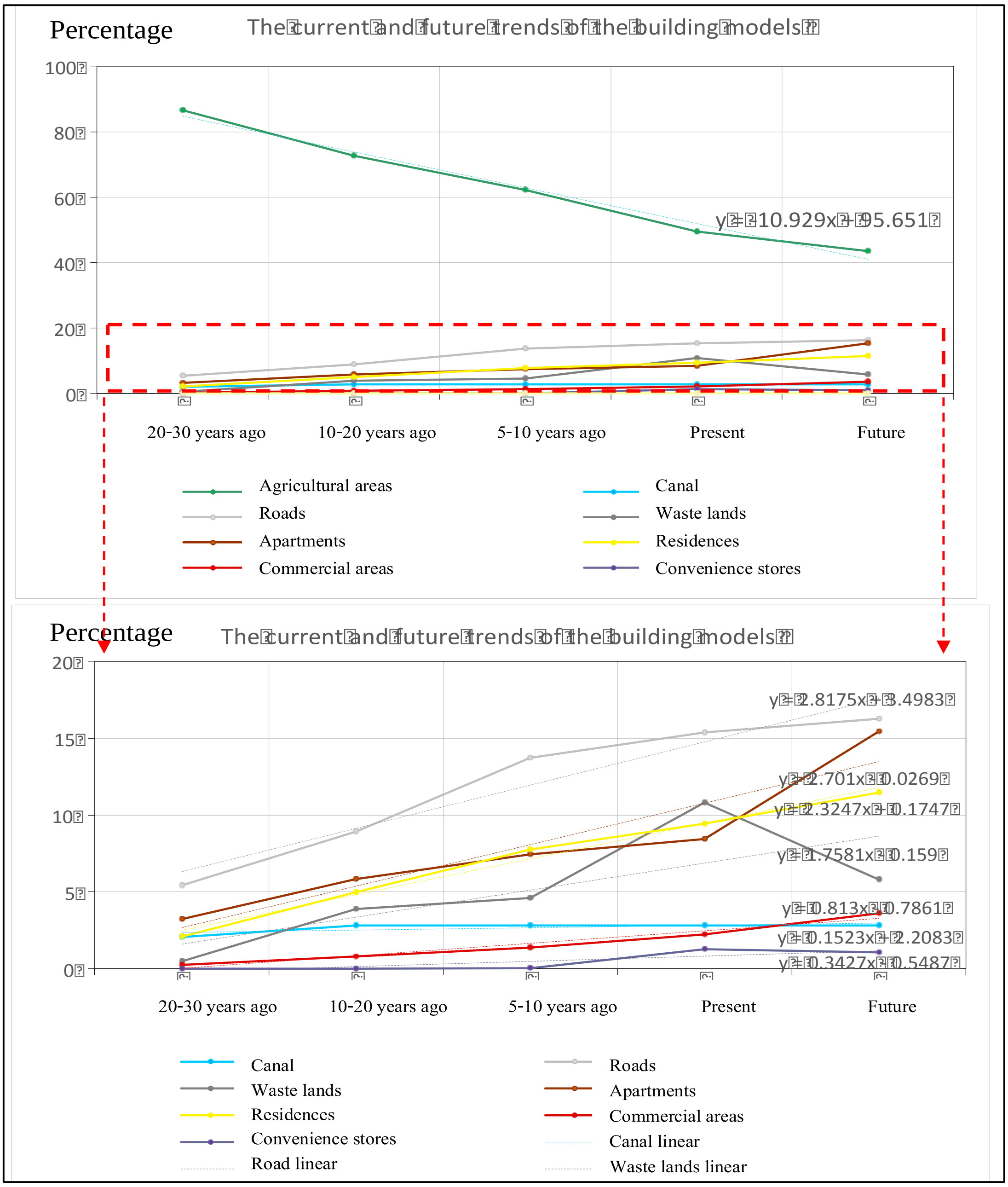

Figure 4. The current patterns and future trends in space utilization by land use types

The traffic in and around the study area is very dense due to its proximity to Rajamangala University of Technology Thanyaburi (RMUTT). In addition, the popular mode of transportation in the study area is a wide range of private cars. According to Thanwiset (2013), non-residents, i.e., from other areas or provinces) who come to study at the university or work in the area constitute a significant bulk of the population and is the main cause of the community sprawl. The rapid population increase also causes overcrowding and traffic jams, which subsequently contribute to air pollution, an unsightly landscape, and increased traffic-related accidents. The findings are consistent with Santitham (2005), who concluded that the effective planning of transportation systems can reduce environmental problems, especially in the areas around a campus.

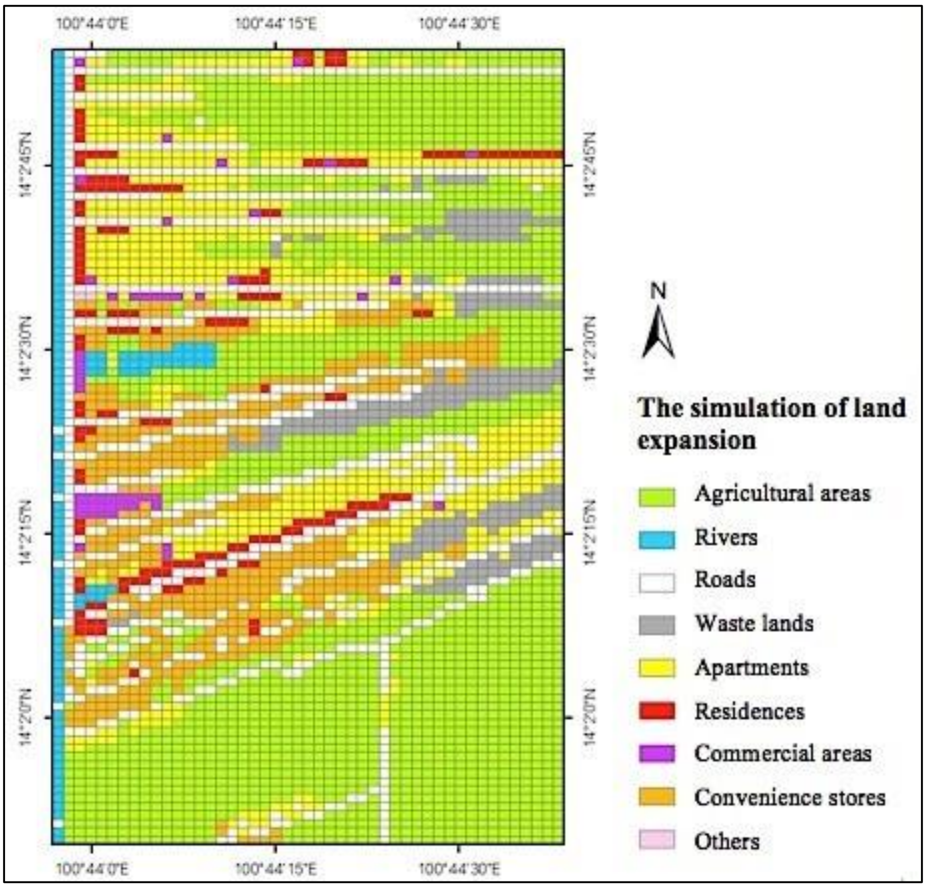

Figure 5. The predicted land utilization by land use types of the study area in the next 5-10 years

The fact that one side of the study area (the west side) is "walled off" by a major irrigation canal has severely limited the road expansion to accommodate additional traffic, resulting in traffic chaos and increased road casualties. In addition, the absence of north-south secondary or tertiary access roads connecting between different west-east thoroughfares compounds the traffic problem in the area. This could be attributed to the lack of urban planning and misuse of the land because this area was originally set aside, during the reign of King Rama V, for agricultural use and thereby was divided into patches of farmlands (Thanwiset, 2014). Nevertheless, the establishment of the university has brought about the rapid and unregulated transformation of agricultural land into residential areas and infrastructure and the eventual traffic problems. This finding is consistent with Shafizadeh-Moghadam and Helbich (2015), who reported that the use of resources for building and facility development has both direct and indirect impacts, including pollution, traffic jams, crime, migration, various pollution-related diseases, and changes in land use. Currently, a significant proportion of the land in the study area has been acquired by either land speculators or real estate developers, so it could be expected with certainty that the amount of land dedicated to agriculture would be further reduced.

4. CONCLUSIONS

This spatial study has revealed that the area under investigation in the past was either greeneries or agricultural farmlands. Nevertheless, the presence of the university and the subsequent influx of non-residents to study or work have contributed to the sprawling residential housing projects and basic services in response to the community growth. This necessitates the conversion of agricultural farmlands into other developments, e.g., residential units, commercial buildings. The findings also indicated that new constructions for residential and commercial purposes steadily increase at the expense of agricultural areas; and that the area suffers from a variety of man-made problems, ranging from traffic jams, environmental degradation, pollution, higher cost of living in unsafe neighbourhoods. Thus, the future planning and management of land use near or around a large educational institution must take into consideration the ensuing rapid growth of the community in close proximity to the institution and the ramifications of the development. This research also indicated that the population in the study area are mostly non-residents, a condition that could lead to a loss of identity indigenous to the area; and that, as the agricultural land is converted to other uses, the local residents, in particular, agriculturists, risk the permanent loss of their traditional livelihoods.

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