แบบจำลองรูปแบบการเจริญเติบโตของเมืองและการคาดการณ์คุณภาพชีวิต ในอำเภอเมืองนครราชสีมา

นางสาวอภิรดี สรวิสูตร

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต
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URBAN GROWTH PATTERN MODELING AND QUALITY OF LIFE PREDICTION IN MUEANG NAKHON RATCHASIMA DISTRICT

Apiradee Saravisutra

A Thesis Submitted in Partial Fulfillment of the Requirements for the

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URBAN GROWTH PATTERN MODELING AND QUALITY OF LIFE PREDICTION IN MUEANG NAKHON RATCHASIMA DISTRICT

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การศึกษาแบบจำลองรูปแบบการเจริญเติบโตของเมืองและการคาดการณ์คุณภาพชีวิตในอำเภอเมืองนครราชสีมา มีวัตถุประสงค์คือ (1) ประเมินการใช้ประโยชน์ที่ดินและการเปลี่ยนแปลงการใช้ประโยชน์ที่ดิน รูปแบบการเจริญเติบโตของเมืองและปัจจัยแรงขับเคลื่อน (2) การประเมินความเหมาะสมแบบจำลองการเจริญเติบโตของเมือง (3) การประเมินดัชนีชี้วัดคุณภาพชีวิต และ (4) การคาดการณ์คุณภาพชีวิตและการเปลี่ยนแปลงคุณภาพชีวิต

ในการจำแนกการใช้ประโยชน์ที่ดิน อาศัยการแปลตีความภาพถ่ายอากาศ ปี พ.ศ. 2529 2537 และ 2545 ด้วยสายตา เพื่อจำแนกประเภทการใช้ประโยชน์ที่ดินตามระบบการจำแนกการใช้ประโยชน์ที่ดินของกรมพัฒนาที่ดิน ซึ่งประกอบด้วย พื้นที่ชุมชนและสิ่งปลูกสร้าง พื้นที่เกษตรกรรม พื้นที่ป่าไม้ แหล่งน้ำ และพื้นที่เบ็ดเตล็ด และนำผลที่ได้รับไปประเมินการเปลี่ยนแปลงการใช้ประโยชน์ที่ดิน รูปแบบการเจริญเติบโตของเมืองและปัจจัยแรงขับเคลื่อน ผลการศึกษาพบว่า ประเภทการใช้ประโยชน์ที่ดินหลักและรอง ปี พ.ศ. 2529 2537 และ 2545 ได้แก่ พื้นที่เกษตรกรรม และพื้นที่ชุมชนและสิ่งปลูกสร้าง ตามลำดับ และพบว่า ในระหว่างปี พ.ศ. 2529-2545 มีพื้นที่เกษตรกรรมและพื้นที่เบ็ดเตล็ดบางส่วนเปลี่ยนแปลงเป็นพื้นที่ชุมชนและสิ่งปลูกสร้าง ในการศึกษารูปแบบการขยายตัวของเมืองพบว่าใน 3 ช่วงเวลา (ระหว่างปี พ.ศ. 2529-2537 พ.ศ. 2537-2545 และ พ.ศ. 2529-2545) พื้นที่เมืองขยายตัวในทุกทิศทาง และส่วนใหญ่เกิดขึ้นภายในรัศมี 500 เมตรจากพื้นที่เมืองเดิม สำหรับปัจจัยขับเคลื่อนการเจริญเติบโตของเมืองใน 3 ช่วงเวลา ได้แก่ พื้นที่เกษตรกรรม พื้นที่เบ็ดเตล็ด ระยะทางเข้าถึงพื้นที่เมือง พื้นที่ป่าไม้ และพื้นที่ชุมชนและสิ่งปลูกสร้าง จากข้อมูลปีเริ่มต้นของแต่ละช่วงเวลา จากผลที่ได้รับบ่งชี้ว่า การขยายตัวของเมือง เกิดจากการเปลี่ยนแปลงการใช้ประโยชน์ที่ดินที่ถูกผลักดันโดยการพัฒนาทางด้านเศรษฐกิจและสังคม

ในการประเมินความเหมาะสมแบบจำลองการเจริญเติบโตของเมือง เริ่มต้นด้วยการนำแบบจำลองเซลลูลาออโตมาตา-มาร์คอฟและการวิเคราะห์สมการถดถอยโลจีสติค ไปคาดการณ์การเจริญเติบโตของเมืองในปี พ.ศ. 2545 จากนั้น นำผลที่ได้รับไปประเมินความถูกต้องกับพื้นที่ชุมชนและสิ่งปลูกสร้างในปี พ.ศ. 2545 ที่ได้จากการแปลตีความภาพถ่ายทางอากาศ แบบจำลองที่ให้ความถูกต้องสูงกว่าจะถูกนำไปใช้ในการคาดการณ์การเจริญเติบโตของเมืองในปี พ.ศ. 2553 และ

พ.ศ. 2561 จากผลการศึกษาพบว่า แบบจำลองเซลลูลาออโตมาตา-มาร์คอฟ ให้ค่าความถูกต้องโดยรวมและค่าสัมประสิทธิ์ของความสอดคล้องแคปปาสูงกว่าแบบจำลองการวิเคราะห์สมการถดถอยโลจีสติค และถูกนำไปใช้ในการคาดการณ์การเจริญเติบโตของเมืองในปี พ.ศ. 2553 และ พ.ศ. 2561

ในการประเมินดัชนีชี้วัดคุณภาพชีวิต นำข้อมูลการรับรู้จากระยะไกล เศรษฐกิจและสังคม และความจำเป็นพื้นฐานไปใช้ในการวิเคราะห์ปัจจัย เพื่อประเมินดัชนีชี้วัดคุณภาพชีวิต และจัดสร้างสมการคุณภาพชีวิตโดยการวิเคราะห์สมการถดถอย ในการศึกษาครั้งนี้พบว่า การวิเคราะห์ปัจจัยสามารถจัดกลุ่มตัวแปร 23 ตัวแปรได้ 7 ปัจจัย ประกอบด้วย (1) สุขภาพดี มีการศึกษา และมีค่านิยมไทย (2) การมีบ้านอาศัย (3) การมีส่วนร่วมในชุมชน (4) ความหนาแน่นของประชากรและจำนวนครัวเรือน (5) รายได้ (6) สิ่งแวดล้อม และ (7) ความปลอดภัยและการมีเงินออม จากนั้นนำปัจจัยที่มีนัยสำคัญไปสร้างดัชนีชี้วัดคุณภาพชีวิต และคำนวณสมการคุณภาพชีวิตสำหรับประเมินคุณภาพชีวิตในปี พ.ศ. 2551 และคาดการณ์คุณภาพชีวิตในปี พ.ศ. 2553 และ พ.ศ. 2561 และนำผลที่ได้รับไปใช้ในการวิเคราะห์การเปลี่ยนแปลงคุณภาพชีวิตที่เกิดขึ้น จากการศึกษา พบว่า ในระหว่างปี พ.ศ. 2551-2553 มีหมู่บ้านที่มีคุณภาพชีวิตสูงกว่าเดิม 58 หมู่บ้าน เหมือนเดิม 165 หมู่บ้าน และต่ำกว่าเดิม 13 หมู่บ้าน และในระหว่างปี พ.ศ. 2551-2561 มีหมู่บ้านที่มีคุณภาพชีวิตสูงกว่าเดิม 40 หมู่บ้าน เหมือนเดิม 171 หมู่บ้าน และ ต่ำกว่าเดิม 25 หมู่บ้าน

สาขาวิชาการรับรู้จากระยะไกล	ลายมือชื่อนักศึกษา อภิวงศ์ สมใจสอง
ปีการศึกษา 2553	ลายมือชื่ออาจารย์ที่ปรึกษา
	ลายมือชื่ออาจารย์ที่ปรึกษาร่วม

APIRADEE SARAVISUTRA : URBAN GROWTH PATTERN MODELING AND QUALITY OF LIFE PREDICTION IN MUEANG NAKHON RATCHASIMA DISTRICT. THESIS ADVISOR : ASST. PROF. SUWIT ONGSOMWANG, Dr. rer. nat. CO-ADVISOR : ASST. PROF. SUTHINEE DONTREE, Doctorat de 3eme Cycle. 213 PP.

URBAN GROWTH MODELING/ CA-MARKOV AND LOGISTIC REGRESSION MODEL/ ASSESSMENT AND PREDICTION OF QUALITY OF LIFE (QOL)

The main objectives of the study on urban growth pattern modeling and quality of life prediction in Mueang Nakhon Ratchasima district are: (1) to assess land use and its change and to identify urban growth pattern and its driving force, (2) to identify an optimum method for urban growth model, (3) to assess quality of life index, and (4) to predict quality of life and its change.

Aerial photographs in 1986, 1994, and 2002 were firstly visually interpreted for major land use types of Land Development Department classification system. These results were then analyzed for land use change, urban growth pattern and its driving force. It was found that major and minor types of land use in 1986, 1994, and 2002 were agricultural land and urban and built-up area, respectively. Some agricultural land and miscellaneous land were converted to urban and built-up area between 1986 and 2002. For urban expansion, it was found that most of urban expansion in three periods (1986-1994, 1994-2002, and 1986-2002) was taken place in all direction within equidistance zone of 500 meter. The most important driving force for urban growth were agriculture land, miscellaneous land, distance to urban area, forest land

and urban and built-up area from beginning year of two dates. These results indicate that the urban expansion was driven spontaneously and naturally by socio-economic development such as land use change.

For assessment of an optimum urban growth models: CA-Markov and logistic regression models were firstly used to predict the urban growth in 2002 and then their results were compared with interpreted urban and built-up area in 2002 to identify an optimum model for urban growth prediction. It was found that CA-Markov model provided higher overall accuracy and Kappa coefficient of agreement than logistic regression model and it was selected for urban growth prediction in 2010 and 2018.

For QOL assessment, remotely sensed data, socioeconomic and Basic Minimum Need data were used to analyze for QOL index by factor analysis and to predict synthetic QOL equation by regression analysis for assessment and prediction of QOL. In this study, 23 extracted variables were divided into 7 factors by factor analysis include (a) health, education, and cultural values, (b) housing, (c) participation, (d) crowdedness, (e) income, (f) environment quality, and (g) safety and saving. After that, significant variables were used to create quality of life index and to calculate synthetic QOL equation for QOL assessment in 2008 and prediction in 2010 and 2018. These results were used to analyze QOL change. There were 58, 165, and 13 villages having better, the same and poorer QOL, respectively from 2008 to 2010. There were 40, 171, and 25 villages having better, the same and poorer QOL, respectively from 2008 to 2018.

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Co-advisor's Signature Anthinee Dontree

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LIST OF ABBREVIATIONS

ANN	=	Artificial Neural Network
AGR	=	Annual urban growth rate
BMN	=	Basic Minimum Need
°C	=	Celsius
CA	=	Cellular Automata
CA-Markov	=	Cellular Automata and Markov Model
CBD	=	Central Business District
CCI	=	Consumer Confidence Index
CDC	=	Centers for Disease Control and Prevention
CIA	=	Central Intelligence Agency
CDD	=	Community Development Department
Com-QOL	=	Cummins' Comprehensive Quality of Life Scale
DN	=	Digital Number
ETM+	=	Enhance Thematic Mapper Plus
GCP	=	Ground control point
GDP	=	Gross Domestic Product
GIS	=	Geographic Information System
GISTDA	=	Geo-informatics and Space Technology Development Agency (Public Organization)
GPI	=	Genuine Progress Index

LIST OF ABBREVIATIONS (Continued)

GPP	=	Gross Provincial Product
GPS	=	Global Positioning System
HDI	=	Human Development Index
HLE	=	Happy Life-Expectancy Scale
IEWB	=	Index of Economic Well-Being
ISP	=	Index of Social Progress
km	=	Kilometer
KMO	=	Kaiser-Meyer-Olkin
LCI	=	Living Conditions Index
LDD	=	Land Development Department
LULC	=	Land Use and Land Cover
MA	=	Multi-agent
MSA	=	Measuring of Sampling Adequacy
Moran’s I	=	Moran's autocorrelation coefficient
NASA	=	National Aeronautics and Space
NESDB	=	National Economic and Social Development Board
NDVI	=	Normalized Difference Vegetation Index
PCA	=	Principal Component Analysis
QOL	=	Quality of Life
RMS	=	Root Mean Square
ROC	=	Relative Operating Characteristic
RS	=	Remote Sensing

LIST OF ABBREVIATIONS (Continued)

SDI	=	Sustainable Development Indicators
SPOT	=	Satellites Pour l'Observation de la Terre
sq. km	=	Square Kilometer
SUT	=	Suranaree University of Technology
TM	=	Thematic Mapper
UN	=	United Nations
US	=	United States
XS	=	Multispectral
WHOQOL	=	World Health Organization Quality of Life

CHAPTER I

INTRODUCTION

1.1 Significant of the problem

According to the area, Nakhon Ratchasima is the biggest province in Thailand and owing to the number of population, it is the second province after Bangkok, with population of 2,565,117 in 2008 (Department of Provincial Administration, Online, 2009b). The municipality of Nakhon Ratchasima was upgraded to a city municipality in 1995 as its population exceeded 50,000 (Nakhon Ratchasima City Municipality, Online, 2009). At present, Mueang Nakhon Ratchasima district becomes a fast-growing urban area with rapid population growth. According to the Department of Provincial Administration statistics, in 2002, about 7.51% of Mueang Nakhon Ratchasima district's population lived in the municipality area and this proportion increased to 9.44% in 2008 (Department of Provincial Administration, Online, 2009b).

The population increase indicates that this district became much more populous and this should be the main factor of urbanization and land use change (Knox, 1994; Seto, Woodcock, Song, Huang, Lu, and Kaufmann, 2002). There are many studies on land use/land cover change related to global change, or global warming as these human activities have affected climate and ecosystem (López, Bocco, Mendoza, and Duhau, 2001). During recent decades, many researches have focused on urban land use changes (Shenghe, Prieler, and Xiubin, 2002; Xiao, Shen, Ge, Tateishi, Tang, Liang, and Huang, 2006) because urban ecosystem are strongly affected by human activities and they have close relation with the life of almost half of the world's population (Stow and Chen, 2002). Many issues concerning spatial and temporal modelling of land use conversion were studied to explain the causes and consequences of land use changes (Muller and Middleton, 1994; Brown, Pijanowski, and Duh, 2000; Irwin and Geoghegan, 2001; Veldkamp and Lampin, 2001; Bürgi, Hersperger, and Schneeberger, 2004).

In the meantime, urban quality of life is a relatively new urban issue that gained notoriety by initiating new forms of environmental rules and regulations and introduced alternative strategies and tactics to mainstream environmentalism. Furthermore, urban quality of life has become a major focus for planners, funding agencies, and local communities (Jensen, Gatrell, Boulton, and Harper, 2004). Besides, improving quality of life becomes one of the most important goals of public policies (Santos and Martins, 2007). In Thailand, Department of Community Development has collected the Basic Minimum Need (BMN) dataset for quality of life measurement of Thai citizens. In fact, BMN is household information for quality of life in different aspects to define people's living standard to live happily in a society (Community Development Department, Online, 2008).

Recent urban studies have integrated techniques, such as geographic information system (GIS) and remote sensing with socio-economic data, to analyze observed urban conditions, and improvement of quality of life (Lo, 1997; Lo and Faber, 1997; Jensen et al., 2004; Jun, 2006; Li and Weng, 2007). Herewith in this study, four main subjects: land use change, urban growth model, assessment of quality of life, and urban growth impact to quality of life will be investigated.

1.2 Research objectives

The main objectives of this work are as follows:

(1) To classify land use and assess land use change and pattern;

(2) To identify optimum method for urban growth model based on CA Markov and logistic regression;

(3) To assess quality of life index using remotely sensed data and socio-economic data;

(4) To predict quality of life and its change

1.3 Scope of the study

Scope and limitations of the study can be briefly explained as follows:

(1) Land use changes will be studied by visual interpretation of aerial photographs in 1986, 1994, and 2002. According to the Land Development Department (LDD)'s land use classification, five land use classes are defined: urban and built-up area, agricultural land, forest land, water body, and miscellaneous land.

(2) Urban growth model will be calculated from the land use in 1986 and 1994 using CA-Markov and logistic regression models to predict urban growth in 2002. The results will be compared with the interpreted land use of the year 2002. After that, the best result will be applied to predict the land use in 2010 and 2018.

(3) Analysis of driving forces for urban growth (1986-1994 and 1994-2002 for short term period and 1986-2002 for long term period) will be calculated using demography, transportation and land use data.

(4) BMN data in 2008 of Community Development Department (CDD), land use data in 2007 from LDD and Landsat-TM data in 2008 from Geoinformatics and

Space Technology Development Agency (GISTDA) will be used to assess the quality of life index of the year 2008 by factor analysis and to predict quality of life index by regression analysis.

(5) The BMN data (in 2004, 2006, 2008, and 2009), Landsat-TM data (in 2006, 2008, and 2009), and predicted land use in 2010 and 2018 will be utilized to predict the quality of life in 2010 and 2018.

(6) Quality of life change, which is explained in term of gain and loss of quality of life's level.

(7) Urban growth pattern and quality of life prediction in Mueang Nakhon Ratchasima district will be evaluated.

CHAPTER II

RELATED CONCEPTS, THEORIES AND LITERATURE REVIEW

2.1 Related concepts and theories

The main related concepts and theories of this study are here summarized including urban growth model and quality of life index.

2.1.1 Urban growth model

2.1.1.1 Causes of urban growth

Barker, Redfern, and Skinner (2006) stated that two main causes of urban growth include (1) natural population growth and (2) rural-urban migration.

(1) Natural population growth

Urban areas tend to have relatively low age profiles. Young adults (15-40 years) have traditionally migrated from rural areas. They are in their fertile years and so that rates of natural increase are higher in cities than in the surrounding rural areas.

(2) Rural-urban migration

The reasons for rural-urban migration are often divided into 'push' and 'pull' factors. Push factors cause people to move away from rural areas, whereas pull factors attract them to urban areas.

Push factors are largely due to poverty caused by:

- Population growth which means the same area of land has to support increasing number of people;
- Fragmentation of land due to system of inheritance that causes land to be subdivided into smaller and smaller plots;
- Systems of tenure that do not allow tenants to have a long-term perspective for their land, so they do not invest in it;
- Debt on high-interest loans taken out to support agricultural change;
- Desertification due to low and unreliable rainfall amounts which results in low agricultural yields;
- High levels of local diseases and inadequate medical provision;
- The conversion of land from subsistence agriculture to the production of cash crops. This has been done to try to pay off the interest on national debts;
- Natural disasters such as floods, tropical storms, and earthquakes have all caused people to flee previously fertile rural area and not to return.

Pull factors include the prospect of:

- Employment in factories and service industries, earning better wages than those in rural areas;
- Earning money from the informal sector, e.g. selling goods on the street, providing transport (taxi/rickshaw driver), and prostitution;
- Better-quality social provisions, from basic needs such as education and health care to entertainment and tourism.

2.1.1.2 Type of urban growth

Urban is synonymous with developed land and includes residential as well as commercial and industrial land uses that result in developed or built landscape. The model identifies three categories of urban growth: infill, expansion, and outlying. For outlying urban growth, it is further separated into isolated, linear branch, and clustered branch growth. The detail of each urban growth type is described as follows:

- An infill growth is characterized by a non-developed areas being converted to urban use and surrounded by at least 40% of existing developed areas.

- An expansion growth is characterized by a non-developed areas being converted and surrounded by no more than 40% existing developed areas.

- Outlying growth is characterized by a change from non-developed to developed land cover occurring beyond existing developed areas. This type of growth has been called development beyond the urban fringe.

- Isolated growth is characterized by one or several non-developed areas, some distance from an existing developed area being developed. This class of growth is characteristic of a new house or similar construction surrounded by little or no developed land.

- Linear branch defines an urban growth such as a new road, corridor, or a new linear development that is generally surrounded by non-developed land, and is some distance from existing developed land.

- Clustered branch defines a new urban growth that is neither linear nor isolated, but instead, a cluster or a group (Camagni, Gibelli, and Rigamonti, 2002; Wilson, Hurd, Civco, Prisloe, and Arnold, 2003).

2.1.1.3 Remote sensing and urban growth modeling

In principle, physicists developed model and theoretical frameworks around simple concepts and constructed experiments that were able to reproduce real observable actions precisely and accurately. From these elemental experiments came more complex models and improved understanding of systems. Models have demonstrated potential for supporting planning and management decisions; these include their ability to:

- provide information and understanding of the dynamics;
- anticipate and forecast future changes or trends;
- describe and assess impacts of future development;
- explore different policies through scenario-based planning (Herold, Hemphill, and Clarke, 2007).

Herold, Couclelis, and Clarke (2005) described five different areas in which remote sensing combined with spatial analysis can support urban modeling. There are (1) basic mapping and data support, (2) model calibration and validation, (3) the interpretation, analysis and presentation of model results, (4) the representation of spatial heterogeneity in urban areas, and (5) the analysis of spatiotemporal urban growth patterns.

2.1.1.4 Type of urban growth modeling

There are a number of ways of classifying the models regarding urban growth, such as in terms of system completeness, dimension, and objectives of analysis. Cheng, Masser, and Ottens (Online, 2003) classified urban growth models as follows:

(1) CA-based modeling

As an effective bottom-up (from structure to process) simulation tool, cellular automata (CA) first offers a new way of thinking for dynamic process modeling and second provide a laboratory for testing the decision-making processes in complex spatial systems. CA-based modeling approach is quite different from top-down and macroscopic approaches. Many applications of CA can be classified into three types: complexity and GIS theory, theoretically artificial urban study and empirical case study. These researches have proved the great potential of CA for discovering the complexity (in particular spatial complexity) of urban system or its subsystems.

(2) Agent-based modeling

Multi-agent (MA) systems are designed as a collection of interaction autonomous agents each having their own capacities and goals that are situated in a common environment. This interaction might involve communication, i.e. the passing of information from one agent and environment to another.

(3) Spatial statistics modeling

Traditional statistic models, e.g. Markov chain analysis, multiple regression analysis, principal component analysis, factor analysis, and logistic regression, have been very successful in interpreting socio-economic activities.

(4) ANN-based modeling

The development of an Artificial Neural Network (ANN) model requires the specification of a 'network topology', learning paradigm, and learning algorithm. Unlike the more commonly used analytical methods, the ANN is not dependent on particular functional relationships, makes no assumptions regarding the distributional properties of the data and requires no a priori understanding of variable relationships. This independence makes the ANN a potentially powerful modeling tool for exploring non-linear complex problems.

(5) Fractal-based modeling

Fractals were originally used for natural objects such as coastlines, plants, and clouds or ill-defined mathematical and computer graphics. These are essentially spatial objects whose forms are irregular, scale-independent, and self-similar.

(6) Chaotic and catastrophe modeling

Catastrophe theory and the theories of bifurcating structures attempt to model urban changes. Chaos theory effectively means that unpredictable long-time behaviour arises in deterministic dynamic systems because of the sensitivity to initial conditions.

2.1.1.5 Driving forces for urban growth

The motors of land-cover/land-use change are countless. Some act slowly (and often obscurely) over centuries, while others trigger events quickly and visibly. In every case, several forces are at work, sometimes operating independently but simultaneously, sometime operating synergistically. No aspect of global change is more complicated than the driving forces. McNeill et al. (1994) classified system of driving force into four major categories included political, economic, demographic and environmental. While Hersperger and Bürgi (2008) assigned five categories of driving force such as political, economic, cultural, technological, and nature/spatial. Their research aimed to analyze the driving force of urbanization, agriculture intensification, and greening in five municipalities of periurban Limmat Valley, near

Zurich, Switzerland and they was studies in multilevel; international, national, cantonal, and local. In local level, groups of driving force were decreased to four groups. Example of driving force in local level was shown in Table 2.1

Table 2.1 List of driving force acting upon periurban Swiss lowlands in local level.

Driving force	Description
1. Political	
- Municipal networks of power	Facilitated the construction of new buildings outside area zoned for development
- Municipal politics	Facilitated the construction of a few buildings outside areas zoned for development
- Nature protection policy	Goal of protection and recreation of nature elements
- Local land-use planning	Zoning to accommodate development
- Development policy	The municipalities did not have a strong development policy
- Regional competition	Improvement of the regional road network (connectors)
- Transportation and Infrastructure policy	Projects of local road construction
2. Economic	
- Property market	Fostered development
- Taxes and subsidies	Fostered development
- Financial strength of the municipalities	Fostered sports infrastructure
3. Cultural	
- Demand for recreational, tourism and cultural facilities	Fostered development and the construction of sports infrastructure
- Previous development of society	Affected spatial configuration
- Demography	Fostered development
4. Natural and spatial	
- Topography	Fostered the construction of transportation infrastructure
- Soil conditions	Fostered agricultural abandonment
- Spatial configuration	Fostered dispersed development patterns

Source: Hersperger and Bürgi (2008).

2.1.2 Quality of life model

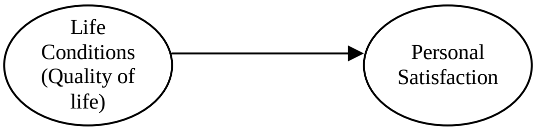
Quality of life is an elusive concept approachable at varying levels of generality from the assessment of societal or community well being to the specific evaluation of the situations of individuals or groups (Felce and Perry, 1995).

Shackman, Liu, and Wang (Online, 2008) stated that quality of life indicators allow government to evaluate how well they are doing compared with, for example, their development goals or the quality of life in the country.

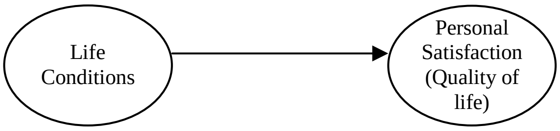
2.1.2.1 Conceptual models of quality of life

Borthwick-Duffy (1992) has presented four perspectives on quality of life base on previous suggestion by Felce and Perry (1995): (a) quality of life defined as the quality of one's life conditions, (b) quality of life defined as one's satisfaction with life conditions, (c) quality of life defined as a combination of both life conditions and satisfaction, and (d) quality of life defined as a combination of life conditions and satisfaction with emphasize on personal values, aspirations and expectation as shown in Figure 2.1.

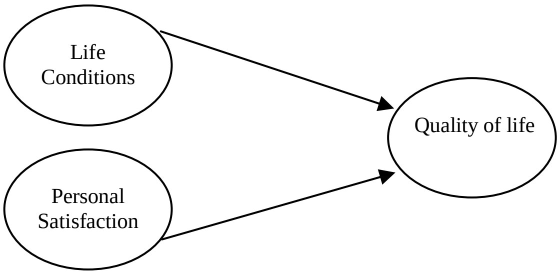
Many indicators are used to measure national quality of life and human development. These can be divided into single indicators and component sets. Some emphasize 'objective' and some 'subjective' measures (Shackman et al., Online, 2008). Objective dimension represents the external condition of life. It refers to reports of factual condition and overt behaviour. Objective indicators are measured based on frequency and they are external to an individual. These are tangible condition such as physical environment and economic or technical factors. Social indicators are frequently used as objective measure of QOL. Subjective QOL stands for measurement of attitudes. Subjective indicators represent the individual's appraisal of objective conditions of life. Subjective indicators are mostly based on, psychological response, such as life satisfaction, job satisfaction, and personal happiness (Das, 2008).



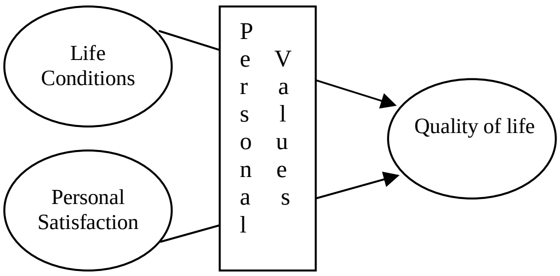
(a) Quality of life is defined in terms of life conditions



(b) Quality of life is defined in terms of satisfaction with life



(c) Quality of life is defined as a combination of life conditions and satisfaction



(d) Quality of life is defined as a combination of life conditions and satisfaction weighted by scale of importance

Figure 2.1 Conceptualizations of quality of life.

Source: Borthwick-Duffy (1992).

2.1.2.2 Quality of life indicators

Malkina-Pykh and Pykh (2008) collected quality of life indices with any of three criteria. They received attention from researchers in the field, they received attention from the press, or they had public policy applications. The list of the reviewed indices includes: CDC's Health-Related Quality of life, WHOQOL, Consumer Confidence Index (CCI), Money's 'Best Places', Index of Economic Well-Being (IEWB), Genuine Progress Index (GPI), American Demographics Index of Well-Being, Johnston's QOL index, Euro barometer, Veenhoven's Happy Life-Expectancy Scale (HLE), International Living Index, U.N Human Development Index (HDI), Miringoffs' Index of Social Health, State-Level QOL Surveys, Estes' Index of Social Progress (ISP), Diener's Basic and Advanced QOL Indexes, Cummins' Comprehensive Quality of Life Scale (Com-Qol), Michalos' North American Social Report, Philippines' Weather Station, Netherlands Living Conditions Index (LCI), German System of Social Indicators, Swedish surveys of living conditions system, and Calvert-Henderson QOL.

Data for a number of the variables used in quality of life scales can be obtained from public domain and non-public domain sources. Shackman et al. (Online, 2008) suggested data for measuring quality of life as follow: US CIA World Fact book, US Census Bureau's International Data Base, US Department of Energy, Freedom House, Michael Coppedge and Wolfgang Reinicke, and Food and Agricultural Organization.

2.1.2.3 Quality of life in Thailand

The development of Thailand in the past focused only on the economic expansion without a systematic use of natural resources, resulting in problem about the environment and natural resources during such period. In addition, the improper production and consumption behaviours of the Thai people caused many problems. In the past, Thailand had a good economy but it had a lot of social problems and its development was neither effective nor sustainable. With this in mind, Thailand and other countries which have been faced with these problems have resorted to sustainable development. They signed the agreement Agenda 21 proposed by the United Nations in 1992 in Rio de Janero, Brazil. To develop Thailand in a sustainable manner, an evaluation framework and effective indicators for evaluation operational results have to be determined. The National Economic and Social Development Board (NESDB) has conducted a study to draw up a framework to evaluate the general sustainable development of Thailand and to determine proper sustainable development indicators (SDI) to follow up and measure the impact of sustainable development. First aims of sustainable development of Thailand there was ‘Quality’. This aim is to improve the quality of life of Thai people so that they can learn by themselves and improve their potential (Pitchdamrong, 2004).

Aryuwat (2005) reviewed scale of quality of life in Thailand and divided it into three levels. The first was quality of life developed from the United Nations' criteria. They were known as Basic Minimum Needs at several levels: households, villages, sub-district, district, and province. The second was developed as measurement of groups e.g. labour, peasant, aged person, etc. And the last was developed from experts as measurement of individuals.

Community Development Department (Online, 2008) was described about Basic Minimum Need. There is household information that presents life quality of household member in different aspects at a specific period. The objectives of Basic Minimum Needs were:

- To use BMN indicators as a tool of learning process for people;
- To promote people participation in community development;
- To use the BMN result as a guide in approving the projects/programs and activities at every level.

At present, BMN data are used to measure quality of life in Thailand from 6 major indicator groups and 42 sub-indicators as follows:

- Group 1: Health with 13 indicators;
- Group 2: Housing with 8 indicators;
- Group 3: Education with 7 indicators;
- Group 4: Economy with 3 indicators;
- Group 5: Values with 6 indicators;
- Group 6: Participation with 5 indicators.

2.2 Literature review

There are plenty of researches related to urban study since the past decade. Some important literatures depicted land use and land cover change, driving force of urban growth and its impact, prediction of urban growth, and quality of life assessment with geoinformatics technology. These studies in recent years are focused in this review.

2.2.1 Land use and land cover change

Satellite imagery has been well utilized in the natural science communities for measuring qualitative and quantitative terrestrial land-cover changes (Masek, Lindsay, and Goward, 2000; Seto and Liu, 2003; Rogan, Miller, Stow, Franklin, Levien, and Fischer, 2003; Fan, Weng, and Wang, 2007). Qualitative changes in landscapes occurrence either as natural phenomena (wildfires, lightning strikes, storms, and pests) or can be human induced (selective logging and agro forestry). Quantitative land-use change is the wholesale categorical transformation of the land and although it can occur as a natural phenomenon as caused by fires and storms, large scale replacement of one land-cover type by another is usually induced by human activity (forest clearing, agricultural expansion, and urban growth). Both qualitative and quantitative changes in land-cover have been successfully monitored with remote sensing (Seto et al., 2002).

A number of change detection techniques have been developed over the last 10 years e.g. image differencing (Xiao et al., 2006; Azócar, Romero, Sanhueza, Vega, Aguaya, and Muñoz, 2007), post-classification (Fan et al., 2007), image regression (Hu and Lo, 2007; Luo and Wei, 2009; Poelmans and Rompaey, 2009), change vector analysis (Seto et al., 2002), vegetation index differencing (Masek et al., 2000), neural network (Seto and Liu, 2003) and classification tree classifier (Rogan et al., 2003).

In practice, study on land use and land cover change was conducted in different periods depend on its objective. Fan et al. (2007) employed two Landsat-TM/ETM+ images in the dry season to detect land use and land cover patterns in 1998 and 2003 and to examine land use and land cover changes in one period (1998 to 2003). The patterns of the changes among five counties of Guangzhou Municipality were analyzed in details by post-classification method.

Azócar et al. (2007) analyzed land use/land cover changes during two periods (1955-1978 and 1978-1998) in Los Angeles, a mid-city located in central Chile. They used Markov's matrix for analyze sequences of land use/land cover changes and used regression analysis for studies relationship between city and population growth. In addition, Tian, Liu, Xie, Yang, Zhuang, and Niu (2005) analyzed Landsat-TM data during three periods (1990/1991, 1995/1996 and 1999/2000) to interpret land use data at the scale of 1:100,000. The study calculated the urban land percentage and urban land expansion index every 1 sq.km cell throughout China.

Land use and land cover change usually represented by land use conversion matrix and maps and then explained the change. Many researchers used several index for measuring quantitative such as: urban land expansion index, intensity index, population elastic index and economic elastic index (Guohua and Yanhua, 2007). This review was emphasizes only urban land expansion. For example, Shenghe et al. (2002) digitized land use maps of Beijing in 1982, 1992, and 1997. It is observed that urban land use growth went beyond the control of urban planning, in term of the extraordinary high growth rate and undesired spatial pattern. Tian et al. (2005) analysed spatio-temporal dynamic pattern and driving forces of urban land in China in 1990s using TM images and GIS. Xiao et al. (2006) studied the temporal and spatial characteristics of urban expansion from 1934 to 2001 and land use/cover change from 1987 to 2001 in Shijiazhuang, China. In addition, Tu, Pu, Zhu, and Wu (2009) studied about land use and land cover change in the area around Taihu Lake, China in 1985, 1995, 2000, and 2005.

2.2.2 Driving force for urban growth

In recent years, the analysis of driving force for urban growth usually used statistics for measuring quantitative. Some researcher developed questionnaires for analysis driving forces e.g. Thapa and Murayama (2010). They explored the driving factors of urban growth in Kathmandu Valley, Nepal. These factors are physical conditions, public service accessibility, economic opportunities, land market, population growth, political situation, and government plans and policies. They have played important different roles in the city core, fringe, and rural areas. Among these factors, economic opportunities in the core, population growth in the fringe, and political situation in the rural areas are identified as the highest impact factors of urban growth.

Many researchers analyzed land use/land cover change with its driving force. For example, such as Henríquez, Aźocar, and Romero (2006) analyzed the land use/land cover change in Chillan and Los Angeles from 1978 to 1998. The most important urbanization driving forces were identified including total population, annual demographic growth rate and provincial land use. It is found that urban growth and population growth are positively correlated in Chillan (r = 0.97) and Los Angeles (r = 0.98), from 1970 to 2002. Long, Tang, Li, and Heilig (2007) analyzed driving forces of land use change in Kunshan, Jiangsu province, China. The major driving forces were industrialization, urbanization, population growth and economic reforms over the period from 1989 to 2002.

Meanwhile, many researches used regression analysis method to analyze urban expansion and driving forces in Xuzhou city, Jiangsu province (Zhao-ling, Pei-jun, and Da-zhi, 2007). They used stepwise linear regression to analysis equation of driving forces. Their equation is:

$$Y = -76.255 + 2.257X_1 + 0.089X_2 + 0.317X_3 + 0.805X_5 - 0.932X_7 \tag{2.1}$$

When Y is the built-up area, X_1 is total population, X_2 is non-agricultural population, X_3 is gross domestic product (GDP), X_5 is the proportion of secondary industries in the local GDP, and X_7 is agriculture production. While Dewan and Yamaguchi (2009) studied urban expansion in Greater Dhaka, Bangladesh. Their equation of driving force by regression is:

$$Y = -5.058 + 1.776 Population + 0.0001 GDP + 0.549 Elevation + 0.028 Slope \quad (2.2)$$

2.2.3 Prediction of urban growth

Many studies and researches on prediction of urban growth using different models have been carried out throughout the world. In this study, we select two models for urban growth prediction: cellular automata (CA) model and logistic regression model which are here summarized.

The most popular automata tools in urban geography, Cellular automata that is a system of spatially located and interconnected finite automata (Benenson and Torrens, 2004). Some researchers used only CA. For example, Syphard, Clarke, and Franklin (2005) calibrated CA from historical growth pattern in the study area and used it to forecast three scenarios of urban growth from 2000 to 2050. Some used integrate CA with other tool. For example, Stevens, Dragicevic, and Rothley (2007) presented a novel tool for predictive modeling of urban growth. The proposed tool, named iCity-Irregular City, extends the traditional formalization of cellular automata to include an irregular spatial structure, asynchronous urban growth, and a high spatio-temporal resolution to aid in spatial decision making for urban planning. The model was examined by generating outputs for three scenarios: high density development, medium density development, and low density development. Most simulation results indicate different scenario outcomes.

Beside, Logistic regression model was usually used for prediction of urban growth in the recent year. Example of reports the logistic regression model as shown in Table 2.2. Goetzke, Judex, Braun, and Menz (2009) explained logistic function of the form:

$$p(Y=1)=\frac{\exp(\beta_0+\beta_1 X_1+..+\beta_n X_n)}{1+\exp(\beta_0+\beta_1 X_1+..+\beta_n X_n)} \quad (2.3)$$

The binary distribution is transformed to a curvilinear response between 0 and 1 with p as the probability for the dependent variable (a land use class) $Y = 1$. β_0 is a constant to be estimated during the regression and β_i is coefficients for every independent explanatory variable X_i .To estimate the model parameters we use the odds and apply the logarithm:

$$p' = \log_e\left(\frac{p}{1-p}\right)=\beta_0+\beta_1 X_1+..+\beta_n X_n \quad (2.4)$$

Some researcher used both of method for their study. For example, Fang, Gertner, Sun, and Anderson (2005) and Ying, Qizhi, and Anrong (2009) used CA to analyze urban sprawl/urban growth model and used logistic regression for analytically weight the scores of the driving factors to create predicting probability maps of land use change. Both methods were supported by Poelmans and Rompaey's research (2009) showing the performance of different modeling approaches for simulation spatial patterns of urban expansion in Flanders and Brussels in the period 1988-2000.

Herein, a set of urban expansion models base on (1) logistic regression equation, (2) CA transition rules, and (3) hybrid procedures. The results showed that a hybrid model structure was the best for predicting probability map.

Table 2.2 Example of logistic regression model for prediction of urban growth.

Researcher	Format of formula $(\beta_0 + \beta_1 X_1 + .. + \beta_n X_n)$	Study area
Allen and Lu (2003)	*p*'= -2.4788+0.893 *Corporate boundary*–0.0069 *Cost distance to downtown*–0.3459 *Distance to existing urban*+0.0586 *Distance to major roads*–0.0331 *Distance to node*+0.0022 *Distance to sewer line*+0.0123 *Distance to waterline*+0.0779 *Distance to water front*+9.3329 *Existing urban*–0.1587 *Forest land*+0.0003 *Population density*–0.*8587 Protected land*+0.3060 *Road density* +0.0456 *Slope*–0.6463 *Wetland*	Charleston region of South Carolina
Hu and Lo (2007)	*p'* = 18.8042–0.5620 *Population density*–0.9630 *Distance to the nearest urban cluster*+0.0210 *Distance to CBD*–0.0840 *Distance to active economy centers*–0.7320 *Distance to the nearest major road*+0.*0187 Number of urban cells within a 7×7 cell window*–2.0444 *High density urban*–1.4690 *Low-density urban*+0.9593 *Bare land*+0.7909 *Cropland/grassland*+0.4215 *Forest*	Atlanta, Georgia
Luo and Wei (2009)	*p*' = 5.453–0.269 *Distance to inter-city highway*–1.369 *Distance to local artery roads*+0.034 *Distance to railways*–0.*100 Distance to Yangtze river*+0.115 *Distance to the Yangtze bridge*–0.192 *Distance to major city centers*–0.073 *Distance to suburban centers*+0.087 *Distance to industrial centers*–2.125 *Distance of agriculture land*+4.039 *Distance of built-up land*–4.812 *Distance of water body*–5.360 *Distance of forest land*	Nanjing, China
Poelmans and Rompaey (2009)	*p*' = –1.864–0.00002 *Distance to cities*–0.0822 *Slope*+0.000012 *Employment potential*–0.00191 *Distance to roads*+2.5672 *Zoning status*	Flanders-Brussels region, Belgium

2.2.4 Quality of life assessment with geoinformatics technology

Integration of remote sensing and socio-economic data for quality of life analysis started from Weber and Hirsch (1992). They believed that computer-assisted approach became the best tool for urban analysis because it provided a more detailed characterization of the urban landscape than using census data alone. Then, they developed urban life quality indices for Strasbourg by using a combination of SPOT XS and census data. Weber and Hirsch found that the relations between population structure and remote sensing data were not as obvious as those between housing structure and remote sensing data. Three urban life quality indices were developed on the basic of these mixed data. The first index designed to define social status, was related to house size and the number of dwellings. The remaining two indices were related to the physical environment. With the use of the presence of green area in the city, the second index defined attractiveness of the living environment. The third index used remotely sensed data only to delimit the predominance of industrial and commercial usage in an area a repulsion index (Lo and Faber, 1997).

During 1996 to 1997, Lo had developed three researches concerning integration of Landsat and U.S census data for quality of life assessment. For the first research, he used Landsat-TM, panchromatic aerial photographs, and U.S. Bureau of Census in 1990 for quality of life assessment using Principal Component Analysis (PCA) method. The study area was Athens-Clarke County, Georgia. PCA was applied to the seven layers; normalized difference vegetation index (NDVI), surface temperature, percent of urban use, population density, per capita income, median home value, and percent of college graduates. A plot of the component pattern indicated two clusters of variables. The first is ‘environmental’ labelled as ‘Greenness’, while the second is ‘socio-economic’ called as ‘Economic Well Being’. Both components explained 75.25% of the total variance (54.20 and 21.05) (Lo, Online, 1996). Regarding the second and the third researches Lo had improved his methodology from the previous research to be more complete. There was more explanation and detailed steps of work (Lo, Online, 1996; Lo, 1997; Lo and Faber, 1997).

During the past two decades, environmental justice studies in the United States have concerned the link between the spatial distribution of environmental risks and the socioeconomic characteristics of surrounding populations. Owing to Jun's research in 2006, industrial hazard-related data was added in quality of life assessment at Atlanta, Georgia metropolitan area. He used eight variables: three environment variables (land use and land cover, NDVI and surface temperature), four socioeconomic variables (population density, per capita income, percent college graduates and medium home value), and one hazard-related variable (cumulative potential relative exposure to toxic release facilities). Even Jun developed quality of life index using PCA method like Lo's research, before the analysis, each variable was standardized through a linear scale transformation method. The extent of spatial clustering among pixels with respect to quality of life scores was measured by Moran's I as a spatial autocorrelation index. It was found that the first principal component had 92.6% of total of variance while the second principal component accounted for only 3.3%. The first principle component showed strong positive loadings on four variables such as NDVI, per capita income, median home value, and percentage of college graduates whereas very strong negative loading on four variables such as urban use, surface temperature, population density, and relative risk.

In 2007, Li and Weng developed quality of life index that was computed and mapped the results based on factor weight in city of Indianapolis, Indiana. Li and Weng extracted 26 socio-economic variables from the 2000 Census and 3 environment variables from Landsat-TM (Green vegetation, impervious surface fractions, and surface temperature). There were three factors: economic aspect, environment conditions, and crowdedness. Development of a synthetic QOL index involved the combination of these three factors to present different aspects of quality of life.

CHAPTER III

THE STUDY AREA

3.1 Location and administration

Mueang Nakhon Ratchasima district of Nakhon Ratchasima province, located in the northeast of Thailand, is selected as the study area. It is located between latitude 14° 47′ 11″ to 15° 8′ 30″ North and longitude 101° 56′ 4″ to 102° 14′ 3″ East with the total area of 773.49 sq.km (or 483,431.25 Rai). The district is subdivided into 25 Sub-districts (Tambon) (Figure 3.1) and consists of 231 villages (see detail in Appendix A). According to local administration, in 2009, there were 8 sub-district municipalities and one city municipality (Department of Provincial Administration, 2009a). The municipality covers an area of 37.5 sq.km or about 4.96% of Mueang Nakhon Ratchasima district (Nakhon Ratchasima City Municipality, Online, 2009).

3.2 Topography

The elevation of the study area ranges approximately from 155 m to 285 m above mean sea level (Figure 3.2). The middle part of the study area, where urban and built-up areas and agricultural land are mostly situated, is flat. The main river in the study area, Lam Takong flows from West to East.

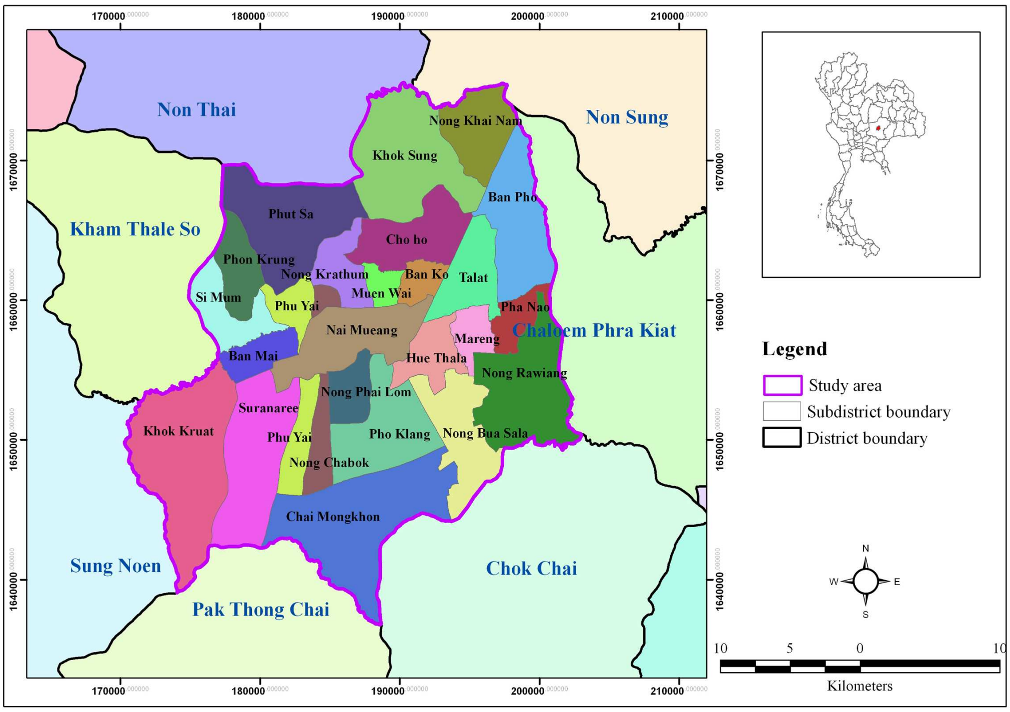


Figure 3.1 Location and administration boundaries.

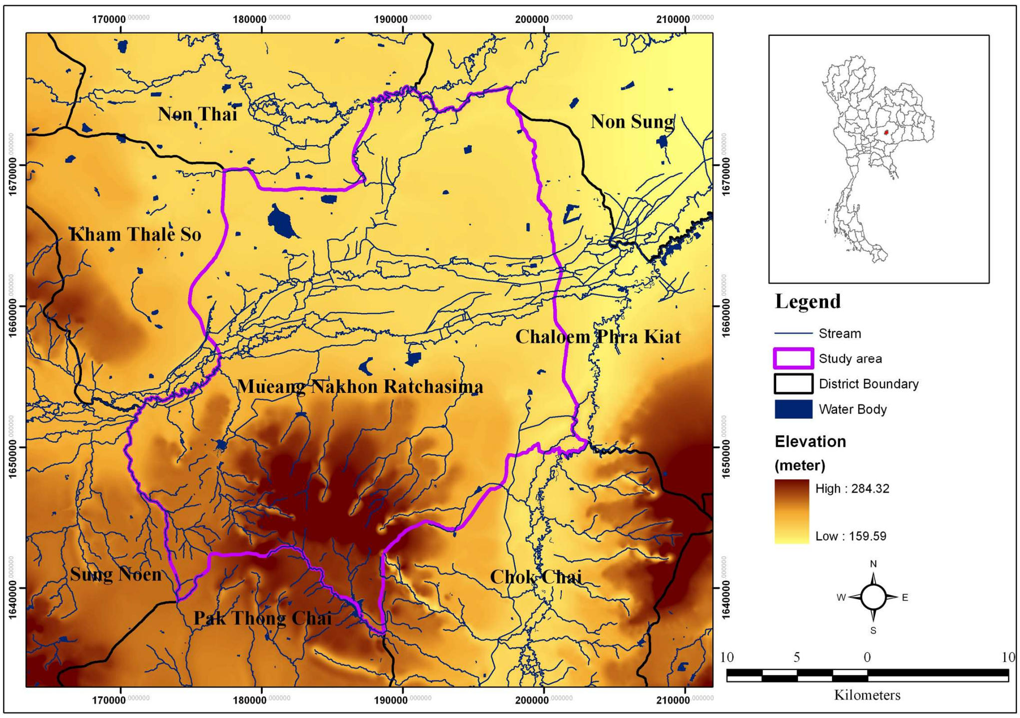


Figure 3.2 Topography.

3.3 Climate, temperature and rainfall

In general, there are three seasons in the region: hot season (mid February to mid May), rainy season (mid May to mid October) and cool dry season (mid October to mid February). Rainy season is under the influence of the southwest monsoons, while cool-dry season is influenced by the northeast monsoon carrying cold air from China.

In 2008, the annual mean temperature is 27.4 °C. The annual mean maximum temperature is 33 °C and annual mean minimum temperature is 22.7 °C. Temperature is highest in April and lowest in January.

The annual mean relative humidity is 71%, annual mean maximum is 89%, and annual mean minimum is 12%. The annual rainfall is 1,019.2 mm and annual mean rainy day is 105 days in 2008 (Nakhon Ratchasima Province, Online, 2008).

3.4 Transportation

Road network in study area consists of highway no. 2 with bypass and four main roads. Highway no. 2 is the main important access from Bangkok via Nakhon Ratchasima to northeastern provinces. While sub-highway no. 205 (route from Non Thai district), no. 224 (route from Chok Chai district), no. 226 (route from Nang Rong district, Burirum province) and no. 304 (route from Pak Thong Chai district) join into Nakhon Ratchasima City Municipality (Figure 3.3). In addition there is main rail road from Bangkok via Mueang Nakhon Ratchasima district to northeastern provinces.

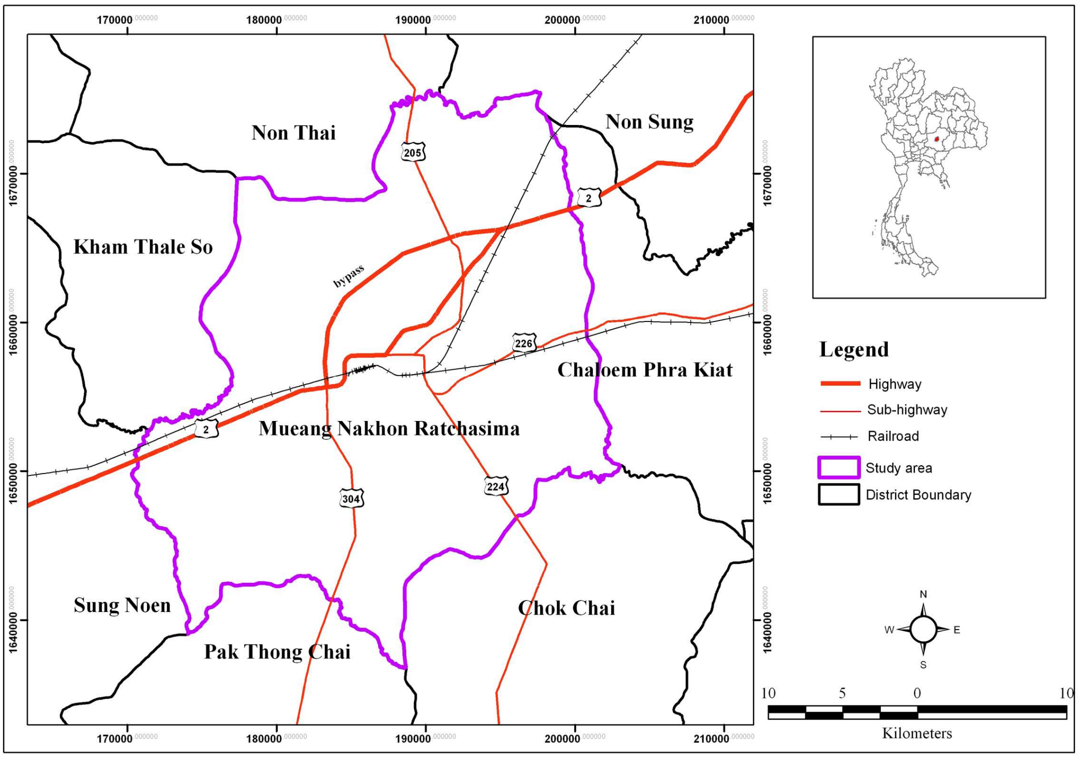


Figure 3.3 Transportation network.

3.5 Land use

In 2007, Land Development Department classified land use types in Mueang Nakhon Ratchasima district into 5 categories (Figure 3.4) including:

- Urban and built-up area 210.24 sq.km;
- Agriculture land 462.51 sq.km;
- Forest land 15.93 sq.km;
- Water body 13.46 sq.km;
- Miscellaneous land 49.84 sq.km

By area, the main land use type is agriculture land of which paddy field is major crop. The second land use type by area is urban and built-up area, almost situated in the city municipality boundary, of which institutional area is major type. For forest area, the third land use type, most of this zone is founded at the Plant Genetic Conservation Project under the Royal initiative of Her Royal Highness Princess Maha Chakri Sirindhorn, located in the east of the study area. Miscellaneous land is located close to urban and built-up area. For water bodies, this zone shares few areas percentage (Land Development Department, Data file, 2007).

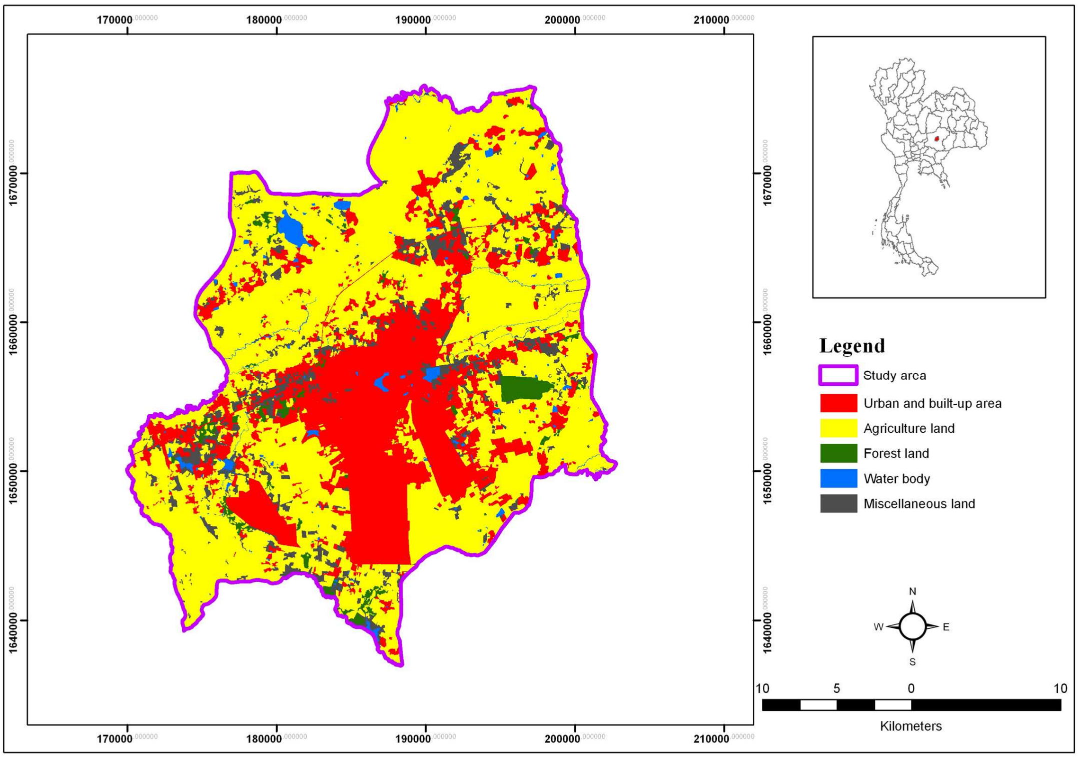


Figure 3.4 Land use in 2007 owing to Land Development Department.

3.6 Socio-economic data

1) Population

According Department of Province Administration, in 2008, Mueang Nakhon Ratchasima district has 191,621 populations and 69,532 households (Department of Province Administration, Online, 2009b).

In 2006, the crude birth rate and the crude death rate of Nakhon Ratchasima province are 10.6 and 5.78 per 1,000 populations, respectively. The life expectancy of male and female is 70.52 and 76.79, respectively (Nakhon Ratchasima Province, Online, 2008).

2) Labours

At the fourth quarter (October - December) of the year 2007, Nakhon Ratchasima province had 1,424,760 employed persons and 637,833 unemployed persons. The unemployment rate was 1.79%. Since 2008, the Ministry of Labour has defined the minimum wage rate in Nakhon Ratchasima province to 165 baht/day (Nakhon Ratchasima Province, Online, 2008).

3) Economic status

Gross provincial product statistics of Nakhon Ratchasima province in 2007 was 150,763 million baht and GPP per capita was 54,362 baht/person (National Economic and Social Development Board, 2009). According to economic structure (Table 3.1), non-agriculture product shared the highest value of which manufacturing is the major sector (National Economic and Social Development Board, 2009).

Table 3.1 Gross provincial product at current market prices by economic sector during 2000-2007.

Year	2000	2001	2002	2003	2004	2005r	2006r	2007p
Agriculture	**13,067**	**14,190**	**15,597**	**18,492**	**18,360**	**19,115**	**23,719**	**29,517**
- Agriculture, Hunting and Forestry	12,765	13,887	15,316	18,245	18,196	18,915	23,551	29,342
- Fishing	302	303	281	247	164	200	168	174
Non-Agriculture	**74,503**	**76,474**	**83,431**	**92,542**	**99,918**	**102,026**	**113,306**	**121,247**
- Mining and Quarrying	707	669	763	777	818	770	846	1,113
- Manufacturing	16,972	18,448	22,217	27,446	29,485	26,394	29,761	32,327
- Electricity, Gas and Water Supply	2,594	2,565	2,714	2,905	3,255	3,462	3,898	3,900
- Construction	5,978	4,830	5,245	6,344	7,428	6,489	7,832	7,588
- Wholesale and Retail Trade; Repair of Motor Vehicles, Motorcycles and Personal and Household Goods	15,780	16,263	16,554	17,611	18,706	19,860	21,593	22,556
- Hotels and Restaurants	5,368	4,956	5,282	5,415	5,912	6,366	7,029	7,535
- Transport, Storage and Communications	4,671	5,191	5,576	5,715	5,737	6,316	6,913	7,445
- Financial Intermediation	2,299	2,414	2,665	2,997	3,486	3,607	4,511	5,035
- Real Estate, Renting and Business Activities	3,407	3,428	3,621	3,724	3,784	4,008	4,132	4,227
- Public Administration and Defence; Compulsory Social Security	6,373	6,828	8,175	8,566	9,241	10,533	11,205	11,961
- Education	6,006	6,477	7,009	7,564	8,285	9,600	10,600	12,135
- Health and Social Work	3,225	3,251	3,008	2,837	3,069	3,626	4,071	4,488
- Other Community, Social and Personal Services Activities	954	980	423	454	516	792	706	718
- Private Households with Employed Persons	169	175	179	187	196	203	208	219
Gross Provincial Product (GPP)	87,571	90,664	99,028	111,034	118,277	121,141	137,025	150,763
GPP Per capita (Baht)	33,559	34,394	37,200	41,321	43,629	44,295	49,744	54,362

r = Revised, p = Preliminary

Source: National Economic and Social Development Board (2009).

CHAPTER IV

DATA, EQUIPMENT AND METHODOLOGY

4.1 Data and Equipment

Data used for this research involves spatial data (remotely sensed data, aerial photographs, topographic map, contour, and road data) and socio-economic attribute data (land use, demography, and BMN data). For equipment, GPS and a notebook are used as hardware while GIS and remote sensing softwares are applied in this study (Table 4.1).

Table 4.1 Data and Equipment.

Data and Equipment	**Date**	**Number of date (sheet)**	**Scale**	**Source/Remarks**
I. RS/GIS Data Types				
1.1 primary datasets				
- Aerial photographs	19/12/1983	4	1:40,000	Royal Thai Survey
	07/03/1986	12	1:50,000	Department
	07/11/1994	9	1:50,000	
	09/11/1994	16	1:50,000	
- Color aerial	10/04/2002	3	1:25,000	
photographs	14/10/2002	2	1:25,000	
	11/01/2003	6	1:25,000	
- Topographic map	2000	1	1:50,000	
(5438IV)				
- Landsat-TM	09/03/2006	-	30×30 m^2	Geo-Informatics and
	03/03/2008			Space Technology
	12/01/2009			Department Agency
				(Public organization)

Table 4.1 Data and Equipment (Continued).

Data and Equipment	Date	Number of date (sheet)	Scale	Source/Remarks
1.2 Secondary datasets				
- Color orthophotographs	2002	312	1:4,000	Land Development
- Land use data	2007	-	1: 25,000	Department
- Administrative boundary, Road, Contour line	2004	-	N/A	Nakhon Ratchasima Rajabhat University
1.3 Attribute data				
- Demography	1994-2008	-	-	Department of Provincial Administration
- BMN data	2004, 2006, 2008, and 2009	-	-	Community Development Department
II Equipment hardware and software				
2.1 Hardware				
- GPS	-	-	-	Remote Sensing Laboratory, SUT
- Compaq notebook	-	-	-	Personal
2.2 Software				
- ArcGIS 9	-	-	-	Remote Sensing
- Erdas Imagine 8.7	-	-	-	Laboratory, SUT
- IDRISI 15.0	-	-	-	Personal

4.2 Methodology

In general, methodological framework of urban growth pattern modeling and its impact to quality of life is schematically displayed in Figure 4.1. Herein, four main research methodologies are developed to fulfil research objectives including:

(1) To classify land use and to analyze land use change and pattern;

(2) To identify an optimum model for urban growth prediction;

(3) To assess quality of life;

(4) To predict quality of life and its change.

The detail of each research methodology is separately described in the following sections.

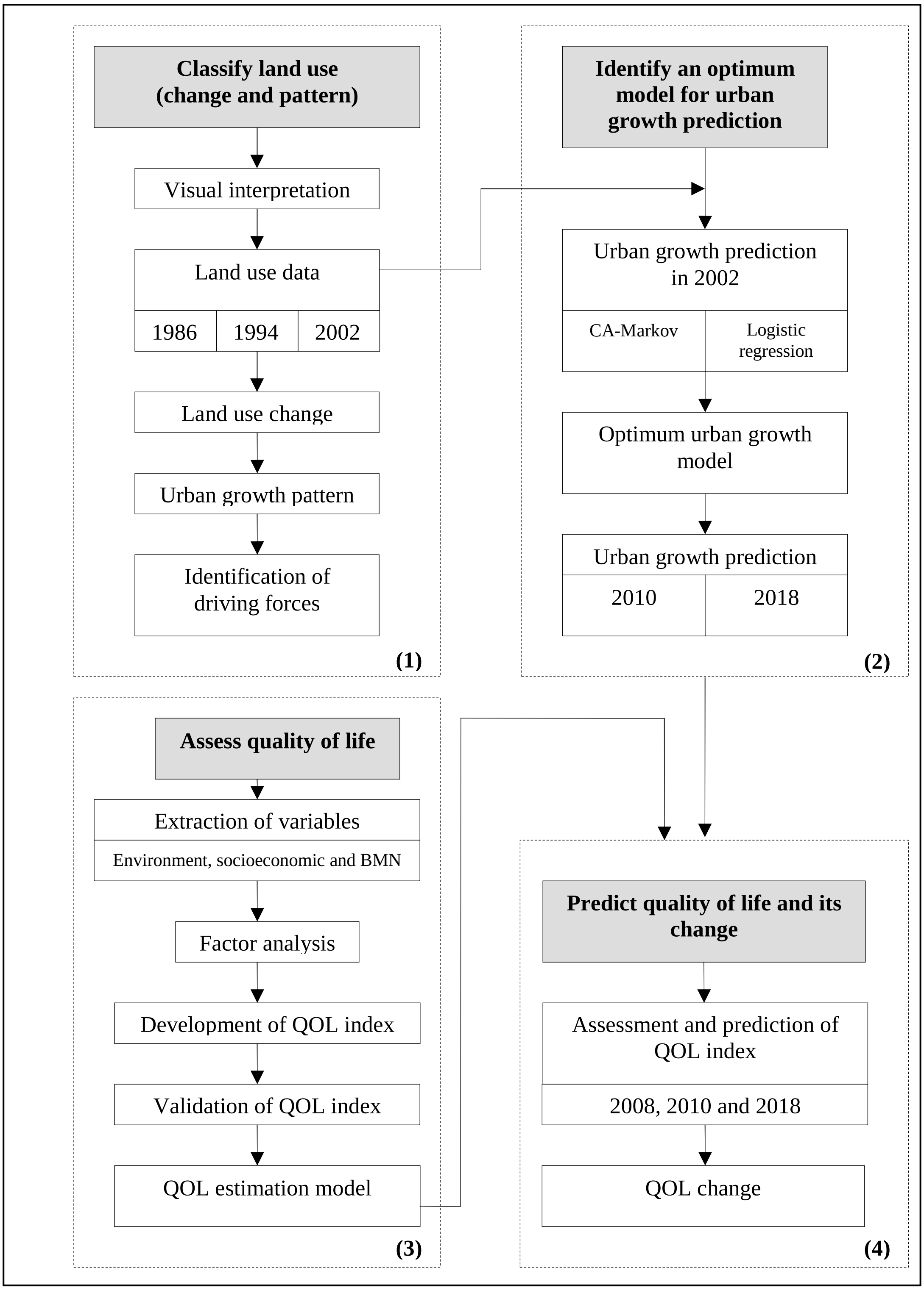


Figure 4.1 Methodology framework.

4.2.1 Classification of land use and analysis of land use change and pattern

This part involves the study of land use and its change by visual interpretation of aerial photographs and by analysis of demographic, transportation, and land use data to define the driving force for urban growth (Figure 4.2). Major tasks in this part are (1) visual interpretation of aerial photograph for land use, (2) land use change detection, (3) urban growth pattern analysis, and (4) identification of driving force for urban growth.

4.2.1.1 Visual interpretation

Land use types are visually interpreted from aerial photographs in 1986, 1994, and 2002 using screen digitizing method with ESRI ArcGIS software. In practice, major steps for visual interpretation of land use categories are conducted as follows:

1) Geometric correction

Geometric correction is normally known as pre-processing operation because they are performed prior to information extraction (Jensen, 2005). Bhatta (2008) suggested working steps for geometric corrections as follows:

1.1) Selection of method: A proper method should be selected after consideration of the characteristics of the geometric distortion as well as the available reference data.

1.2) Determination of parameters: Unknown parameters which define the mathematical equation between the image coordinate system and the geographic coordinate system should be determined with calibration data and/or GCPs.

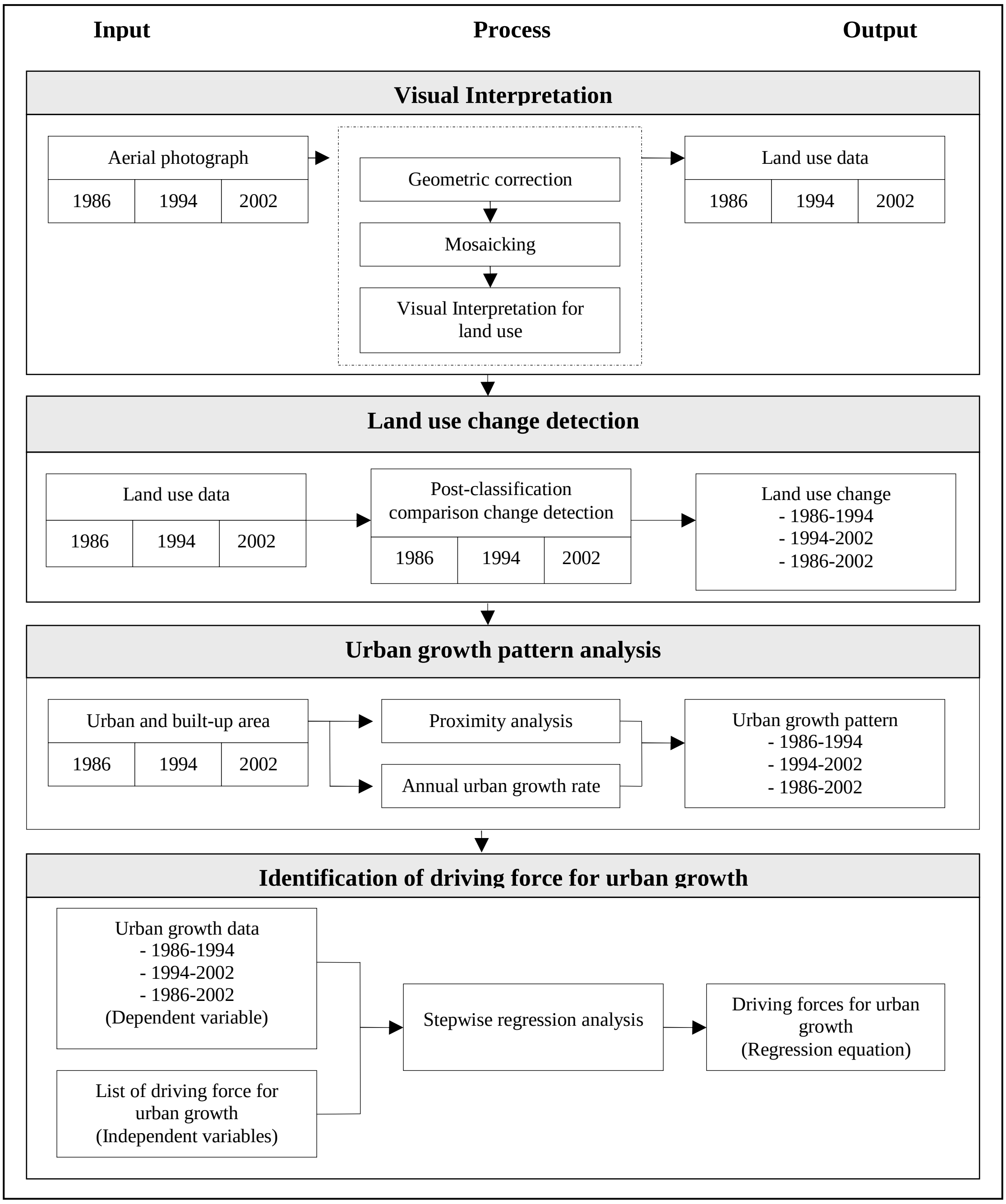


Figure 4.2 Methodology for land use changes and their driving force.

1.3) Accuracy check: Accuracy of the geometric correction should be checked and verified. If the accuracy does not meet the criteria, the method or the data used should be checked and corrected in order to avoid the errors.

1.4) Interpolation and resampling: Geocoded image should be produced by the technique of resampling and interpolation. This study was chose nearest neighbour approach which uses the value of the closest input pixel for the output pixel value.

In this study, all scanned aerial photographs were geometric corrected with image to image rectification based on color orthophotographs of Ministry of Agriculture and Cooperative taken in 2002. Herein, second order transformation for spatial interpolation and nearest neighbour resampling for intensity interpolation were conducted with RMS errors less than 1.0 pixel (10 m).

2) Mosaicking

Mosaicking is the process of combining multiple images into a single seamless composite image. Mosaicking n rectified images requires several steps. First, the individual images should be rectified to the same map projection and datum. Ideally, rectification of the n images is performed using the same intensity interpolation resampling logic and pixel size. Next, one of the images to be mosaicked is designated as the base image. The base image and image 2 will normally overlap a certain amount. A representative geographic area in the overlap region is identified (Jensen, 2005).

3) Visual interpretation for land use

Visual interpretation may also be performed by examining digital imagery displayed on a computer screen. Both analog and digital imageries can be displayed a black and white images, or as color image (Bhatta, 2008). There are a number of characteristics that enable the viewer to detect, recognize or even identify objects from the vertical imagery. These recognition elements are: shape, size, pattern, shadow, tone or color, texture, association, and site (Campbell, 2002; Jensen, 2007; Ongsomwang, 2007; Bhatta, 2008).

For this study, five main land use categories are visually interpreted by screen digitizing method at the scale of 1:10,000. The land use classification referred to Land Development Department's land use categories at first level including:

3.1) Urban and built-up area: This category concerns, related urbanized areas of several usages: residential, industrial, commercial, institutional, rural settlement, transportation, communication, and other utilities.

3.2) Agricultural land: This category composes of paddy field, field crop, perennial tree, orchard, horticulture, swidden cultivation, pasture and farm house, aquatic plant, aquacultural land, and integrated farm/diversified farm.

3.3) Forest land: This category includes natural forest, forest plantation, and agro-forestry.

3.4) Water body: This category comprises natural water body and man-made water body.

3.5) Miscellaneous land: This category involves rangeland, marsh and swamp, mine, pit, garbage dump, landfill, and vacant land.

4.2.1.2 Land use change detection

Post-classification comparison change detection which is a heavily used quantitative change detection method (Jensen, 2005) were used to quantified change of land use between 1986 and 1994, 1994 and 2002, and 1986 and 2002 for urban growth pattern analysis and CA-Markov model.

4.2.1.3 Urban growth pattern analysis

Urban growth pattern was analyzed based on land use change matrix and quantitative explained by distance and expansion intensity index. In this study, proximity analysis will be applied for measurement of urban expansion in distance unit. Herewith, concentric equidistance zone with 500 m distance will be firstly generated from earlier boundary of urban and built-up area. Then, it will be used to overlay with later boundary of urban and built-up area for calculation of urban expansion area in each equidistance zone.

Also, the expansion intensity index describes the degree of differentiation of urban expansion in different directions and denotes the growth of the urban areas of a spatial unit as a percentage of the total area of the land unit in the study period (Liu, Wu, and Shen, 2000 quoted in Zhao-ling et al., 2007). The annual expansion intensity index of a spatial unit can be used to compare the intensity of urban expansion at different study periods. This index is calculated from the expansion intensity index of each spatial unit divided by the number of years between two successive images. The equation is:

$$AGR = \frac{UA_{n+i} - UA_i}{nTA_{n+i}} \times 100\% \tag{4.1}$$

Where AGR is annual urban growth rate, TA_{n+i} is the total land area of the target unit to be calculated at the time point of $i+n$; UA_{n+i} and UA_i is the urban area or built-up area in the target unit at time $i+n$ and i, respectively and n is the interval of the calculating period (in years) (Shenghe et al., 2002; Xiao et al., 2006; Zhao-ling et al., 2007).

Zhao-ling et al. (2007) was divided AGR into five grades: high-speed expansion if AGR > 1.92; fast-speed expansion if 1.05 < AGR ≤ 1.92; medium-speed expansion if 0.59 < AGR ≤ 1.05; slow-speed expansion if 0.28 < AGR ≤ 0.59; slow expansion if 0 ≤ AGR ≤ 0.28.

4.2.1.4 Identification of driving force for urban growth

A stepwise regression was used to evaluate the driving forces behind the urban expansion of Mueang Nakhon Ratchasima district. Whereas correlation is used to measure the strength of linear association between variables, regression analysis refers to the more complete process of studying the causal relationship between a dependent variable and a set of independent, explanatory variables. Linear regression analysis begins by assuming that a linear relationship exists between the dependent variable (y) and the independent variables (x), proceeds by fitting a straight line to the set of observed data and is then concerned with the interpretation and analysis of the effects of the x variables on y and with the nature of the fit. It is most often the case that there is more than one variable that are thought to affect the dependent variable (Rogerson, 2001). The general linear regression model, with normal error terms, simply in term of X variables:

$$Y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \ldots + \beta_{p-1} x_{i,p-1} + \varepsilon_i \qquad (4.2)$$

where: $\beta_0, \beta_1, ..., \beta_{p-1}$ are parameters, $x_{i1}, x_{i2}, ...x_{i,p-1}$ are known constants, ε_I are independent N (0,σ^2), i =1,2,…n.

The response function for regression model (4.2) is, since $E\{\varepsilon\}$ =0;

$$E\{Y\} = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + ... + \beta_{p-1} x_{i,p-1} \tag{4.3}$$

Thus, the general linear regression model with normal error terms implies that the observation Yi are independent normal variables, with mean E{Yi} as given by (4.4) and with constant variance σ^2 (Kutner, Nachtsheim, Neter, and Li, 2005).

An alternative way to select variables for inclusion in a regression equation is the *forward* selection approach. The variable that is most highly correlated with the dependent variable is entered first. Then, given that that variable is already in the equation, a search is made to see whether there are other variables that would be significant if added. If so, the one with the greatest significance is added. In this way, a regression equation is built up. The procedure terminates when there are no variables in the set of potential variables that would be significant if entered into the equation. *Backward* selection starts with the kitchen-sink equation, where all of the possible independent variables are in the equation. Then the one that contributes least to the r^2 value is removed if the reduction in r^2 is not significant. The process of removing variables continues until the removal of any variable in the equation would constitute a significant reduction in r^2. *Stepwise regression* is a combination of the forward and backward procedures. Variables are added in the manner of forward selection. However, as each variable is added, variables entered on earlier steps are re-checked to see if they are still significant. If they are not still significant, they are removed (Rogerson, 2001).

In this study, driving force factors for urban growth are selected after reviewing several researches (Allen and Lu, 2003; Hu and Lo, 2007; Luo and Wei, 2009). These include population density, urban growth, urban and built-up area, agricultural land, forest land, water body, miscellaneous land, distance from existing urban area, distance from railway, distance from main roads, and road density.

In practice, all variables are prepared and recoded before performing stepwise regression analysis using SPSS software.

4.2.2 Identification of an optimum model for urban growth prediction

CA-Markov and logistic regression models will be here selected to predict urban growth and then compared their results with interpreted land use in 2002. After that the model which provides higher accuracy will be used for urban growth prediction in 2010 and 2018. Major tasks concern urban growth prediction in 2002 using CA-Markov and logistic regression models, selection of optimum model for urban growth prediction in the future and prediction of urban growth in 2010 and 2018 (Figure 4.3).

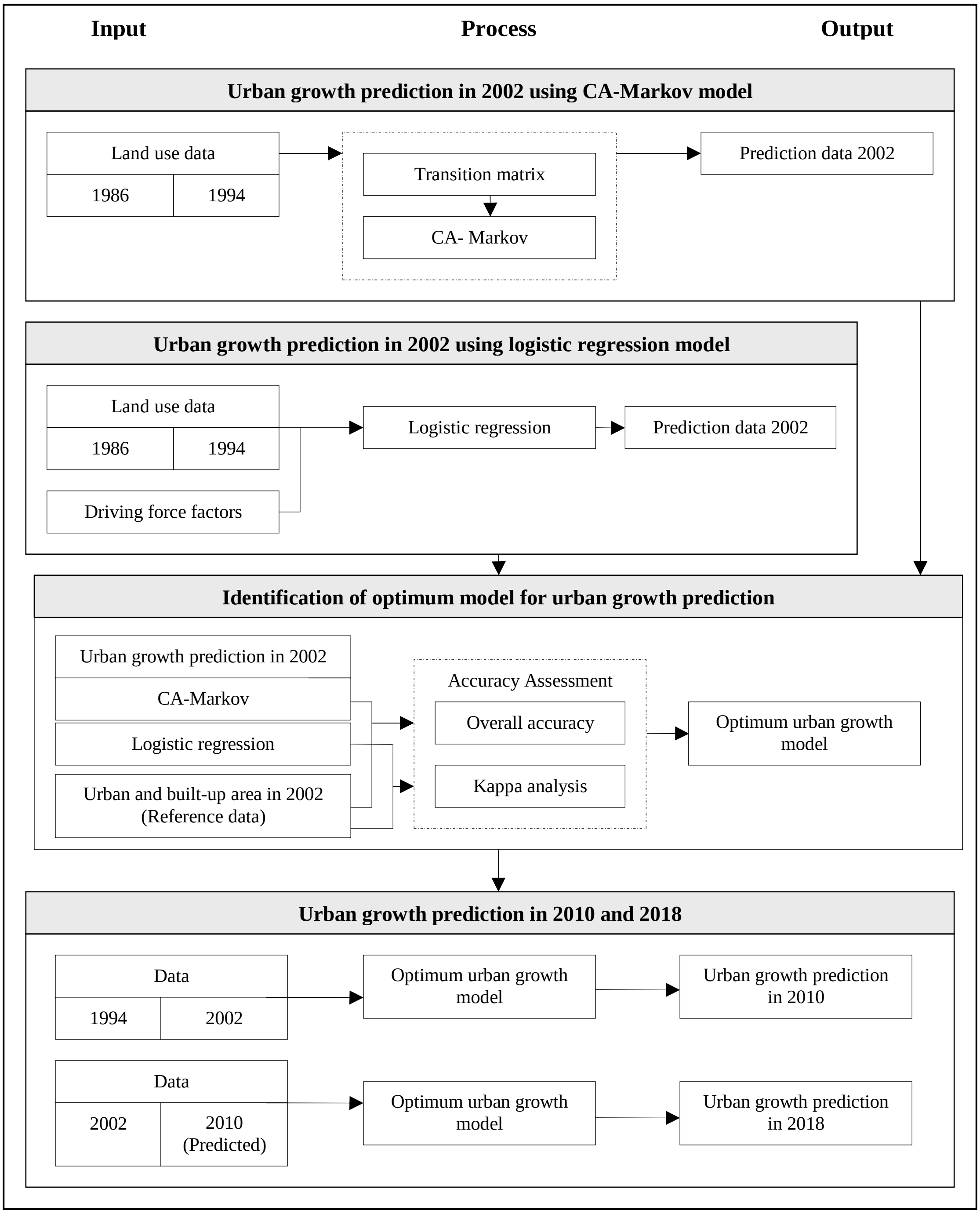


Figure 4.3 Methodology of optimum model identification for urban growth prediction.

4.2.2.1 Urban growth prediction in 2002 using CA-Markov model

1) Cellular Automata

Automata are useful abstraction of 'behaving objects' for many reason, they can provide principally an efficient formal mechanism for representing their fundamental properties: attributes behaviours, relationships, environments and time. Formally, a finite automaton (A) can be represented by means of a finite set of states S = {S1, S2, …, SN} and a set of transition rules (T).

$$A \sim (S, T) \tag{4.4}$$

Two popular automata types that provide the basis for geographic automata are cellular automata and multiagent systems (Benenson and Torrens, 2004).

Cellular automata are dynamic models being discrete in time, space and state. A simple of cellular automata A is defined by a lattice (L), a state space (Q), a neighbourhood template (δ) and a local transition function (f):

$$A = (L, Q, \delta, f) \tag{4.5}$$

Each cell of L can be in a discrete state out of Q. The cells can be linked in different ways. Cells can change their states in discrete time-steps. Usually cellular automata are synchronous, i.e. all cells change their states simultaneously. The fate of a cell is dependent on its neighbourhood and the corresponding transition function f (Adamatzky, 1994 quoted in Balzter, Braun, and Köhler, 1998).

2) Markov process

Formal definition of Markov processes is very close to that of CA. Markov process is considered in discrete time and characterized by variables that can be in one of N states from $S = \{S_1, S_2, \ldots, S_N\}$. The set T of transition rules is substituted by a matrix of transition probabilities (P) and this is reflective of the stochastic nature of the process:

$$P = \left\| p_{ij} \right\| = \left\| \begin{matrix} p_{1,1} & p_{1,2} & \cdots & p_{1,N} \\ p_{2,1} & p_{2,2} & \cdots & p_{2,N} \\ \cdots & \cdots & \cdots & \cdots \\ p_{N,1} & p_{N,2} & \cdots & p_{N,N} \end{matrix} \right\| \tag{4.6}$$

Where p_{ij} is the conditional probability that the state of a cell at moment t+1 will be S_j, given it is S_i at moment t:

$$\mathrm{Prob}(S_\mathrm{i} \rightarrow S_j) = p_{ij} \tag{4.7}$$

The Markov process as a whole is given by a set of status S and a transition matrix P. By definition, in order to always be ‘in one of the state’ for each i, the condition $\sum_j p_{ij} = 1$ should hold (Benenson and Torrens, 2004).

4.2.2.2 Urban growth prediction in 2002 using logistic regression model

A logistic regression model is used to associate the urban growth with driving forces and to generate an urban growth probability map. The nature of the land use and land cover change of a cell is dichotomous: either the presence of urban growth or absence of urban growth. The binary values 1 and 0 are used to represent urban growth and no urban growth, respectively (Hu and Lo, 2007). The general form of logistic regression is described as follows:

$$y = a + b_1x_1 + b_2x_2 + ... + b_mx_m \tag{4.8}$$

$$y = \log_e\left(\frac{P}{1-P}\right) = \text{logit(P)} \tag{4.9}$$

$$P = \frac{e^y}{1+e^y} \tag{4.10}$$

Where x_1, x_2, … x_m are explanatory variables, y a linear combination function of the explanatory variables representing a linear relationship (Eq. 4.8). The parameter b_1, b_2, …b_m are the regression coefficients to be estimated. The P means the probability of occurrence of a new unit. Function y is represented as logit(P) (Eq. 4.9). In logistic regression, the probability value can be a non-linear function of the explanatory variables (Eq. 4.10) (Cheng and Masser, 2003).

4.2.2.3 Identification of optimum model for urban growth prediction

The optimum model for urban growth prediction between CA-Markov and logistic regression models will be justified based on overall accuracy and kappa analysis. The model which generates higher accuracy will be used for prediction of urban growth between 2010 and 2018.

4.2.2.4 Urban growth prediction in 2010 and 2018

The optimum model for urban growth prediction which is derived from the previous task will be applied for the future two periods. The first period is urban growth in 2010, based on data in 1994 and 2002 (8 years). The second period is urban growth in 2018, based on data in 2002 and 2010 (predicted data).

Furthermore, accuracy assessment of predicted land use in 2010 will be conducted using univariate and multivariate statistical analysis.

4.2.3 Quality of life assessment

This part focuses on the study of quality of life assessment, based on remotely sensed, socio-economic and BMN data. Schematic diagram of this part is shown in Figure 4.4, including (1) extraction of variables for factor analysis: environment, socioeconomic, and BMN indicators, (2) factor analysis, (3) development of QOL index, (4) validation of QOL index, and (5) QOL estimation model.

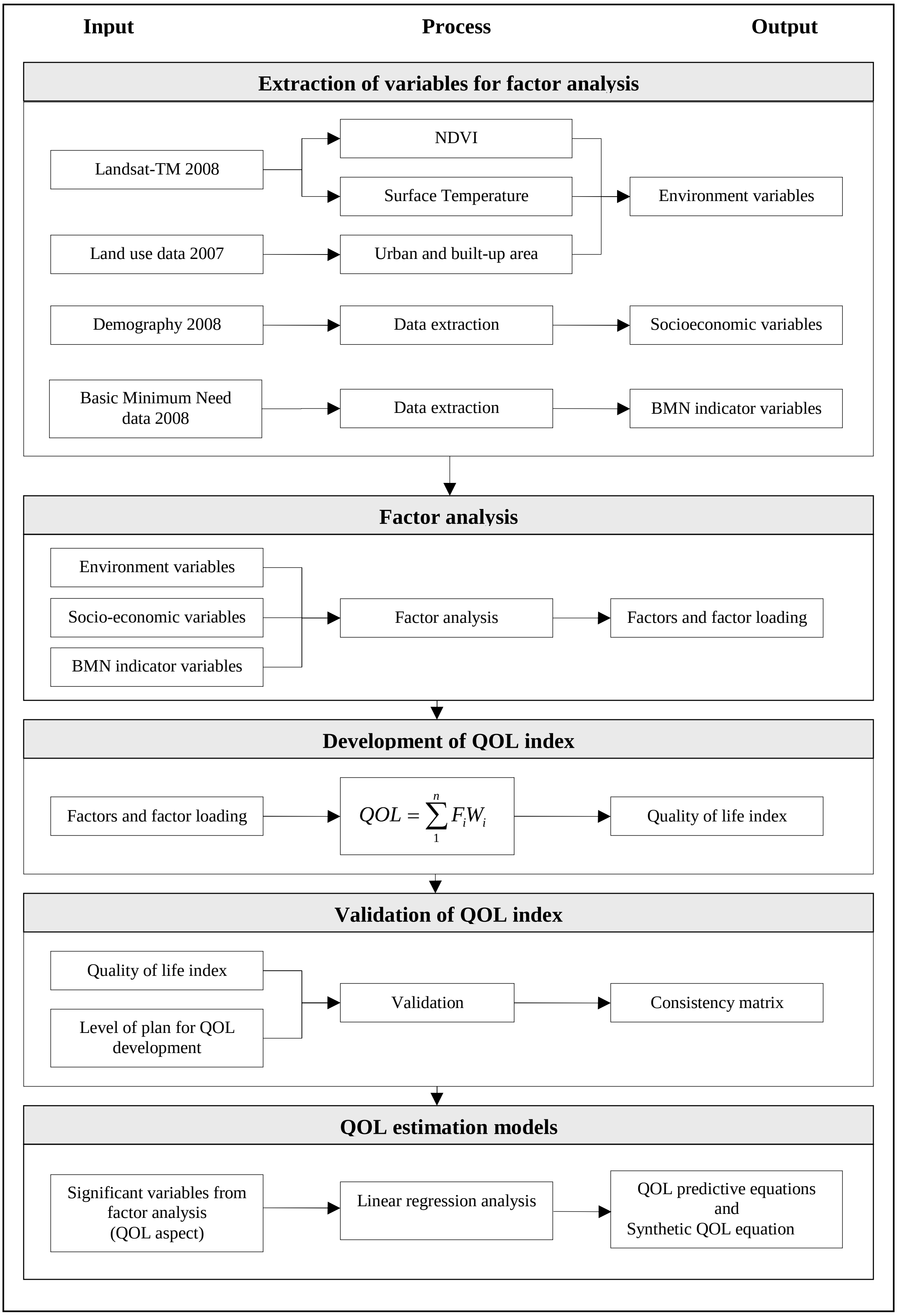


Figure 4.4 Methodology for quality of life assessment.

4.2.3.1 Extraction of variables for factor analysis

1) Extraction of environmental variables

The environment variables, including NDVI, surface temperature and land use, are extracted from two sources. The first is Landsat-TM data, path 128 and 50 acquired on 3 March 2008, for NDVI (Normalized Difference Vegetation Index) and surface temperature analysis. The second is land use data in 2007, obtained from Land Development Department for extraction of urban and built-up area.

1.1) Normalized Difference Vegetation Index

Normalized Difference Vegetation Index (NDVI) was developed by Rouse, Hass, Schell, and Deering in 1974, using the following equation:

$$NDVI = \frac{\rho_{nir} - \rho_{red}}{p_{nir} - \rho_{red}} \tag{4.11}$$

Where ρ_{red} is red radiant flux, and ρ_{nir} is near-infrared radiant flux.

1.2) Surface Temperature

National Aeronautics and Space Administration (2008) suggested the equation and information to compute surface temperature as follows:

(1) Convert DN back to radiance units

The following equation is used to convert DN in a 1G product back to radial units:

$$L_{\lambda} = "gain" \times QCAL + "offset" \tag{4.12}$$

this is also expressed as:

$$L_{\lambda} = \frac{LMAX_{\lambda} - LMIN_{\lambda}}{QCALMAX - QCALMIN} \times (QCAL - QCALMIN) + LMIN_{\lambda} \qquad (4.13)$$

where:

L_{λ}	=	Spectral Radiance at the sensor's aperture in watts/(sq.m× steradian×μm)
'gain'	=	Rescaled gain (the data product 'gain' contained in the Level 1 product header or ancillary data record) in watts/(sq.m×steradian×μm)
'offset'	=	Rescaled bias (the data product 'offset' contained in the Level 1 product header or ancillary data recode) in watts/(sq.m×steradian×μm)
QCAL	=	the quantized calibrated pixel value in DN
$LMIN_{\lambda}$	=	the spectral radiance that is scaled to QCALMIN in watts/(sq.m×steradian×μm)
$LMAX_{\lambda}$	=	the spectral radiance that is scaled to QCALMAX in watts/(sq.m×steradian×μm)
QCALMIN	=	the minimum quantized calibrated pixel value (corresponding to $LMIN_{\lambda}$) in DN
		= 1 for LPGS products
		= 1 for NLAPS products processed after 4/4/2004
		= 0 for NLAPS products processed before 4/4/2004

QCALMAX = the maximum quantized calibrated pixel value (corresponding to $LMAX_\lambda$) in DN = 255

(2) Convert spectral radiance to temperatures

The Landsat Band 6 imagery can also be converted from spectral radiance to a more physically useful variable. This is the effective at-satellite temperatures of the viewed Earth-atmosphere system under an assumption of unity emissivity and using pre-launch calibration constants listed in Table 4.2. The conversion formula is:

$$T = \frac{K2}{\ln(\frac{K1}{L_\lambda} + 1)} \qquad (4.14)$$

where:

T = Effective at-satellite temperature in Kelvin

$K2$ = Calibration constant 2 from Table 4.3

$K1$ = Calibration constant 1 from Table 4.3

L_λ = Spectral radiance in watt/(meter squared×ster×μm)

Table 4.2 ETM+ and TM Thermal band calibration constants.

	Constant 1($K1$) watt/(meter square×ster×μm)	Constant 2 ($K2$) Kelvin
Landsat 7	666.09	1282.71
Landsat 5	607.76	1260.56

Source: National Aeronautics and Space Administration (2008).

1.3) Land use

Five major land use classes of LDD: urban and built-up, agriculture land, forest land, water body, and miscellaneous land, are reclassified into two classes: urban and built-up class (value = 1), and non- urban and built-up area (value = 0).

Three environmental variables comprising NDVI, surface temperature, and urban and built-up area data, are pixel-based data. Based on previous studies (Lo and Faber, 1997; Jun, 2006; Li and Weng, 2007) these pixel-based data should be aggregated to zonal units to tackle the incompatibility problem in areal units among different data. According the cited studies, all three environmental variables used in this research will be also aggregated from pixel based data to village units.

2) Extraction of socioeconomic variables

Based on socioeconomic data (population and income) in 2008 derived from BMN dataset of Community Development Department, five variables will be extracted including: population density, household density, persons per house hold, per capita income, and per household income.

3) Extraction of BMN indicator variables

Basically, BMN indicators are divided into two levels based on data collection unit: by person and by household. For this study, household unit will be extracted from the BMN data in 2008. Herein, 18 variables from the six major BMN measurements: health, housing, education, economy, values, and participation, will be extracted as follows:

3.1) Health measurement

(1) Everybody in a household has quality and standard security

(2) A household correctly knows about medicine usage

3.2) Housing measurement

(3) A house is durable at least for 5 years and has tenure security

(4) A household has sufficient water to consume

(5) A household has safe water, sufficient to drink

(6) A household area is healthily managed

(7) A household does not bother from pollution

(8) A household knows how to prevent accidents

(9) A household has no harm to lives and properties

(10) A household has warm family

3.3) Education measurement

(11) A household receives advantageous information at least 5 times a week

3.4) Economic measurement

(12) A household has regular saving

3.5) Cultural values measurement

(13) People behave under Thai customs and manner

(14) A household practices religious activities at least one a week

3.6) Participation measurement

(15) A household is member of at least one community group

(16) A household participates and shares their thought in community meetings

(17) A household participates in natural conservation activities

(18) A household participates in community activities.

Table 4.3 shows the summary of description and coding of these extracted 26 variables of environmental, socioeconomic, and BMN indicators which will be used in factor analysis for QOL.

Table 4.3 List of coding and variables for factor analysis.

Coding	Description	Year
	Environmental variables	
NDVI	Normalized Different Vegetation Index	2008
ST	Surface Temperature	2007
Urban	Urban and built-up area	2007
	Socioeconomic variables	
Pop_den	Population density (person/km^2)	2008
HH_den	Household density (household/km^2)	2008
Per_HH	Persons per household	2008
Pop_income	Per capita income	2008
HH_income	Per household income	2008
	Basic Minimum Need variables	
Group 1 : Health		
G109	Everybody in a household has quality and standard security	2008
G110	A household correctly knows about medicine usage	2008
Group 2 : Housing		
G214	A house is durable at least for 5 years and has tenure security	2008
G215	A household has sufficient water to consume	2008
G216	A household has safe water sufficient to drink	2008
G217	A household area is healthily managed	2008
G218	A household does not bother from pollution	2008
G219	A household knows how to prevent the accidents	2008
G220	A household has no harm to lives and properties	2008
G221	A household has warm family	2008
Group 3 : Education		
G328	A household receives advantageous information at least 5 times a week	2008
Group 4 : Economy		
G431	A household has regular saving	2008
Group 5 : Cultural values		
G534	People behave under Thai customs and manner	2008
G535	A household practices religious activities at least one a week	2008
Group 6: Participation		
G638	A household belongs to at least one community group	
G639	A household participates and shares their thought in community meetings	2008
G640	A household participates in natural conservation activities	2008
G641	A household participates in community activities	2008

4.2.3.2 Factor analysis

Factor analysis attempts to explain the covariance (or correlation) among a large number of variables in terms of a smaller number of factors. Factors cannot be observed and are unobservable random variables. Such a situation is particularly suitable for studies in subjects like psychology where it is not possible to measure exactly the concepts one is interested in, e.g., intelligence, kindness, and devotion. Basically, the factor analysis is motivated by the following consideration. Suppose that variables can be grouped by their correlations. That is, all variables within a particular group are highly correlated among themselves, but have relatively small correlations with variables in a different group. It can then be conceived that each group of variables represents a single underlying factor that is responsible for correlations (Mukhopodhyay, 2009).

The normal methods for testing of data appropriation, including Bartlett's test of sphericity (measuring of sampling adequacy (MSA) and anti-image correlation matrix) and the Kaiser-Meyer-Olkin (KMO) (measure of sampling adequacy) (Habing, Online, 2003; Friel, Online, 2010).

1) Bartlett's test of sphericity

The process started by calculating the determinant of the matrix of sums of products and cross-products (S) from which the inter-correlation matrix is derived. After that, the determinant of the matrix S is converted to a chi-square statistic and tested for significance. The null hypothesis is that the inter-correlation matrix comes from a population in which the variables are non-collinear (Friel, Online, 2010). Li and Weng (2007) suggested that the significant level of Bartlett's test should be less than 0.1.

2) Kaiser-Meyer-Olkin (KMO)

One method of orthogonal factor rotation often used is called varimax rotation. This is based on the assumption that the interpretability of factor *j* can be measured by the variance of the square of its factor loadings, i.e., the variance of $a_{1j}^2, a_{2j}^2, ..., a_{pj}^2$. If this variance is large then the a_{ij}^2 values tend to be either close to zero or close to unity. Varimax rotation therefore maximizes the sum of these variances for all the factors. H.F Kaiser was the first person who suggested this approach (Manly, 1986).

Friel (2010) described the interpretation of the KMO as characterized by Kaiser, Meyer and Olkin as follows:

- KMO value was 0.90-1.00 that degree of common variance is 'Marvelous'
- KMO value was 0.80-0.89 that degree of common variance is 'Meritorious'
- KMO value was 0.70-0.79 that degree of common variance is 'Middling'
- KMO value was 0.60-0.69 that degree of common variance is 'Mediocre'
- KMO value was 0.50-0.59 that degree of common variance is 'Miserable'
- KMO value was 0.00-0.49 that degree of common variance is 'Don't Factor'

The number of factors to be selected depends on the percentage of variance explained by each factor. There are different factor extraction methods. The principal component is one that will be used in this study. Factors, whose eigenvalues greater than 1 should be extracted (Li and Weng, 2007).

4.2.3.3 Development of QOL index

Each factor can be viewed as one aspect of QOL. Therefore QOL index is the composite of different aspects. It is computed by the following equation.

$$QOL = \sum_{1}^{n} F_i W_i \qquad (4.15)$$

Where n = the number of factors selected, F_i = factor i score, W_i = the percentage of variance factor i (Li and Weng, 2007). Finally, QOL data will be created to show the geographic patterns of QOL.

4.2.3.4 Validation of QOL index

QOL index derived from factor analysis will be validated with the level of defining a plan for QOL developed by Community Development Department. Herein, the Community Development Department has used a number of passed Basic Minimum Need (BMN) indicators to identify a priority for defining a plan to develop QOL of village/community in three levels as follows:

- High priority. Village/community fells to pass BMN indicators between 20 and 28 indicators
- Moderate priority. Village/community fells to pass BMN indicators between 12 and 19 indicators;
- Low priority. Village/community fells to pass BMN indicators between 4 and 11 indicators. (Community Development Department, 2008).

4.2.3.5 QOL estimation models

Ideally, either single or synthetic QOL index developed from factor analysis should be related to real QOL (Li and Weng, 2007). Therefore, in this study, QOL indices comprising the QOL by factors analysis and synthetic QOL will be created by linear regression using original indicators. In fact, specific QOL, predicting variables, are those having the highest correlation with the corresponding factors. In addition, derived synthetic QOL index will be applied to predict QOL in 2010 and 2018.

4.2.4 Quality of life prediction and its change

For this section, change of quality of life in 2010 and 2018 will be calculated from synthetic QOL model. Major tasks include assessment of QOL index in 2008, prediction of QOL index in 2010 and 2018 and explanation of QOL change in term of gain and loss (Figure 4.5).

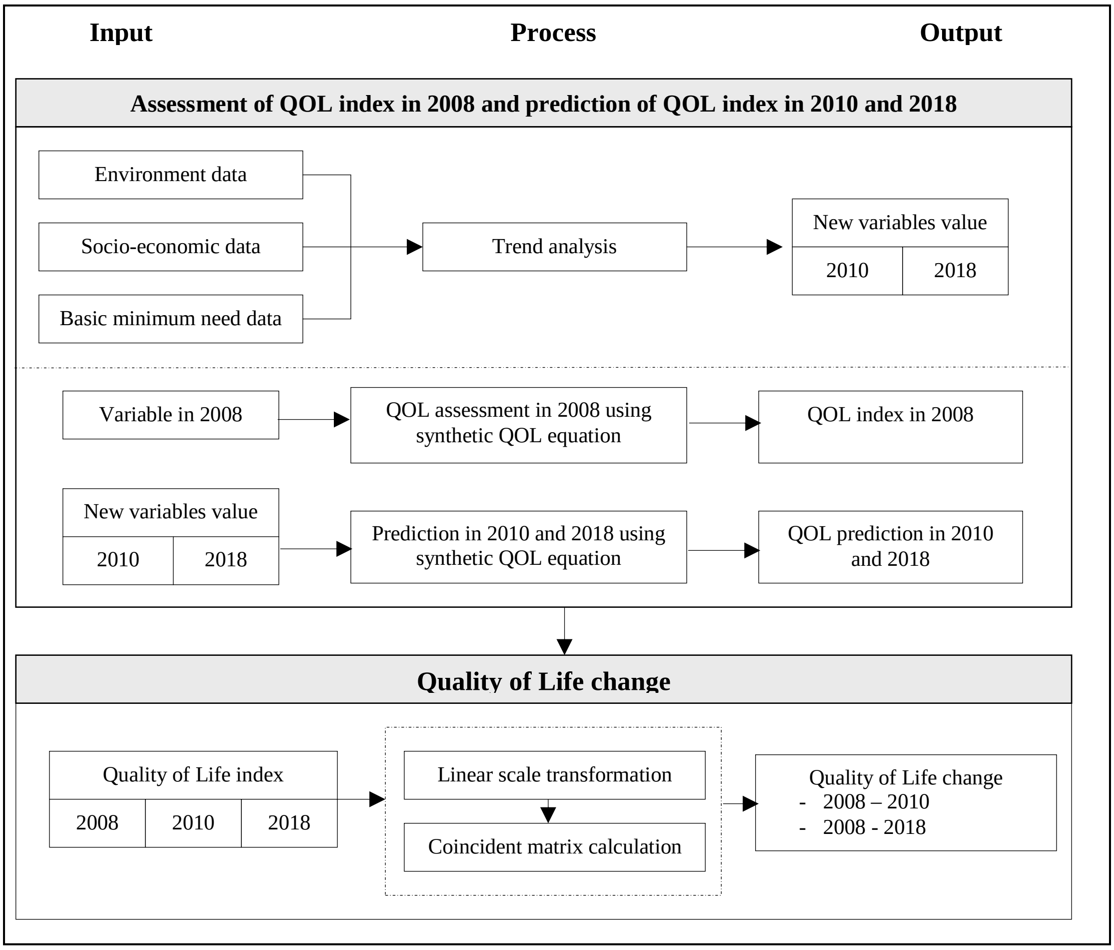


Figure 4.5 Methodology for quality of life prediction and its change.

4.2.4.1 Assessment of QOL index in 2008 and prediction of QOL index in 2010 and 2018

There are two steps for assessment of QOL index in 2008 and prediction of QOL index in 2010 and 2018 as follows:

1) Trend analysis

The outputs of regression equation from quality of life assessment (section 4.2.3.5) depend on variables used in each equation. Herein, relevant variables in each regression equation for each QOL factors in 2010 and 2018 will be estimated using trend analysis of MS Excel spreadsheet as time-series linear regression.

In theory, time series display a steady tendency of increase or decrease through time. Such tendency is called a trend. When we plot the observations against time, we may notice that a straight line can describe the increase or decrease in the series as time goes on. A simple linear regression equation is fit to the data being least squares (Aczel and Sounderpandian, 2009).

$$Z_t = \beta_0 + \beta_1 t + a_t \tag{4.16}$$

Where t is time and a_t is the error term. The coefficient β_0 and β_1 are regression intercept and slope, respectively.

2) Assessment and prediction of synthetic QOL index

Variables in 2018 and estimated variables in 2010 and 2018 derived from trend analysis will be applied to synthetic QOL index as mentioned in section 4.2.3.5.

4.2.4.2 Explanation of quality of life change

Two main steps: linear scale transformation of QOL and identification of urban growth impact on QOL are here conducted.

1) Linear scale transformation

If we want to combine various criterion map layers, their scales must be commensurate (Malczewski, 1999). The linear scale transformation methods will convert raw data into standardized criterion scores. They are calculated by dividing the difference between a given raw score and the minimum score. For the criterion by the score range for the benefit criterion and the standardized score, it can be obtained by dividing the difference between the maximum score and a given raw score by the score range for cost criterion as shown in the following equation:

For benefit criterion

$$x_{ij}^{'} = \frac{x_{ij} - x_j^{\min}}{x_j^{\max} - x_j^{\min}} \quad (4.17)$$

For cost criterion

$$x_{ij}^{'} = \frac{x_j^{\max} - x_{ij}}{x_j^{\max} - x_j^{\min}} \quad (4.18)$$

Where

$x_{ij}^{'}$ is the standardized score for the i^{th} object and the j^{th} attribute,

x_{ij} is the raw score, $x_j^{\max}$ is the maximum score for the j^{th} attribute,

$x_j^{\min}$ is minimum score for the j^{th} attribute,

$x_j^{\max} - x_j^{\min}$ is the range of a given criterion.

Then, the standardized score (0 to 1) of QOL in 2008, 2010, and 2018 will be equally divided into 5 levels to explain level of QOL as follows:

- 0.0-0.2 Very poor QOL;
- 0.2-0.4 Low QOL;
- 0.4-0.6 Moderate QOL;
- 0.6-0.8 Good QOL;
- 0.8-1.0 Very good QOL.

2) Coincident matrix calculation

In this section, the linear transformed QOL index in 2008, 2010, and 2018 will be used to identify quality of life change. The QOL change will be divided into two periods (2008 and 2010 for short term period and 2008 and 2018 for long term period) using coincident matrix in term loss and gain value.

CHAPTER V

LAND USE ASSESSMENT AND ITS CHANGE AND DRIVING FORCE

The content of this chapter will present the results of the first objective focusing on land use assessment, its change, change pattern of urban and built-up area, and driving forces for urban growth in the study area.

5.1 Land use assessment

Land use of Mueang Nakhon Ratchasima district, Nakhon Ratchasima province in 1986, 1994, and 2002, were derived from visual interpretation of aerial photographs. Owing to LDD's land use categories, there are five land use types: urban and built-up area, agriculture land, forest land, water body, and miscellaneous land. The land use characteristics of each year are described in the following sections.

5.1.1 Land use in 1986

Due to unavailable aerial photographs data in 1986, land use of Meuang Nakhon Ratchasima sub-district was not covered the whole study area. The most dominant land use type is agriculture land covering an area of 473.28 sq.km or 62.93% of the study area (Table 5.1 and Figure 5.1). This zone was found in the north and east of the study area, mostly comprising paddy field and cassava. Urban and built-up areas were located in the center of the study area, covering an area of

106 sq.km or 14.09% of the study area. This urbanized area was almost situated in the municipal area and the major land use was institutional area. For forest land, the main part was situated in the eastern part of the study area, is used as a community forest (Institute of Research and Development, Online, 2009). This area was also established to be the Plant Genetic Conservation Project under the Royal initiative of Her Royal Highness Princess Maha Chakri Sirindhorn in 1994 (Alumni of Mechanical Technology Rajamangala, Online, 2009). In addition, some few natural forests were found in the western part of the study area.

Table 5.1 Area and percentage of land use in 1986.

Land use types	**Area in sq.km**	**Percentage**
Urban and built-up area	105.99	14.09
Agriculture land	473.28	62.93
Forest land	38.58	5.13
Water body	6.49	0.86
Miscellaneous land	21.50	2.86
No data	106.22	14.13
Total	**752.06**	**100.00**

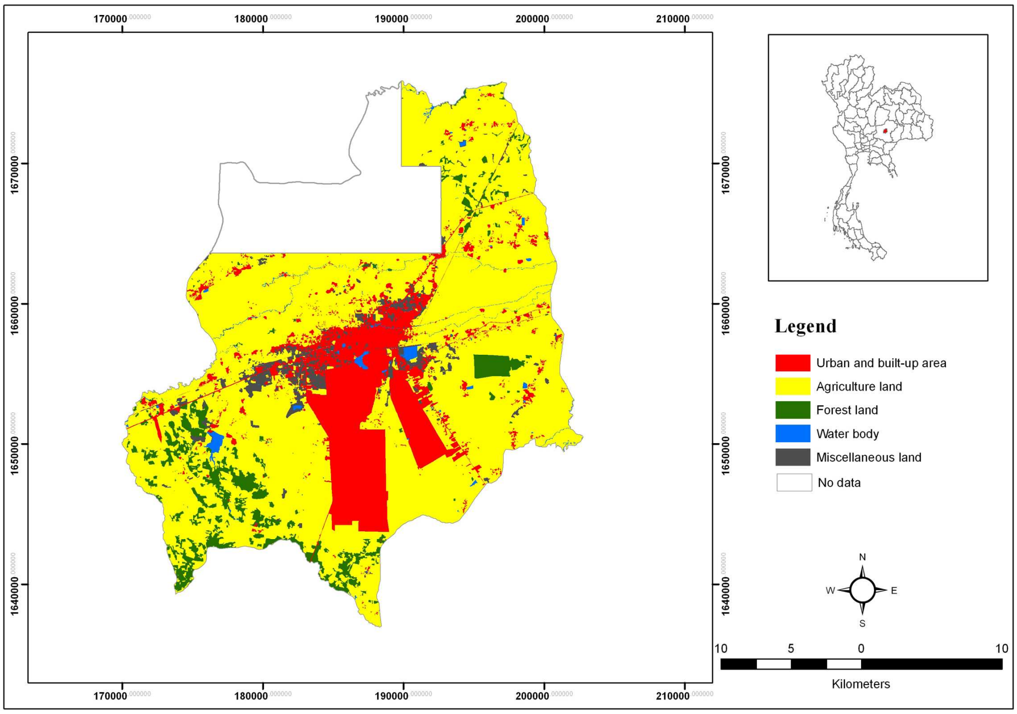


Figure 5.1 Distribution of land use in 1986.

5.1.2 Land use in 1994

In 1990, Suranaree University of Technology was established in the southwest of the study area. The university covered an area of 11 sq.km (Suranaree University of Technology, Online, 2009). Although this had also increased more area for the urban and built-up zone, the most dominant land use type was still agriculture land covering an area of 532.47 sq.km or 70.80% of the study area (Table 5.2 and Figure 5.2). Furthermore, the forest area in the southwest of the study area was converted to agriculture land. For miscellaneous land, abandoned areas were remarkably increased close to urban and built-up land, mostly changed to agriculture land.

Table 5.2 Area and percentage of land use in 1994.

Land use type	Area in sq. km	Percentage
Urban and built-up area	153.07	20.35
Agriculture land	532.47	70.80
Forest land	18.80	2.50
Water body	10.83	1.44
Miscellaneous land	36.89	4.91
Total	**752.06**	**100.00**

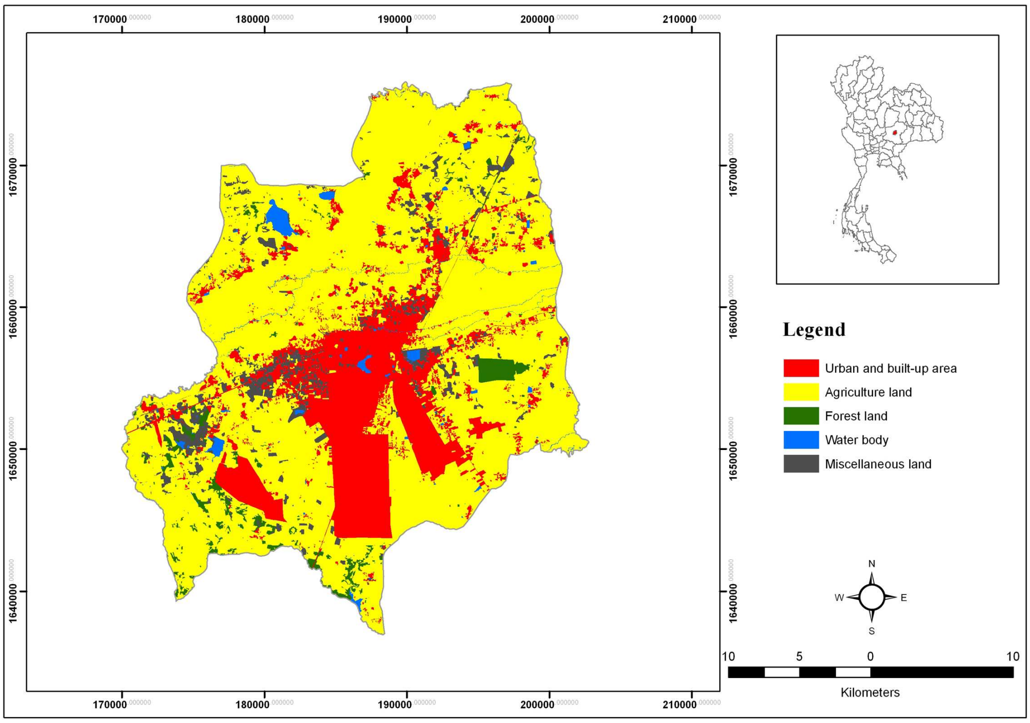


Figure 5.2 Distribution of land use in 1994.

5.1.3 Land use in 2002

In general, land use in 2002 had the same pattern like those in 1994. The most important land use type was still agriculture land covering an area of 496.37 sq.km or 66.00% of the study area (Table 5.3 and Figure 5.3). Comparing with land use in 1994, there were several land use conversions: from forest lands to agriculture lands, agriculture lands to urban and built-up areas and abandoned areas and old abandoned areas to urban and built-up areas. In addition, Suranaree Industrial Estate was also established in 1996 (Thailand board of investment, Online, 2009) in southeast of the study area.

Table 5.3 Area and percentage of land use in 2002.

Land use type	Area in sq.km	Percentage
Urban and built-up area	190.66	25.35
Agriculture land	496.37	66.00
Forest land	10.91	1.45
Water body	13.21	1.76
Miscellaneous land	40.91	5.44
Total	**752.06**	**100.00**

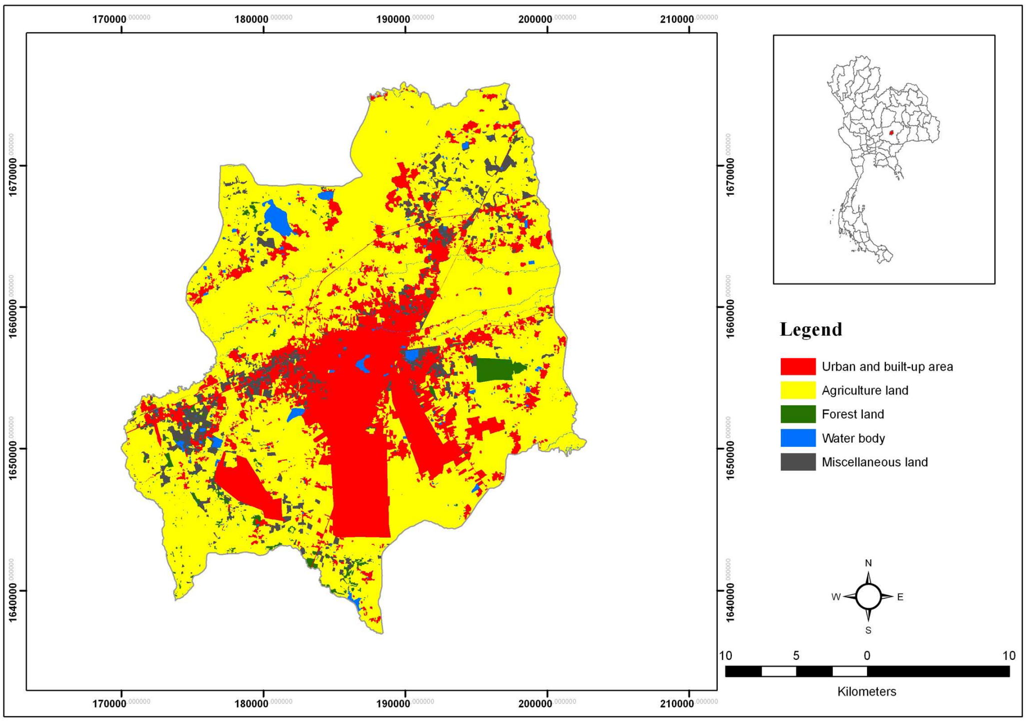


Figure 5.3 Distribution of land use in 2002.

In summary, land use categories in 1986, 1994, and 2002 were presented to compare land use changes (Table 5.4). This indicated the land use changes, especially those related to urban and built-up area during 16-year period (1986-2002). It was found that urban and built-up area, water body and miscellaneous land were continuously increased, while agriculture land and forest land were continuously decreased.

Table 5.4 Allocation for land use categories in 1986, 1994, and 2002.

Land use types	1986		1994		2002	
	sq. km	%	sq. km	%	sq. km	%
Urban and built-up area	105.99	16.41	144.87	22.43	178.67	27.67
Agriculture land	473.28	73.28	444.27	68.79	412.29	63.84
Forest land	38.58	5.97	17.71	2.74	10.02	1.55
Water body	6.49	1.01	7.10	1.10	8.95	1.38
Miscellaneous land	21.50	3.33	31.89	4.94	35.91	5.56
Total area	**645.84**	**100.00**	**645.84**	**100.00**	**645.84**	**100.00**

Note: Total area was adapted according to available aerial photographs in 1986.

5.2 Land use change

The change detection algorithm for the comparison of land use changes was here applied for the land use changes during 1986-1994, 1994-2002, and 1986-2002.

5.2.1 Land use change between 1986 and 1994

During this period, urban and built-up area had an increased area of 38.88 sq.km or 6.02% of the study area, or 4.86 sq.km per annum. Most of these increased areas came from agriculture land. At the same time, water body and miscellaneous land had also increased having area of 0.61 and 10.39 sq.km or 0.09% and 1.61% of the study area, respectively. Their annual increase areas were 0.08 and 1.30 sq.km, respectively, and came from agriculture land.

For decreased land use types, agriculture land had lost an area of 29.01 sq.km or 4.49% of the study area, or 3.63 sq.km per annum. They were changed to urban and built-up area, water body and miscellaneous land. Forest land also had a decreased area of 20.87 sq.km or 3.23% of the study area, or 2.61 sq.km per annum. It was converted to urban and built-up area, agriculture land, water body and miscellaneous land (Table 5.5 and Figure 5.4).

Table 5.5 Land use change matrix between 1986 and 1994.

Unit: sq.km

Land use in 1986	Land use in 1994					
	U	A	F	W	M	Total
Urban and built-up area (U)	105.99	0.00	0.00	0.00	0.00	**105.99**
Agriculture land (A)	27.95	429.67	0.00	1.33	14.34	**473.28**
Forest land (F)	3.93	13.27	17.71	0.07	3.59	**38.58**
Water body (W)	0.03	0.51	0.00	5.53	0.42	**6.49**
Miscellaneous land (M)	6.97	0.82	0.00	0.16	13.54	**21.50**
Total	**144.87**	**444.27**	**17.71**	**7.10**	**31.89**	**645.84**
Area of change (sq. km.)	**38.88**	**-29.01**	**-20.87**	**0.61**	**10.39**	
Percentage of study area (%)	**6.02**	**-4.49**	**-3.23**	**0.09**	**1.61**	
Area per annum (sq. km.)	**4.86**	**-3.63**	**-2.61**	**0.08**	**1.30**	

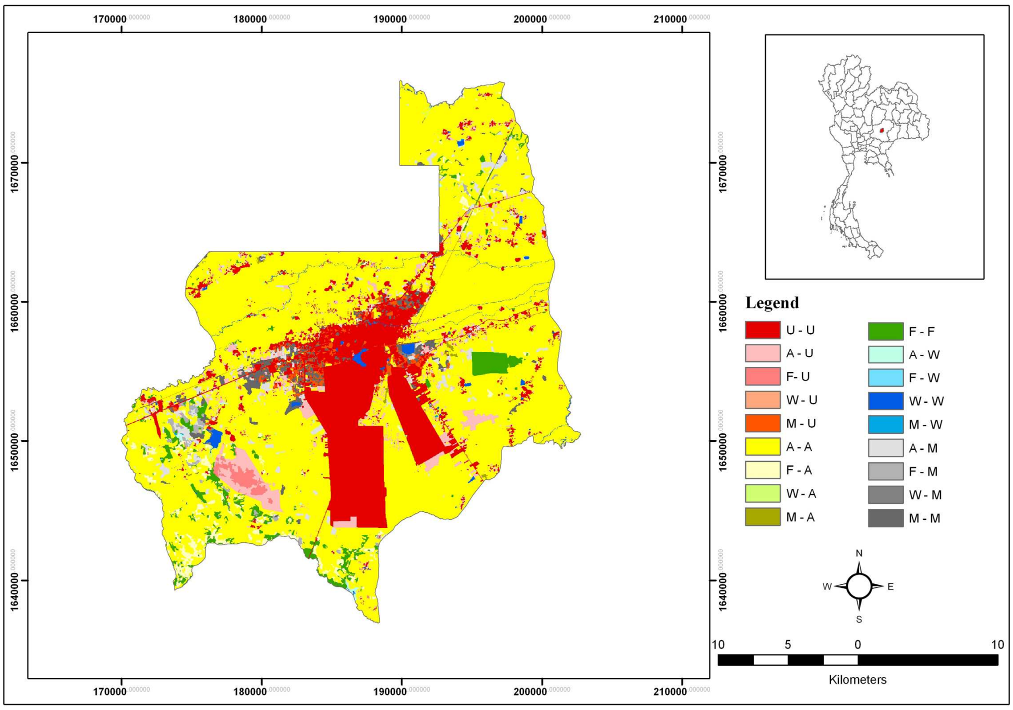


Figure 5.4 Land use change between 1986 and 1994.

5.2.2 Land use change between 1994 and 2002

During this period, types of land use having increasing areas were urban and built-up area, water body and miscellaneous area. Urban and built-up area had increased 33.80 sq.km or 5.23% of the study area or 4.23 sq.km a year. Most of this urbanized area came from agriculture land and miscellaneous land. Regarding, water body and miscellaneous land, these areas had increased 1.85 and 4.02 sq.km or 0.29% and 0.62% of the study area, or 0.23 and 0.50 sq.km a year, respectively. Water body had been converted from agriculture land while miscellaneous land came from agricultural and forest lands.

Agriculture land and forest area were decreased land use types. Agricultural area was decreased 31.98 sq.km or 4.95% of the study area or 4.00 sq.km per year. It was changed into urban and built-up area, water body and miscellaneous land. At the same time, forest land was decreased 7.69 sq.km or 1.19% of the study area or 0.96 sq.km a year. These lands were changed into urban and built-up area, agriculture land, water body, and miscellaneous land (Table 5.6 and Figure 5.5).

Table 5.6 Land use change matrix between 1994 and 2002.

Unit: sq. km

Land use in 1994	**Land use in 2002**					
	U	**A**	**F**	**W**	**M**	**Total**
Urban and built-up area (U)	144.87	0.00	0.00	0.00	0.00	**144.87**
Agriculture land (A)	25.96	406.96	0.00	1.45	9.90	**444.27**
Forest land (F)	0.37	4.10	10.02	0.07	3.15	**17.71**
Water body (W)	0.00	0.31	0.00	6.48	0.31	**7.10**
Miscellaneous land (M)	7.47	0.92	0.00	0.96	22.54	**31.89**
Total	**178.67**	**412.29**	**10.02**	**8.95**	**35.91**	**645.84**
Area of change (sq.km)	**33.80**	**-31.98**	**-7.69**	**1.85**	**4.02**	
Percentage of study area (%)	**5.23**	**-4.95**	**-1.19**	**0.29**	**0.62**	
Area per annum (sq.km)	**4.23**	**-4.00**	**-0.96**	**0.23**	**0.50**	

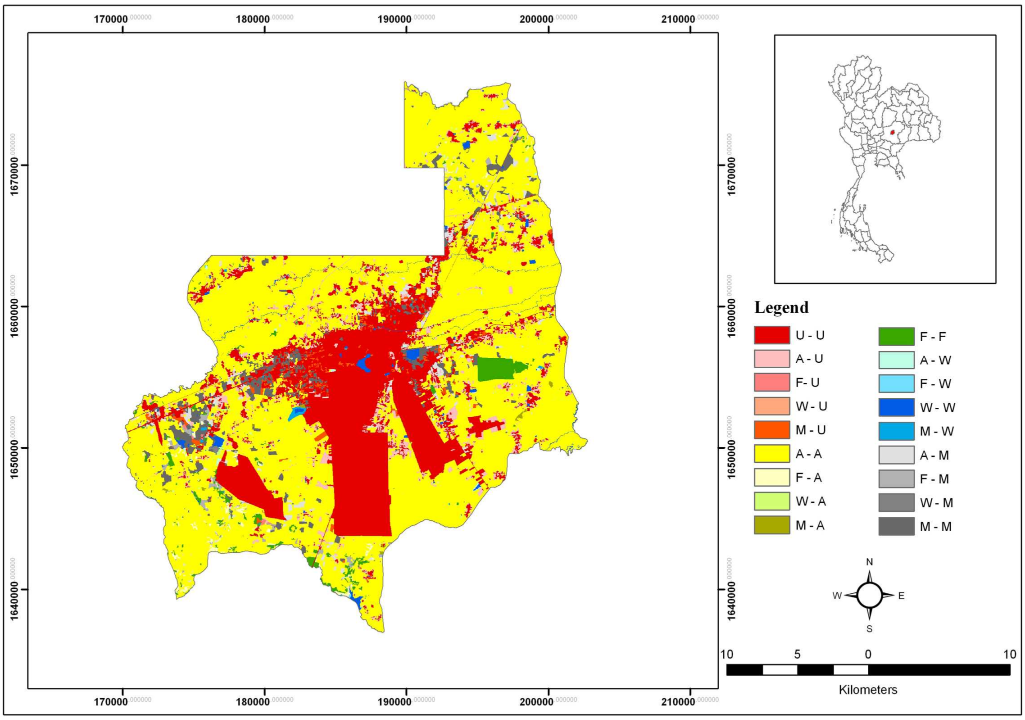


Figure 5.5 Land use change between 1994 and 2002.

5.2.3 Land use change between 1986 and 2002

For long term period (1986-2002), urban and built-up area had increased 72.68 sq.km or 11.25% of study area or 4.54 sq.km a year. Most of increasing urban and built-up area came from agriculture land, forest land and miscellaneous land. At the same time, water body and miscellaneous land increased an area of 2.46 and 14.41 sq.km or 0.38% and 2.23% of the study area, or 0.15 and 0.90 sq.km a year, respectively. The majority of increased water body came from agriculture land while miscellaneous land came from agriculture and forest lands.

Concerning agriculture land and forest land, there were decreased areas of 60.99 and 28.56 sq.km or 9.44% and 4.22% of the study area, or 3.81 and 1.79 sq.km a year, respectively. Most of agriculture land was changed into urban and built-up area and miscellaneous land while most of forest land was changed into agriculture land (Table 5.7 or Figure 5.6).

Table 5.7 Land use change matrix between 1986 and 2002.

Unit: sq.km

Land use in 1986	Land use in 2002					
	U	**A**	**F**	**W**	**M**	**Total**
Urban and built-up (U)	105.99	0.00	0.00	0.00	0.00	**105.99**
Agriculture (A)	56.59	393.54	0.00	2.71	20.44	**473.28**
Forest (F)	4.95	16.57	10.02	0.34	6.70	**38.58**
Water body (W)	0.06	0.74	0.00	4.99	0.70	**6.49**
Miscellaneous (M)	11.09	1.43	0.00	0.91	8.07	**21.50**
Total	**178.67**	**412.29**	**10.02**	**8.95**	**35.91**	**645.84**
Area of change (sq. km.)	**72.68**	**-60.99**	**-28.56**	**2.46**	**14.41**	
Percentage of study area (%)	**11.25**	**-9.44**	**-4.42**	**0.38**	**2.23**	
Area per annum e (sq. km.)	**4.54**	**-3.81**	**-1.79**	**0.15**	**0.90**	

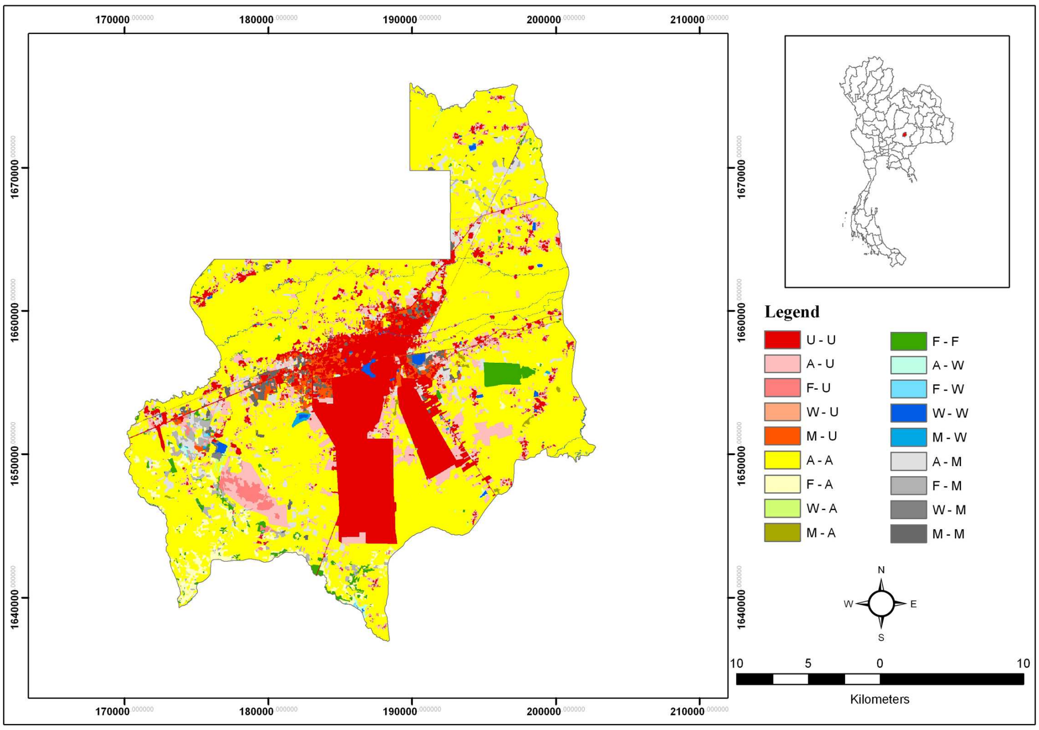


Figure 5.6 Land use change between 1986 and 2002.

5.3 Urban growth patterns and types

In order to understand the urban growth pattern, it is essential to develop some kinds of comparable and comprehensive indicators of development. In this study, proximity analysis and annual urban growth rate for describing the spatial differentiation of urban growth was applied. Thus, urban growth pattern between 1986 and 1994, 1994 and 2002, and 1986 and 2002 were here summarized.

5.3.1 Urban growth pattern between 1986 and 1994

During 1986 to 1994 as short period, urban and built-up area had increased an area of 38.88 sq.km or 6.02% of the study area. At the same time, urban and built-up area in 1986 was expanded in all directions in 1994 with the longest distance of 4 km. Most of urban expansion was taken place within equidistance zone of 500 meter (Table 5.8). Distribution of urban expansion between 1986 and 1994 was displayed Figure 5.7.

In addition, the urban growth of Mueang Nakhon Ratchasima district between 1986 and 1994 is considered to be expansion growth type because non-developed areas being converted to urban land had covered the area less than 40% of the existing developed areas. It was found that annual urban growth rate between 1986 and 1994 was 0.75. This value represented urban growth with medium-speed expansion.

Table 5.8 Urban expansion for each equidistance zone between 1986 and 1994.

Equidistance zone from urban and built-up area in 1986 (m)	Expansion of urban and built-up area between 1986 and 1994 in each equidistance zone (sq.km)	Percent of new urban and built-up area
500	26.1725	67.3162
1000	4.1045	10.5567
1500	6.3913	16.4385
2000	2.1954	5.6467
2500	0.0073	0.0189
3000	0.0050	0.0129
3500	0.0017	0.0044
4000	0.0022	0.0057
Total	38.8800	100.0000

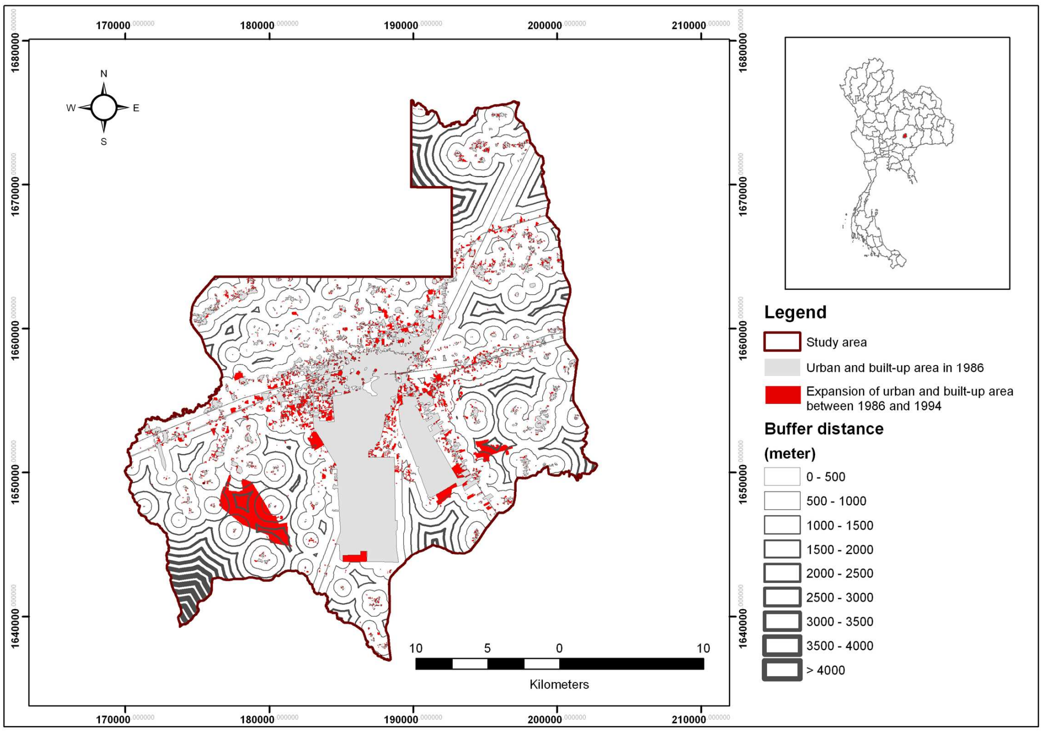


Figure 5.7 Urban expansions between 1986 and 1994.

5.3.2 Urban growth pattern between 1994 and 2002

Between 1994 and 2002 as another short period, urban and built-up area change had increased area of 33.80 sq.km or 5.23% of the study area. At the same time, urban and built-up area in 1994 was expanded in all directions in 2002 with the longest distance of 1.5 km. Most of urban expansion was taken place within equidistance zone of 500 meter (Table 5.9). Distribution of urban expansion between 1994 and 2002 was displayed Figure 5.8.

The urban growth type of Mueang Nakhon Ratchasima district between 1994 and 2002 was expansion growth. According to the annual urban growth rate between 1994 and 2002 of 0.65%, the urban growth seems to be medium-speed expansion.

Table 5.9 Urban expansion for each equidistance zone between 1994 and 2002.

Equidistance zone from urban and built-up area in 1994 (m)	Expansion of urban and built-up area between 1994 and 2002 in each equidistance zone (sq.km)	Percent of new urban and built-up area
500	32.9290	97.4231
1000	0.7310	2.1627
1500	0.1400	0.4142
Total	33.8000	100.0000

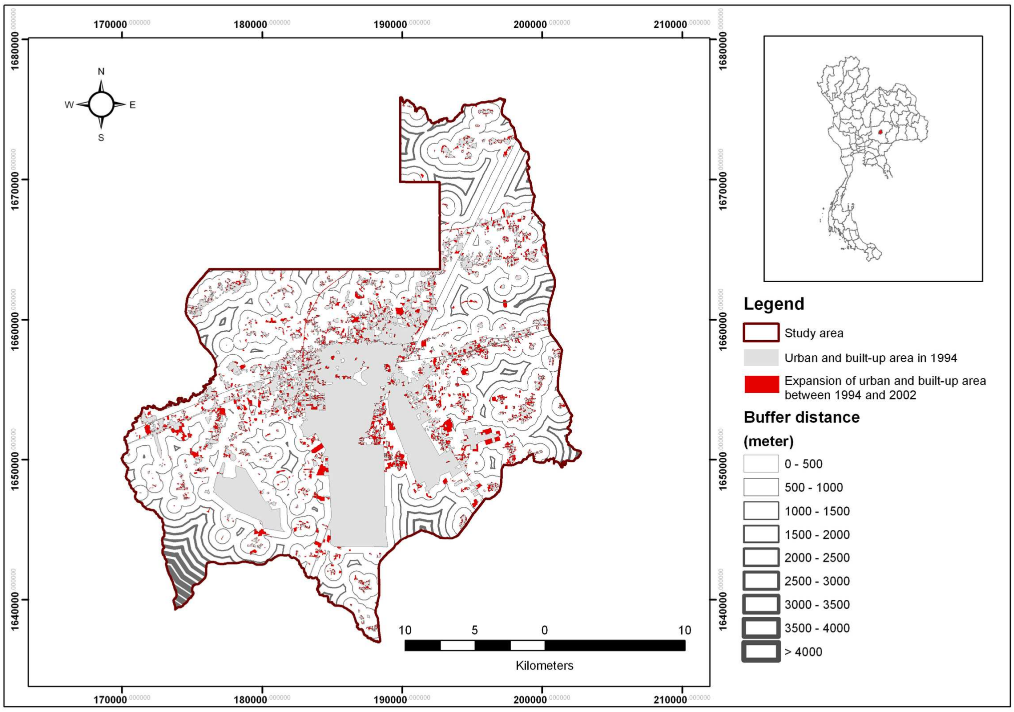


Figure 5.8 Urban expansions between 1994 and 2002.

5.3.3 Urban growth pattern between 1986 and 2002

For long term period (1986-2002), urban and built-up area change between 1986 and 2002 was increased 72.68 sq.km or 11.25% of the study area. At the same time, urban and built-up area in 1986 was expanded in all directions in 2002 with the longest distance of 4 km. Most of urban expansion was taken place within equidistance zone of 500 meter (Table 5.10). Distribution of urban expansion between 1986 and 2002 was displayed Figure 5.9.

The type of urban growth of Mueang Nakhon Ratchasima district between 1986 and 2002 infill growth because non-developed areas being converted at least 40% of existing developed areas. It was found that annual urban growth rate between 1986 and 2002 was 0.70. It indicated urban growth with medium-speed expansion.

Table 5.10 Urban expansion for each equidistance zone between 1986 and 2002.

Equidistance zone from urban and built-up area in 1986 (m)	Expansion of urban and built-up area between 1986 and 2002 in each equidistance zone (sq.km)	Percent of new urban and built-up area
500	55.9841	77.0283
1000	7.0889	9.7535
1500	7.0919	9.7577
2000	2.3921	3.2913
2500	0.0765	0.1052
3000	0.0118	0.0163
3500	0.0028	0.0039
4000	0.0319	0.0438
Total	72.6800	100.0000

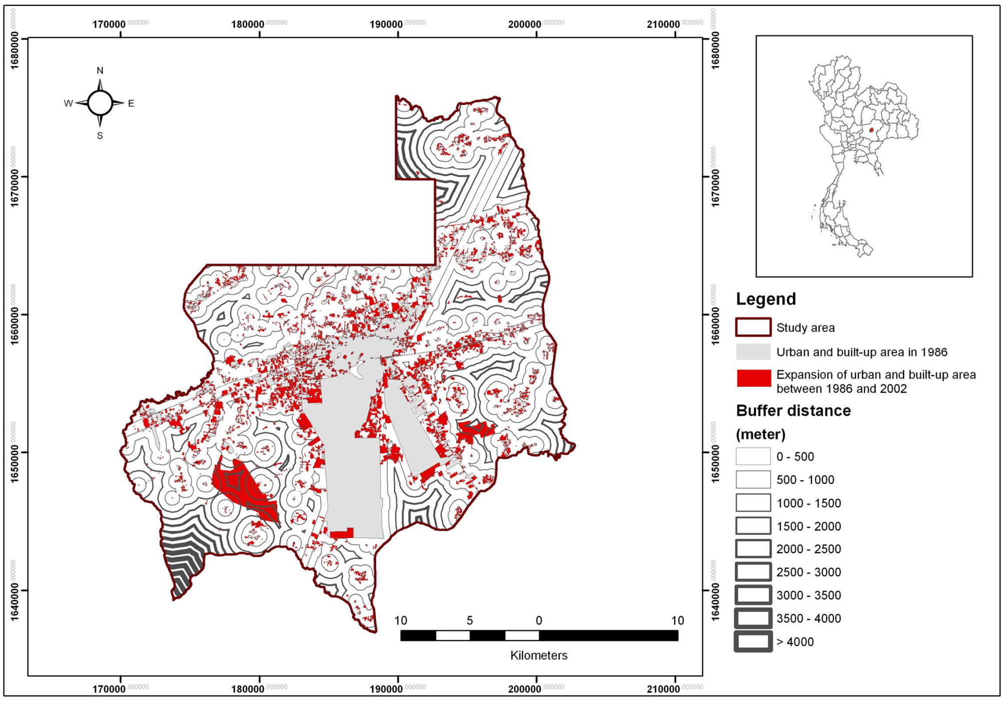


Figure 5.9 Urban expansions between 1986 and 2002.

5.3.4 Urban growth rate by sub-district

Annual growth rate by sub-district in Mueang Nakhon Ratchasima district was here calculated to identify type of urban growth. Table 5.11 presents statistics of the annual growth rate for 25 sub-districts in three periods (1986-1994, 1994-2002, and 1986-2002 while Figure 5.10 to 5.12 shows spatial urban growth rate in each respective year.

In this study, the derived AGR value of Mueang Nakhon Ratchasima district between 1986 and 2002 was used as standard scores to reclassify urban expansion speed. AGR values were divided into five grades using mean and one standard deviation values included: (1) high-speed expansion if AGR > 1.51, (2) fast-speed expansion if 1.04 < AGR ≤ 1.51, (3) medium-speed expansion 0.58 < AGR ≤ 1.04, (4) slow-speed expansion 0.12 < AGR ≤ 0.58, and (5) slow expansion 0 ≤ AGR ≤ 0.12.

Table 5.11 Annual growth rates of district and sub-district.

Name	Annual growth rate		
	Period 1986-1994	Period 1994-2002	Period 1986-2002
District			
Mueang Nakhon Ratchasim	0.75	0.65	0.70
Sub-district			
Nai Mueang	1.53	1.17	1.35
Pho Klang	0.58	0.87	0.73
Nong Chabok	0.81	1.54	1.17
Khok Sung	-	0.25	-
Mareng	0.94	1.46	1.20
Nong Rawiang	0.34	0.67	0.51
Pru Yai	0.83	0.84	0.84
Muen Wai	1.53	1.25	1.39
Phon Krung	-	0.40	-
Nong Phai Lom	0.01	0.05	0.03
Hue Thale	1.60	1.16	1.38
Ban Ko	1.19	1.38	1.28
Ban Mai	1.36	0.78	1.07
Phut Sa	-	0.30	-
Ban Pho	0.34	0.60	0.47
Cho ho	-	0.87	-
Khok Kruat	0.47	0.54	0.50
Chai Mongkhon	0.53	0.29	0.41
Nong Bua Sala	1.19	1.14	1.16
Suranaree	2.42	0.61	1.52
Si Mum	0.14	0.25	0.20
Talat	0.26	0.21	0.24
Pha Nao	0.25	0.63	0.44
Nong Krathum	-	0.79	-
Nong Khai Nam	0.34	0.37	0.35

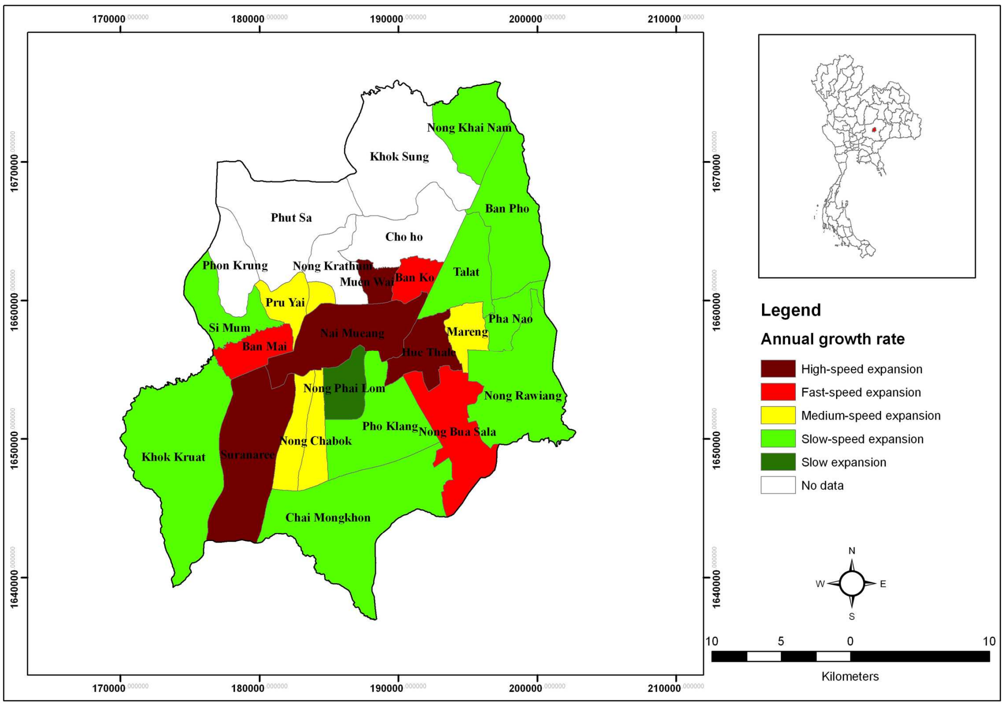


Figure 5.10 Annual growth rates for the period 1986-1994.

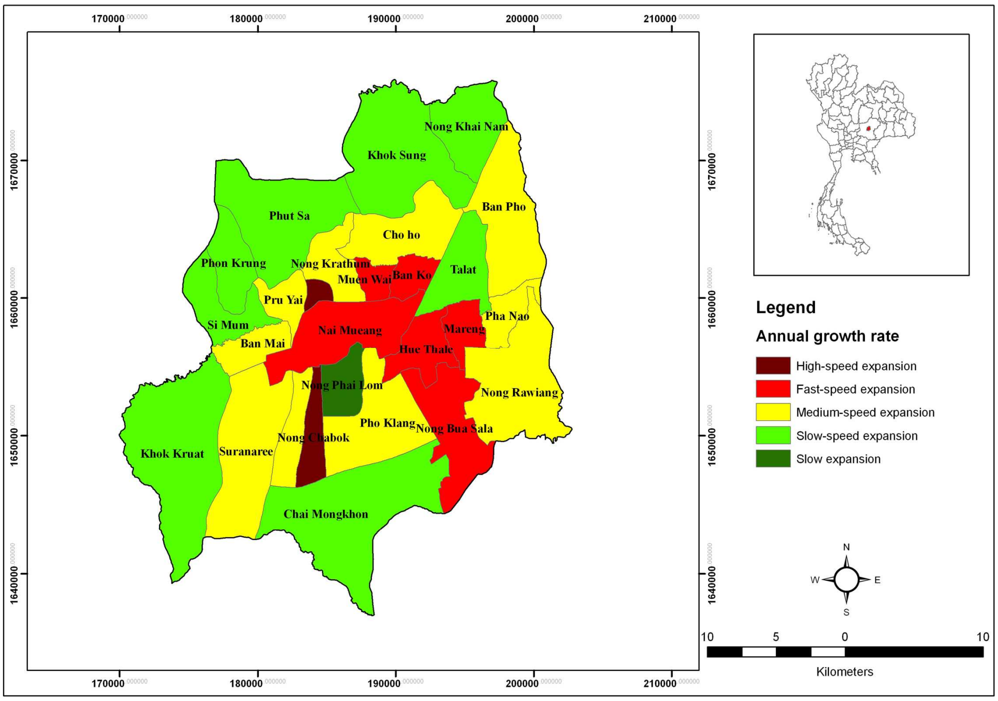


Figure 5.11 Annual growth rates for the period 1994-2002.

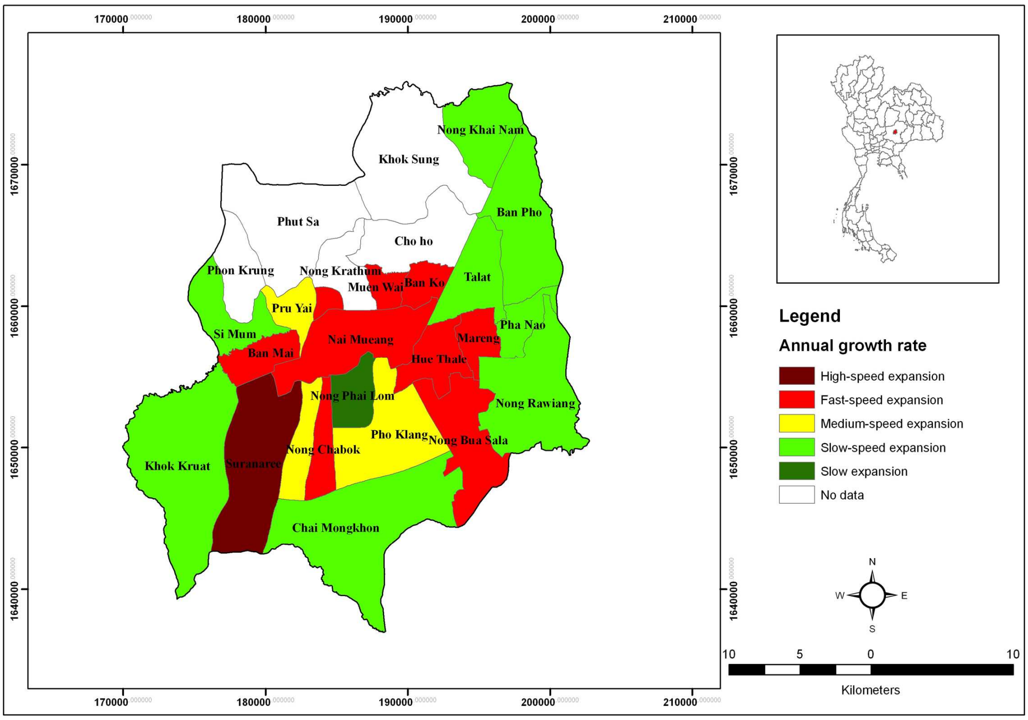


Figure 5.12 Annual growth rates for the period 1986-2002.

As short term period (1986-1994 and 1994-2002), based on annual growth rate of each sub-district and levels of urban speed expansion, it was found that between 1986 and 1994 number of sub-districts with high-speed, fast-speed, medium-speed, slow-speed, and slow were 4, 3, 3, 9, and 1, respectively. This period was excluded 5 sub-districts with no annual growth rate data. In addition, it was found that between 1994 and 2002 number of sub-districts with high-speed, fast-speed, medium-speed, slow-speed, and slow expansion was 1, 6, 9, 8, and 1, respectively.

As long term period (1986-2002), it was found that Suranaree sub-district had high speed expansion with annual growth rates of 1.52. In fact, in 1990 Suranaree University of Technology was established in this sub-district. Based on annual growth rate of each sub-district and level of urban speed expansion, it was found that between 1986 and 2002 number of sub-districts with high-speed, fast-speed, medium-speed, slow-speed, and slow expansion was 1, 8, 2, 8, and 1, respectively. This period was excluded 5 sub-districts with no annual growth rate data. It was here to notice that Nong Phai Lom sub-district had annual growth rate nearly 0 because urban and built-up area in 1986 covered more than 95% of sub-district area.

5.4 Driving force for urban growth

This part was focused to find suitable regression equations to explain the observed change of urban and built-up area. The variables in this study were reviewed and selected based on relevant research papers including Allen and Lu (2003), Hu and Lo (2007), and Luo and Wei (2009).

The variables for analysis driving force for urban growth were summarized as shown in Table 5.12. Each variable were firstly prepared and recoded before performing stepwise regression analysis using SPSS software were here briefly described as follows:

1) Urban growth (UG). Urban growth is the change of urban and built-up area between two years. For example, the urban growth between 1986 and 1994 (UG_{86_94}) is calculated by subtraction of urban and built-up area in 1986 from that in 1994 (Figure 5.13a to 5.13c).

2) Urban and built-up area (URBAN) Only the urban and built-up area from the beginning year of two selected years is extracted and recoded as 1 and other categories are defined as 0 (Figure 5.14a and 5.14b).

3) Agriculture land (AGRI). The agriculture land from the beginning year of two selected years is extracted and recoded as 1 and other categories are defined as 0 (Figures 5.15a and 5.15b).

4) Forest land (FOREST). The forest land from the beginning year of two selected years is extracted and recoded as 1 and other categories are defined as 0 (Figures 5.16a and 5.16b).

5) Water body (WATER). Water body in the beginning year of land use change was extracted and recoded as 1 and others categories as 0 (Figures 5.17a and 5.17b).

6) Miscellaneous land (MISC). Miscellaneous land in the beginning year of land use change was extracted and recoded as 1 and others categories as 0 (Figures 5.18a and 5.18b).

7) Distance to existing urban area (DIST_URBAN). Distance to existing urban area was distance between each cell and the nearest of a set of urban cell. This distance was calculated from not restricted to the urban cell based on urban and built-up in the beginning year (Figures 5.19a and 5.19b).

8) Distance to main roads (DIST_MRD). Distance to main roads was computed by distance from not restricted to main roads based on urban and built-up in end year (Figures 5.20a and 5.20b).

9) Distance to railway station (DIST_TRAIN). Distance to railway station was computed by distance from not restricted to railway station (Figure 5.21).

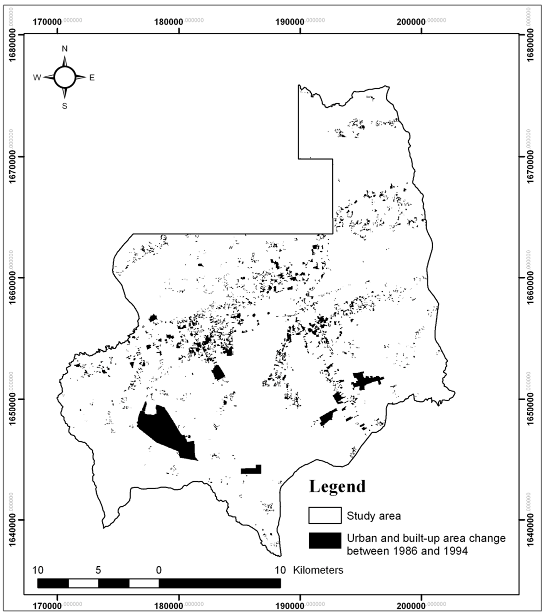
10) Population density (POP_DEN). Population density of each district was calculated based on population data in end year. For example, if we use land use

change between 1986 and 1994, population data in 1994 will be used to calculate population density (Figures 5.22a and 5.22b).

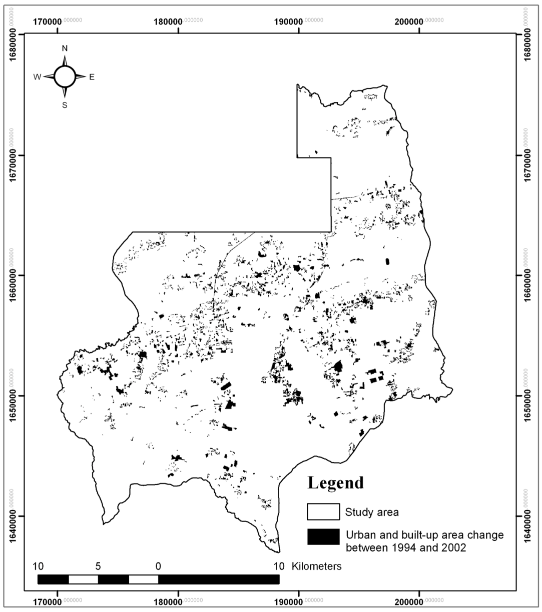
11) Road density (RD_DEN). Road density of each district was calculated using road length of the last year. For example, between 1986 and 1994, the road length in 1994 will be used to calculate the road density (Figures 5.23a and 5.23b).

Table 5.12 List of variables for regression model.

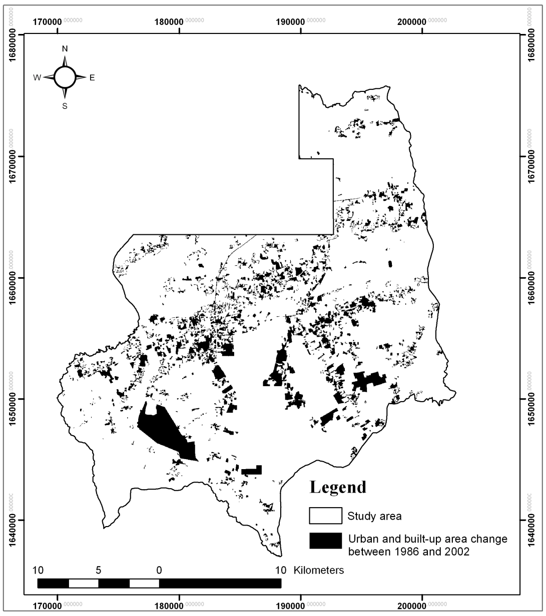
Variable	Meaning	Nature of variable
Dependent		
UG	1 = urban growth; 0 = not urban growth	Dichotomous
Independent		
URBAN	1 = urban and built-up area; 0 = not urban and built-up area	Design
AGRI	1 = agriculture land; 0 = not agriculture land	Design
FOREST	1 = forest land ; 0 = not forest land	Design
WATER	1 = water body ; 0 = not water body	Design
MISC	1 = miscellaneous land ; 0 = not miscellaneous land	Design
DIST_URBAN	Distance to existing urban area	Continuous
DIST_MRD	Distance to main roads	Continuous
DIST_TRAIN	Distance to railway station	Continuous
POP_DEN	Population density (person/km^2)	Continuous
RD_DEN	Road density (m/km^2)	Continuous



(a) Urban growth areas between 1986 and 1994

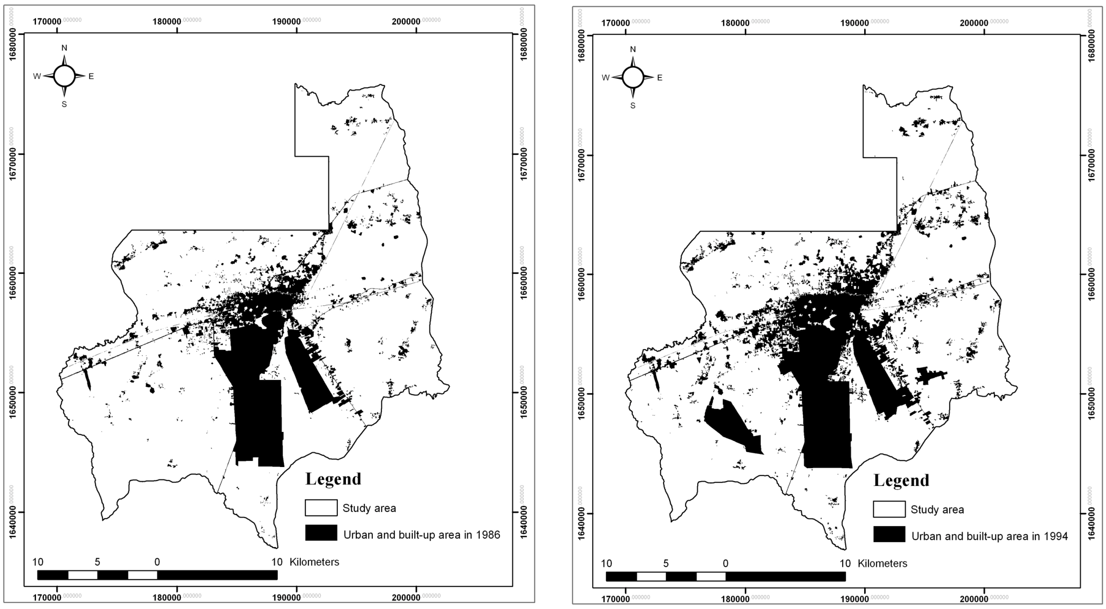


(b) Urban growth areas between 1994 and 2002



(c) Urban growth areas between 1986 and 2002

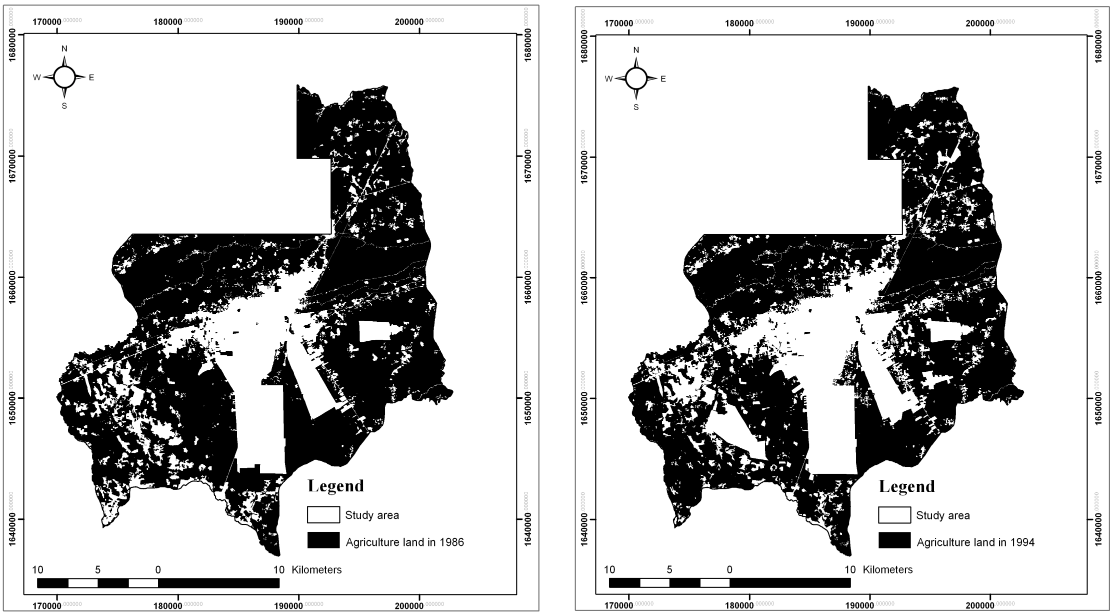
Figure 5.13 Urban growth area in three periods.



(a) Extracted urban and built-up areas in 1986

(b) Extracted urban and built-up areas in 1994

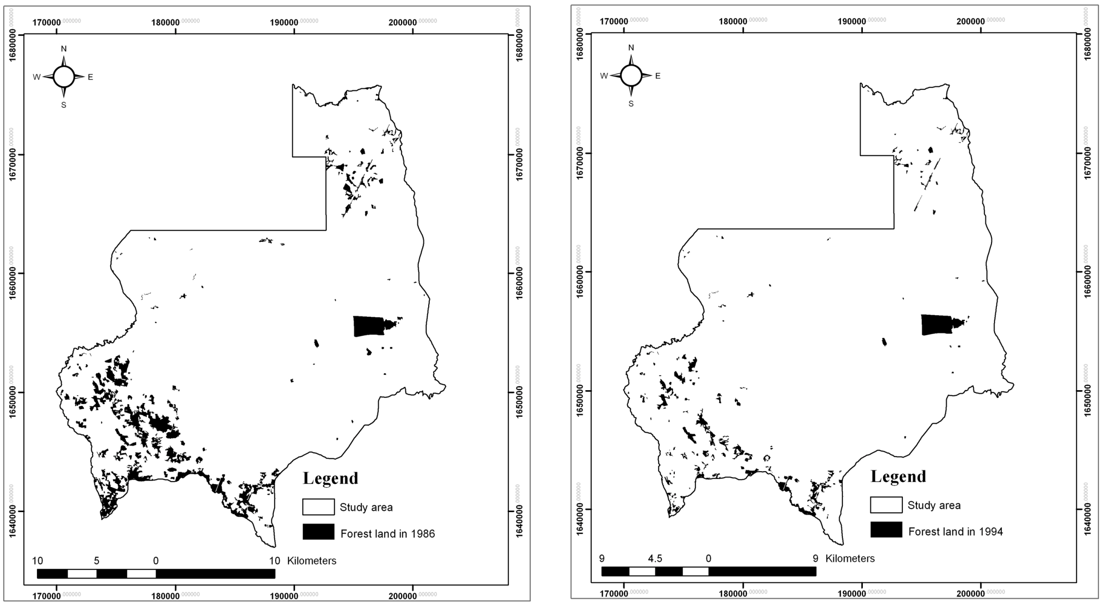
Figure 5.14 Extracted urban and built-up areas.



(a) Extracted agriculture land in 1986

(b) Extracted agriculture land in 1994

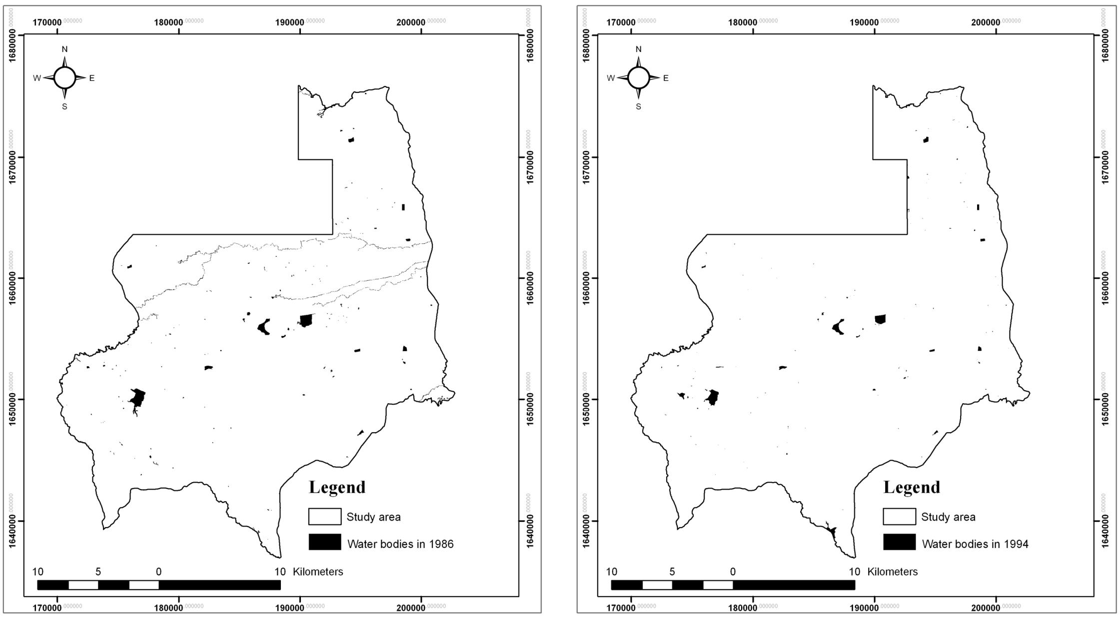
Figure 5.15 Extracted agriculture land.



(a) Extracted forest land in 1986

(b) Extracted forest land in 1994

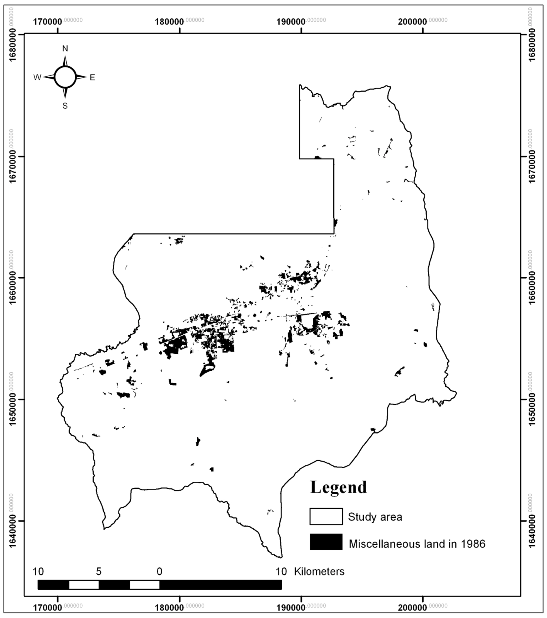
Figure 5.16 Extracted forest land.



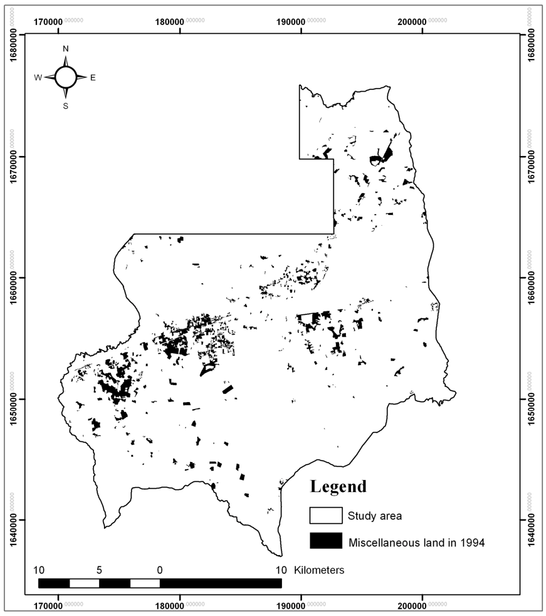
(a) Extracted water bodies in 1986

(b) Extracted water bodies in 1994

Figure 5.17 Extracted water bodies.

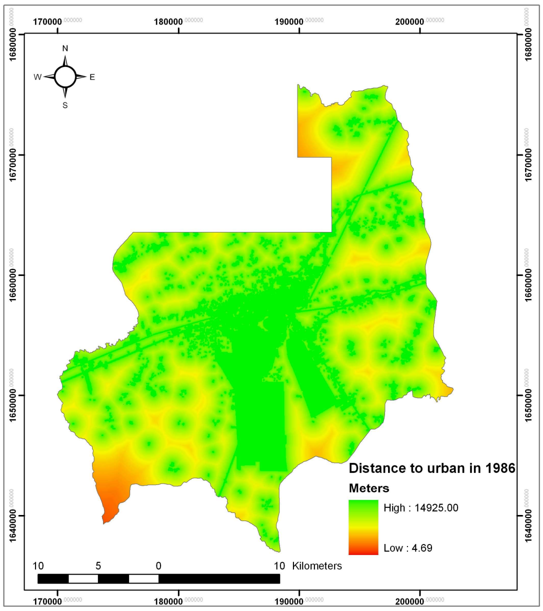


(a) Extracted miscellaneous land in 1986

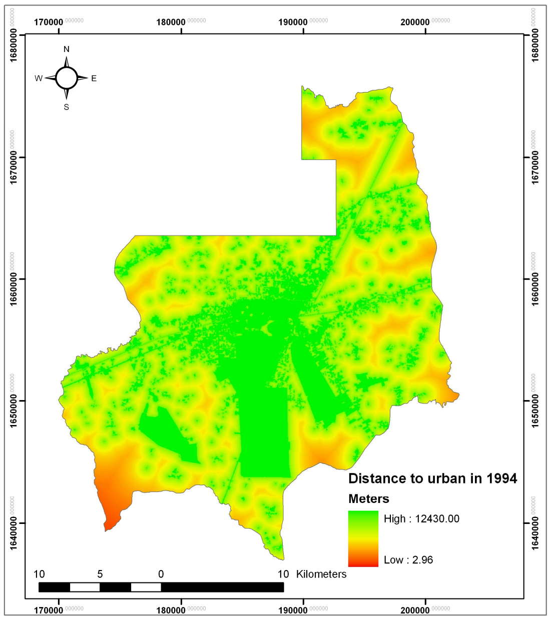


(b) Extracted miscellaneous land in 1994

Figure 5.18 Extracted miscellaneous land.

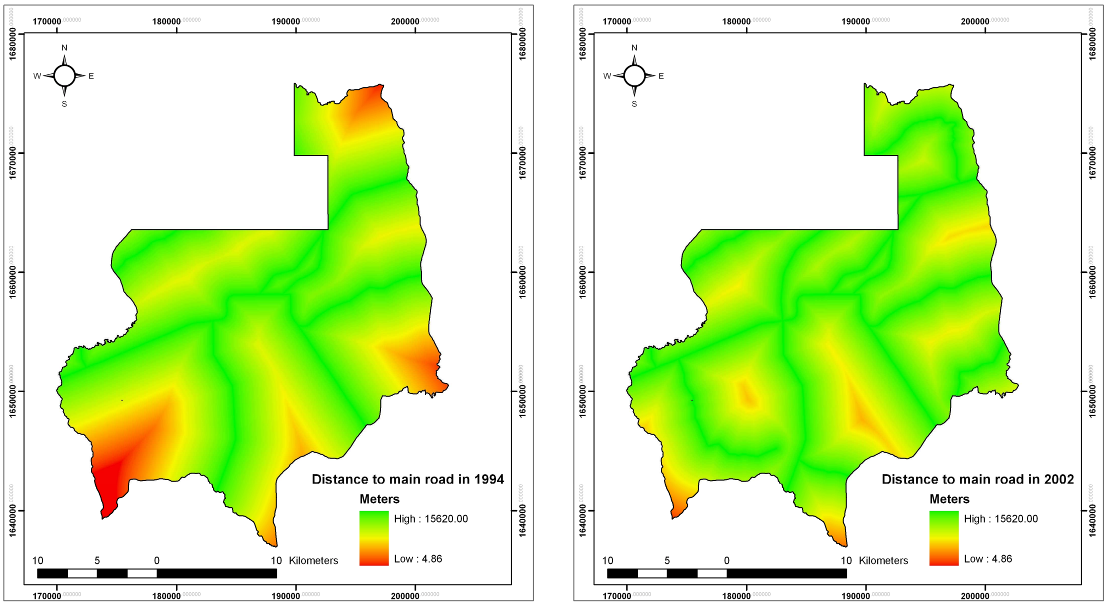


(a) Distance to urban area in 1986



(b) Distance to urban area in 1994

Figure 5.19 Distance to existing urban area.



(a) Distance to main roads in 1994 (b) Distance to main roads in 2002

Figure 5.20 Distance to main roads.

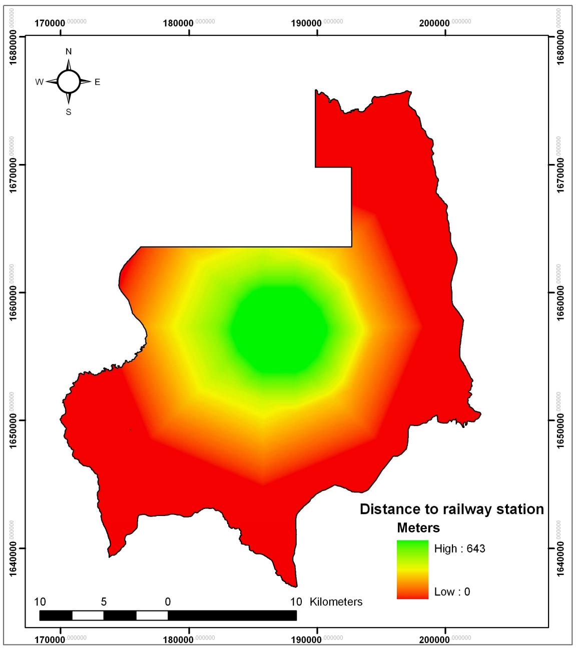


Figure 5.21 Distance to railway station.

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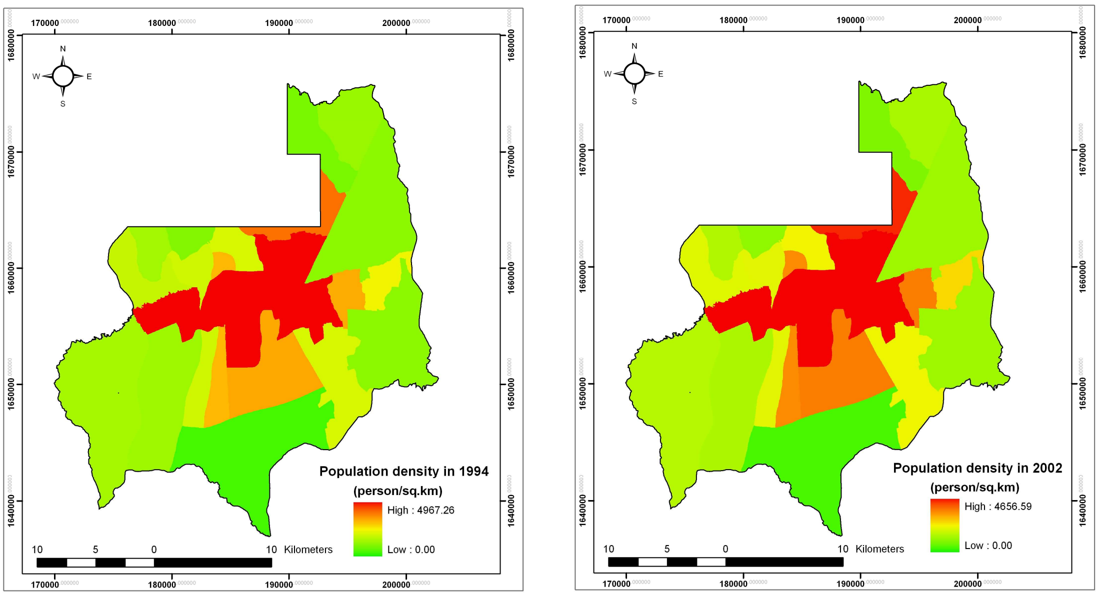
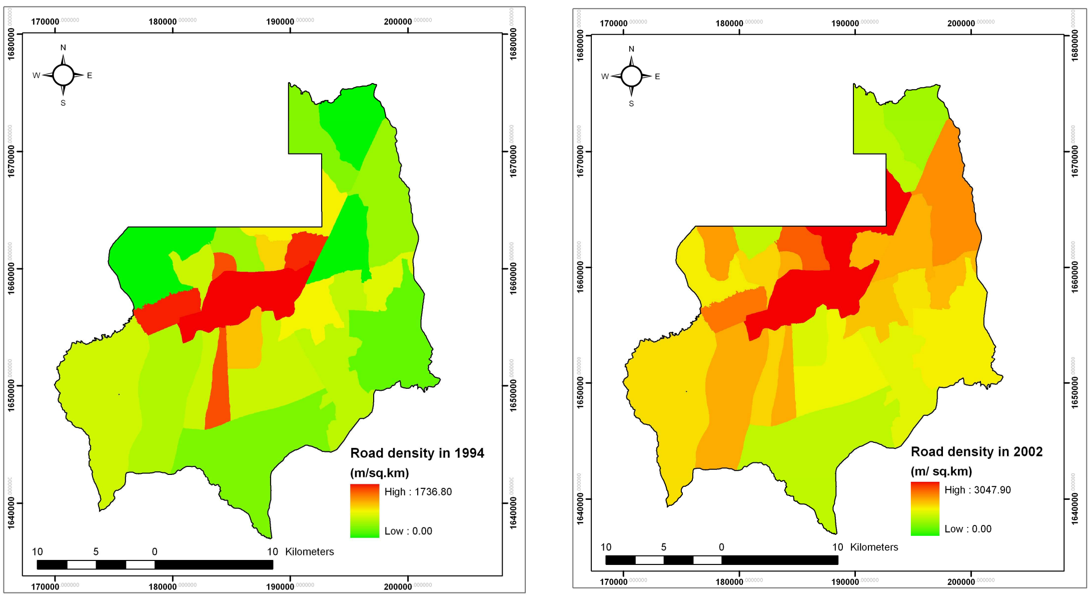


(a) Population density in 1994 (b) Population density in 2002

Figure 5.22 Population density.



(a) Roads density in 1994 (b) Roads density in 2002

Figure 5.23 Roads density.

5.4.1 Driving force for urban growth between 1986 and 1994

Significant predictive variables at 95% with two sides confidence level as driving forces for urban growth between 1986 and 1994 are selected using stepwise algorithm: (1) agriculture land in 1986 ($AGRI_{86}$), (2) miscellaneous land in 1986 ($MISC_{86}$), (3) distance to existing urban area in 1986 ($DIST\_URBAN_{86}$), (4) forest land in 1986 ($FOREST_{86}$), (5) urban and built up area in 1986 ($URBAN_{86}$), (6) population density in 1994 (POP_DEN_{94}), and (7) distance to main road in 1994 ($DIST\_MRD_{94}$) (Table 5.11). The seventh models with these 7 predictors having highest values of R and R^2 is here selected to generate regression equation for explanation of driving forces for urban growth. The regression equation for this period is as follows:

$$UG_{86\_94} = 0.454 + 0.781\ AGRI_{86} + 0.385\ MISC_{86} + 0.193\ DIST\_URBAN_{86} + 0.114\ FOREST_{86} - 0.093\ URBAN_{86} + 0.027\ POP\_DEN_{94} - 0.026\ DIST\_MRD_{94} \quad (5.1)$$

According to Eq. 5.1, it is found that five driving force factors: (1) agriculture land in 1986, (2) miscellaneous land in 1986, (3) distance to existing urban area in 1986, (4) forest land in 1986, and (5) population density in 1994, have positive relationship with the urban growth, while urban and built up area in 1986 and distance to main road provides negative relation with the urban growth. This result seems to be reasonable because recent urban and built-up areas were developed from miscellaneous land and agriculture land. In addition, when Suranaree University of

Technology was established on agriculture lands in 1990, it has induced more urban and built-up area.

As the coefficient (R and R^2) are used to find the most influence driving force for urban growth between 1986 and 1994 (Table 5.13), it is found that the significant driving forces are agriculture land in 1986, miscellaneous land in 1986, distance to existing urban area in 1986, forest land in 1986, and urban and built-up area in 1986.

Table 5.13 Model summary to find significant driving forces for urban growth between 1986 and 1994.

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
1	0.714[a]	0.509	0.509	0.349
2	0.818[b]	0.670	0.670	0.286
3	0.828[c]	0.686	0.686	0.279
4	0.838[d]	0.703	0.702	0.272
5	0.840[e]	0.706	0.706	0.270
6	0.841[f]	0.707	0.706	0.270
7	0.841[g]	0.707	0.707	0.270

Note:
a. Predictors: (Constant), $AGRI_{86}$
b. Predictors: (Constant), $AGRI_{86}$, $MISC_{86}$
c. Predictors: (Constant), $AGRI_{86}$, $MISC_{86}$, $DIST\_URBAN_{86}$
d. Predictors: (Constant), $AGRI_{86}$, $MISC_{86}$, $DIST\_URBAN_{86}$, $FOREST_{86}$
e. Predictors: (Constant), $AGRI_{86}$, $MISC_{86}$, $DIST\_URBAN_{86}$, $FOREST_{86}$, $URBAN_{86}$
f. Predictors: (Constant), $AGRI_{86}$, $MISC_{86}$, $DIST\_URBAN_{86}$, $FOREST_{86}$, $URBAN_{86}$, POP_DEN_{94}
g. Predictors: (Constant), $AGRI_{86}$, $MISC_{86}$, $DIST\_URBAN_{86}$, $FOREST_{86}$, $URBAN_{86}$, POP_DEN_{94}, $DIST\_MRD_{94}$

5.4.2 Driving force for urban growth between 1994 and 2002

Significant predictive variables at 95% with two sides confidence level as driving forces for urban growth between 1994 and 2002 are selected using stepwise algorithm: (1) agriculture land in 1994 ($AGRI_{94}$), (2) miscellaneous land in 1994

($MISC_{94}$), (3) distance to existing urban area in 1994 ($DIST\_URBAN_{94}$), (4) forest land in 1994 ($FOREST_{94}$), (5) urban and built-up area in 1994 ($URBAN_{94}$), (6) road density in 2002 (RD_DEN_{02}), and (7) distance to main road in 2002 ($DIST\_MRD_{02}$) (Table 5.12). The seventh model using 7 predictors has R and R^2 highest values and then is here selected to create regression equation for explanation of driving forces for urban growth. The regression equation for this period is as follows:

$$UG_{94\_02} = 0.476 + 0.804\ AGRI_{94} + 0.427\ MIST_{94} + 0.192\ DIST\_URBAN_{94} + 0.091\ FOREST_{94} - 0.092\ URBAN_{94} + 0.037\ RD\_DEN_{02} - 0.020\ DIST\_MRD_{02} \quad (5.2)$$

According to Eq. 5.2, the mentioned seven driving force factors are used to perform the urban growth models. Among these driving forces five of them: (1) agriculture land in 1994, (2) miscellaneous land in 1994, (3) distance to existing urban area in 1994, (4) forest land in 1994, and (5) road density in 2002 have positive relationship with urban growth. While the other two driving force factors: urban and built-up area in 1994 and distance to main roads in 2002 have negative relation with urban growth. These indicate that urban development in the study area has occurred towards the directions to suburban areas where lands for urban development such as agricultural, forest, and miscellaneous lands are still available. Consequently, the relation of driving force variables with urban growth between two periods can be concluded to have similar patterns.

In addition, if we considered the most influence driving force for urban growth between 1994 and 2002 based on coefficient (R and R^2) in model summary

(Table 5.14), the most significant driving forces are agriculture land in 1994, miscellaneous land in 1994, distance to existing urban area in 1994, forest land in 1994, and urban and built-up area in 1994.

Table 5.14 Model summary to find significant driving forces for urban growth between 1994 and 2002.

Model	R	R^2	Adjusted R^2	Std. Error of the Estimate
1	0.736[a]	0.542	0.542	0.338
2	0.860[b]	0.740	0.740	0.255
3	0.870[c]	0.756	0.756	0.247
4	0.874[d]	0.765	0.764	0.242
5	0.877[e]	0.768	0.768	0.240
6	0.877[f]	0.770	0.769	0.240
7	0.877[g]	0.770	0.770	0.240

Note: a. Predictors: (Constant), $AGRI_{94}$
b. Predictors: (Constant), $AGRI_{86}$, $MISC_{86}$
c. Predictors: (Constant), $AGRI_{94}$, $MISC_{86}$, $DIST\_URBAN_{94}$
d. Predictors: (Constant), $AGRI_{94}$, $MISC_{94}$, $DIST\_URBAN_{94}$, $FOREST_{94}$
e. Predictors: (Constant), $AGRI_{94}$, $MISC_{94}$, $DIST\_URBAN_{94}$, $FOREST_{94}$, $URBAN_{94}$
f. Predictors: (Constant), $AGRI_{94}$, $MISC_{94}$, $DIST\_URBAN_{94}$, $FOREST_{94}$, $URBAN_{94}$, RD_DEN_{02}
g. Predictors: (Constant), $AGRI_{94}$, $MISC_{94}$, $DIST\_URBAN_{94}$, $FOREST_{94}$, $URBAN_{94}$, RD_DEN_{02}, $DIST\_MRD_{02}$

5.4.3 Driving force for urban growth between 1986 and 2002

For long term period study (1986-2002), eight significant predictive variables as driving forces for urban growth are selected using stepwise algorithm: (1) agriculture land in 1986 ($AGRI_{86}$), (2) miscellaneous land in 1986 ($MISC_{86}$), (3) distance to existing urban area in 1986 ($DIST\_URBAN_{86}$), (4) forest land in 1986 ($FOREST_{86}$), (5) urban and built-up area in 1986 ($URBAN_{86}$), (6) population density in 2002 (POP_DEN_{02}), (7) distance to main road in 2002 ($DIST\_MRD_{02}$), and (8) distance to railway station (Table 5.15). For the results, the eighth model with 8 predictors provides the highest values of R and R^2, it is then selected to generate regression equation as follows:

$$UG_{86\_02} = 0.487 + 0.826\ AGRI_{86} + 0.426\ MISC_{86} + 0.202\ DIST\_URBAN_{86} + 0.135\ FOREST_{86} - 0.099\ URBAN_{86} + 0.026\ POP\_DEN_{02} - 0.024\ DIST\_MRD_{02} - 0.013\ DIST\_TRAIN \quad (5.3)$$

According to Eq. 5.3, it was found that five driving force factors: (1) agriculture land in 1986, (2) miscellaneous land in 1986, (3) distance to existing urban area in 1986, (4) forest land in 1986, and (5) population density in 2002 have positive relationship with urban growth. At the same time, urban and built-up area in 1986, distance to main road and distance to railway station have negative relation with urban growth. This result could be acceptable because recent urban and built-up areas in 2002 were developed from miscellaneous land, agriculture land and forest land in 1986.

In addition, if we considered the most influence driving force for urban growth between 1986 and 2002 based on coefficient (R and R^2) in model summary (Table 5.13), it was found that major driving forces were agriculture land in 1986, miscellaneous land in 1986, distance to existing urban area in 1986, forest land in 1986 and urban and built-up area in 1986.

Table 5.15 Model summary to find significant driving forces for urban growth between 1986 and 2002.

Model	**R**	**R^2**	**Adjusted R^2**	**Std. Error of the Estimate**
1	0.747[a]	0.558	0.558	0.332
2	0.868[b]	0.754	0.754	0.248
3	0.879[c]	0.772	0.772	0.239
4	0.891[d]	0.793	0.793	0.227
5	0.893[e]	0.797	0.797	0.225
6	0.893[f]	0.798	0.798	0.225
7	0.894[g]	0.798	0.798	0.225
8	0.894[h]	0.799	0.798	0.225

Note: a. Predictors: (Constant), $AGRI_{86}$
b. Predictors: (Constant), $AGRI_{86}$, $MISC_{86}$
c. Predictors: (Constant), $AGRI_{86}$, $MISC_{86}$, $DIST\_URBAN_{86}$
d. Predictors: (Constant), $AGRI_{86}$, $MISC_{86}$, $DIST\_URBAN_{86}$, $FOREST_{86}$
e. Predictors: (Constant), $AGRI_{86}$, $MISC_{86}$, $DIST\_URBAN_{86}$, $FOREST_{86}$, $URBAN_{86}$
f. Predictors: (Constant), $AGRI_{86}$, $MISC_{86}$, $DIST\_URBAN_{86}$, $FOREST_{86}$, $URBAN_{86}$, POP_DEN_{02}
g. Predictors: (Constant), $AGRI_{86}$, $MISC_{86}$, $DIST\_URBAN_{86}$, $FOREST_{86}$, $URBAN_{86}$, POP_DEN_{02}, $DIST\_MRD_{02}$
h. Predictors: (Constant), $AGRI_{86}$, $MISC_{86}$, $DIST\_URBAN_{86}$, $FOREST_{86}$, $URBAN_{86}$, POP_DEN_{02}, $DIST\_MRD_{02}$, DIST_TRAIN

CHAPTER VI

PREDICTION OF URBAN GROWTH

For this chapter, two urban growth models, CA-Markov and logistic regression models were applied to predict the urban growth in 2002 and then compared their results with the interpreted land use in 2002. After that, the best optimum model will was selected to predict the future urban growth in 2010 and 2018. Four expected outputs will be calculated: (1) urban growth prediction in 2002 using CA-Markov model (2) urban growth prediction in 2002 using logistic regression model, (3) selection of an optimum model for urban growth prediction, and (4) prediction of the future urban growth in 2010 and 2018.

6.1 Urban growth prediction in 2002 using CA-Markov model

Urban growth prediction using CA-Markov was performed under IDRISI software. The Markov module in IDRISI software is capable to generate a transition probability matrix using two land use data as input. This model will provide two outputs concerning a transition areas matrix and a transition probability matrix, able to predict the expected urban growth later.

(1) A transition areas matrix. This expresses the total area expected to change over the projected period.

(2) A transition probability matrix. Transition probabilities indicate the likelihood that a pixel of a given class will change to any other class (or remain the same) during the evolution process.

In this study, land use types in 1986 and 1994 (see Figure 5.1 and 5.2) were used to generate a transition area matrix and a transition probability matrix between 1986 and 1994 as shown in Table 6.1 and Table 6.2, respectively. Then, a transition probability matrix will be applied to create a set of conditional probability data for five major land use types between 1986 and 1994 (Figure 6.1).

After deriving the outputs of Markov model, a transition areas matrix, a set of conditional probability data between 1986 and 1994, and an original land use types in 1994 were exported into CA-Markov module to create predicted land use types in 2002 based on Markov chain analysis and multi-criteria evaluation/multi-objective land allocation routines (Figure 6.2). Table 6.3 summarized area of predicted land use types in 2002. The predicted urban and built-up area in 2002 covers area of 183.29 sq.km as shown in Figure 6.3.

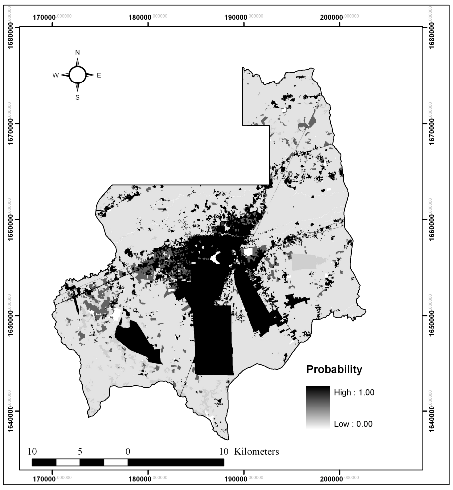
Table 6.1 Transition area matrix for land use change between 1986 and 1994.

Unit: sq.km

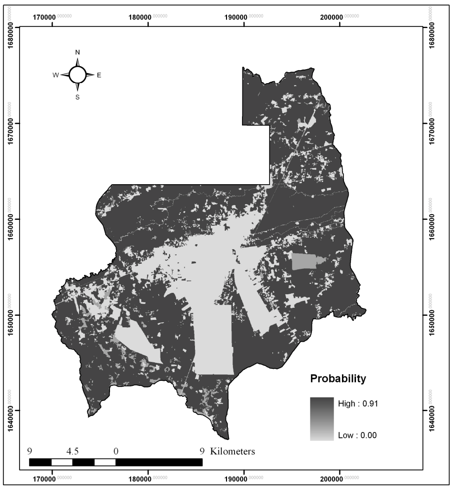
Land use in 1994	Land use types					
	U	**A**	**F**	**W**	**M**	**Total**
Urban and built-up area (U)	144.87	0.00	0.00	0.00	0.00	144.87
Agriculture land (A)	26.24	403.33	0.00	1.25	13.46	444.27
Forest land (F)	1.81	6.09	8.13	0.03	1.65	17.71
Water body (W)	0.03	0.56	0.00	6.05	0.46	7.10
Miscellaneous land (M)	10.34	1.22	0.00	0.24	20.09	31.89
Total	183.29	411.20	8.13	7.57	35.65	645.84

Table 6.2 Transition probability matrix for land use change between 1986 and 1994.

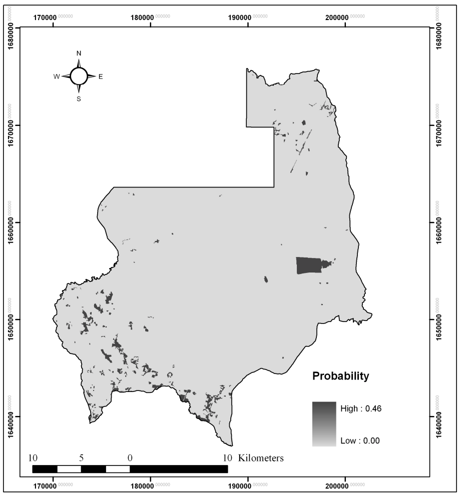
Land use in 1994	Land use types					
	U	**A**	**F**	**W**	**M**	**Total**
Urban and built-up area (U)	1.000	0.000	0.000	0.000	0.000	1.000
Agriculture land (A)	0.059	0.908	0.000	0.003	0.030	1.000
Forest land (F)	0.102	0.344	0.459	0.002	0.093	1.000
Water body (W)	0.004	0.079	0.000	0.852	0.065	1.000
Miscellaneous land (M)	0.324	0.038	0.000	0.008	0.630	1.000



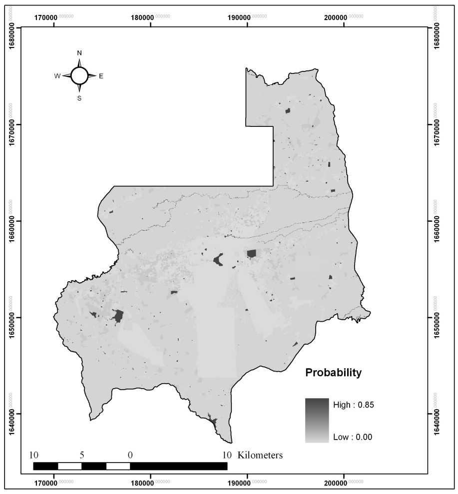
(a) urban and built-up area



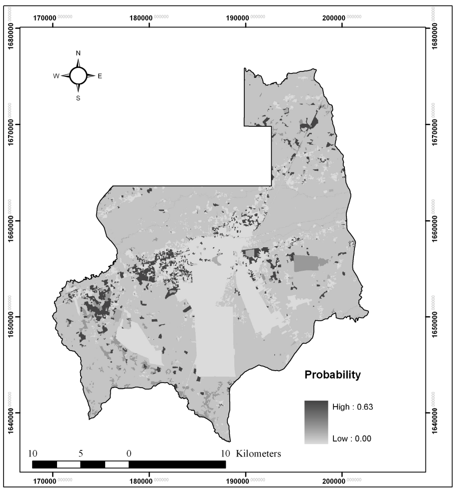
(b) agriculture land



(c) forest land



(d) water body



(e) miscellaneous land

Figure 6.1 Condition probabilities of five land use types (1986-1994).

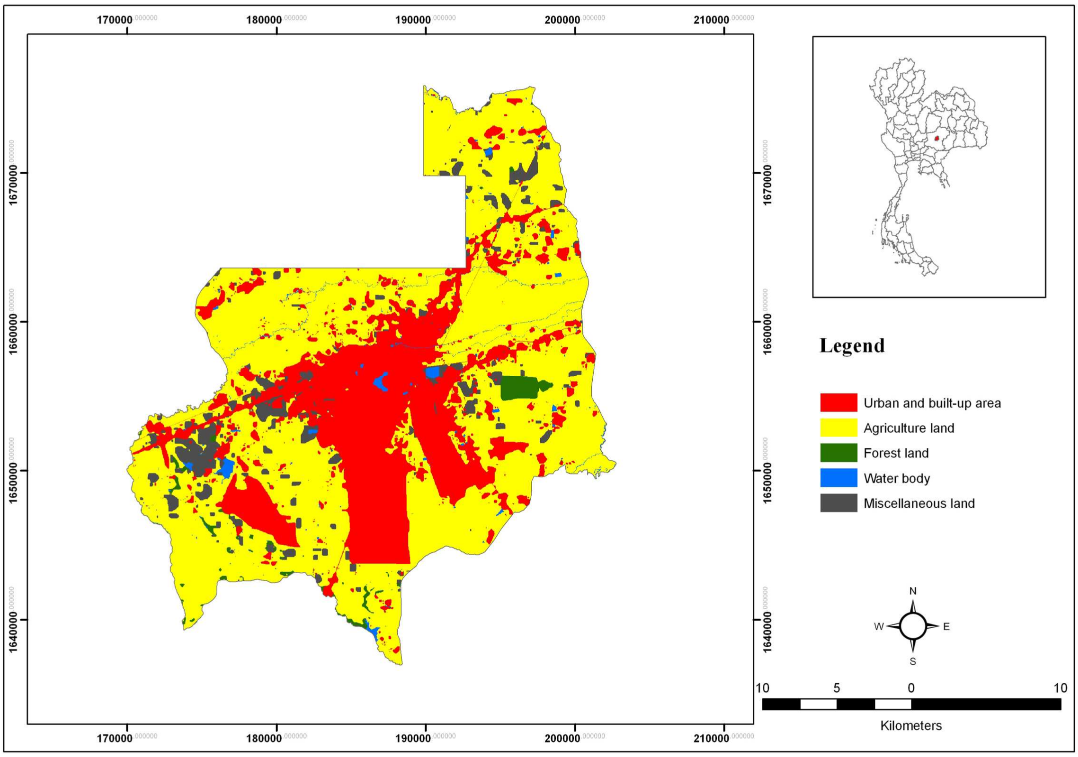


Figure 6.2 Predicted land use types in 2002 by CA-Markov model.

Table 6.3 Area and percentage of predicted land use types in 2002.

Land use types	**Area in sq.km**	**Percentage**
Urban and built-up area	183.29	28.38
Agriculture land	411.20	63.67
Forest land	8.13	1.26
Water body	7.57	1.17
Miscellaneous land	35.65	5.52
Total	645.84	100.00

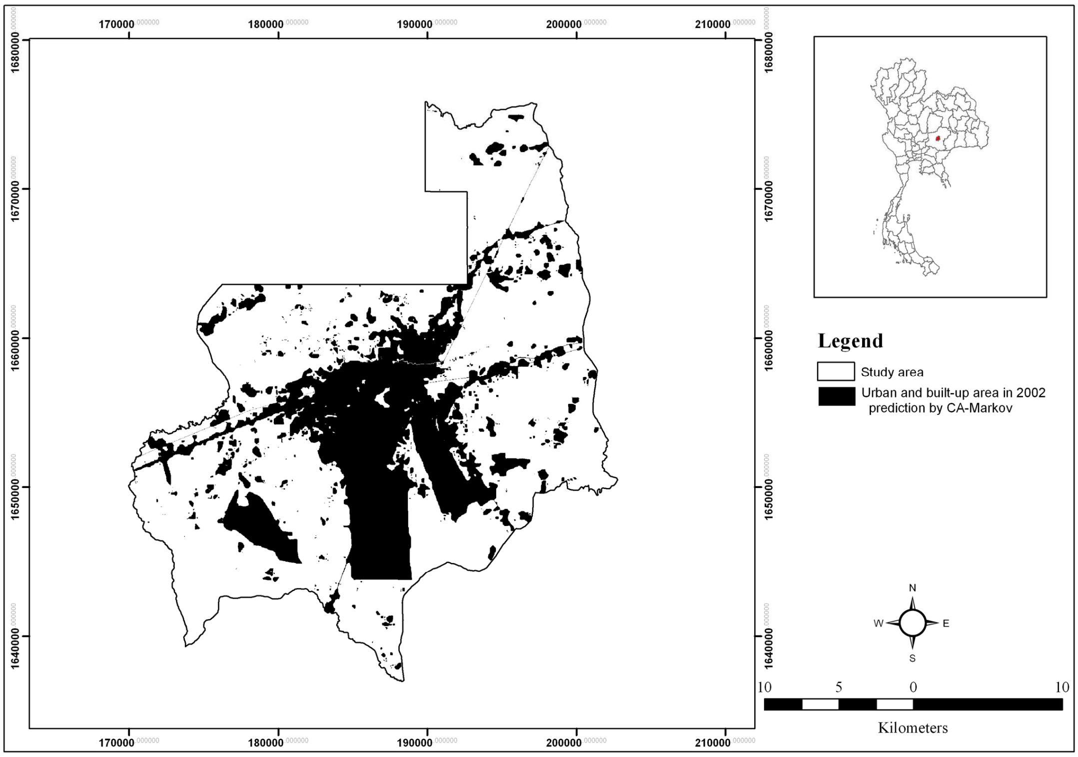


Figure 6.3 Predicted urban and built-up areas in 2002 by CA-Markov model.

6.2 Urban growth prediction in 2002 using logistic regression model

A logistic regression model is used to associate urban growth with driving force factors and to generate an urban growth probability data. Herewith, urban growth equation (Eq. 5.1) with 7 driving force factors was used as initial equation for logistic regression model. Predicted urban change between 1986 and 1994 is an output from model, having probability values between 0.12 and 0.82. Histogram of probability value for urban growth between 1986 and 2002 was shown in Table 6.4 while probability value of predictive urban growth between 1986 and 2002 was displayed in Figure 6.4.

Table 6.4 Histogram of probability value for urban growth.

Lower Limit	Upper Limit	Frequency	Area (sq.km)
0.11	0.12	14	0.01
0.12	0.13	302	0.19
0.13	0.14	372	0.23
0.14	0.15	571	0.36
0.15	0.16	598	0.37
0.16	0.17	569	0.36
0.17	0.18	404	0.25
0.18	0.19	429	0.27
0.19	0.20	341	0.21
0.20	0.21	534	0.33
0.21	0.22	574	0.36
0.22	0.23	506	0.32
0.23	0.24	601	0.38
0.24	0.25	389	0.24
0.25	0.26	403	0.25
0.26	0.27	103,676	64.80
0.27	0.28	33,777	21.11
0.28	0.29	35,576	22.24
0.29	0.30	2,565	1.60
0.30	0.31	2,621	1.64
0.31	0.32	2,796	1.75
0.32	0.33	2,446	1.53
0.33	0.34	3,212	2.01
0.34	0.35	3,181	1.99
0.35	0.36	5,014	3.13
0.36	0.37	5,959	3.72
0.37	0.38	6,786	4.24
0.38	0.39	5,948	3.72
0.39	0.40	5,887	3.68
0.40	0.41	5,927	3.70
0.41	0.42	5,720	3.58
0.42	0.43	3,728	2.33
0.43	0.44	1,411	0.88
0.44	0.45	387	0.24
0.45	0.46	379	0.24
0.46	0.47	503	0.31
0.47	0.48	498	0.31
0.48	0.49	378	0.24
0.49	0.50	465	0.29

Table 6.4 Histogram of probability value for urban growth (Continued).

Lower Limit	Upper Limit	Frequency	Area (sq.km)
0.50	0.51	656	0.41
0.51	0.52	853	0.53
0.52	0.53	817	0.51
0.53	0.54	983	0.61
0.54	0.55	1,280	0.80
0.55	0.56	1,491	0.93
0.56	0.57	1,726	1.08
0.57	0.58	1,944	1.22
0.58	0.59	2,420	1.51
0.59	0.60	3,052	1.91
0.60	0.61	3,778	2.36
0.61	0.62	4,874	3.05
0.62	0.63	6,569	4.11
0.63	0.64	10,269	6.42
0.64	0.65	16,090	10.06
0.65	0.66	23,947	14.97
0.66	0.67	33,146	20.72
0.67	0.68	46,065	28.79
0.68	0.69	61,485	38.43
0.69	0.70	80,458	50.29
0.70	0.71	99,809	62.38
0.71	0.72	135,888	84.93
0.72	0.73	159,381	99.61
0.73	0.74	42,901	26.81
0.74	0.75	14,003	8.75
0.75	0.76	1,036	0.65
0.76	0.77	1,494	0.93
0.77	0.78	2,226	1.39
0.78	0.79	4,897	3.06
0.79	0.80	13,353	8.35
0.80	0.81	1,896	1.19
0.81	0.82	9,108	5.69

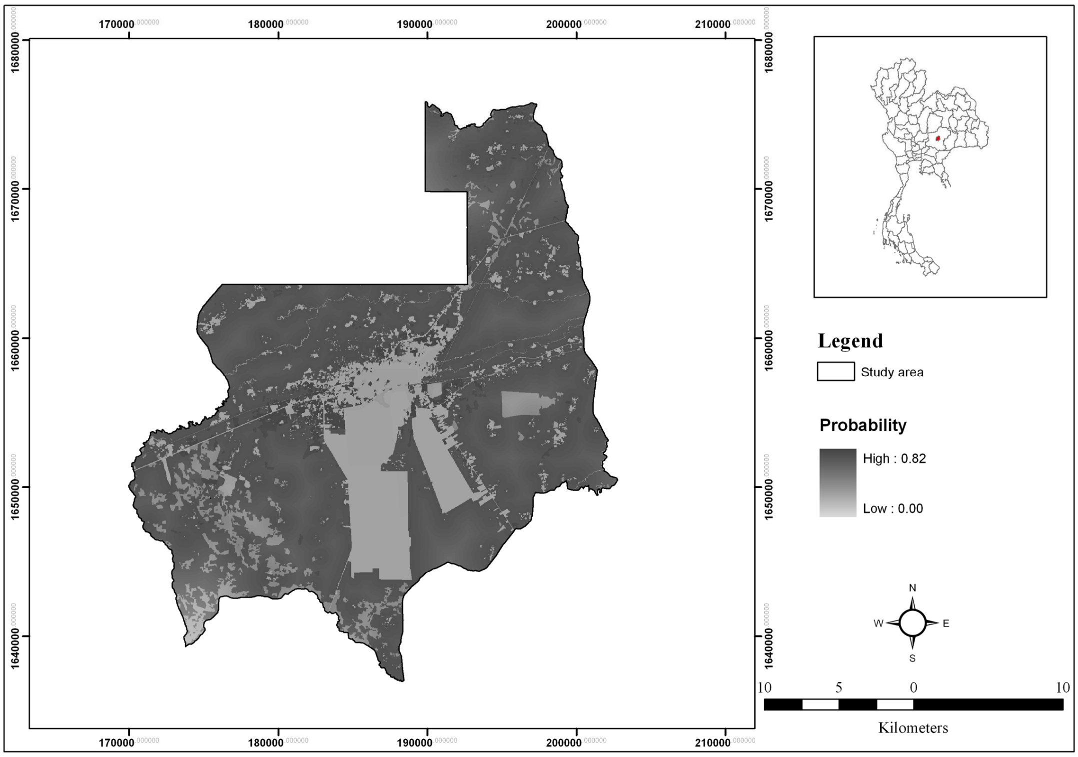


Figure 6.4 Probability value of predictive urban growth by logistic regression model.

It is important to note that the output of the logistic regression is continuous data as probability value while the output of the CA-Markov is discrete data as integer data. Yang, Skidmore, Melick, Zhou, and Xu (2006) suggested sensitivity analysis for identifying optimum probability values of urbanization in order to convert continuous data to discrete data (presence or absence value) by using threshold technique.

In this study, probability values for urban growth (0.11-0.82) were firstly used to extract the predictive urban and built-up area in 2002. After that we compared this predictive result with the interpreted urban and built-up area in 2002 using overall accuracy and kappa analysis assessment. These two accuracy assessment methods and the probability values for urban growth are calculated to derive a threshold value setting (Table 6.5 and Figure 6.5). The best threshold value with high overall accuracy and kappa hat coefficient of agreement is 0.79 which is used to generate the predictive urban and built-up area in 2002 (Figure 6.6). The areas of urban and built-up area and non-urban and built-up area in 2002 are 121.21 sq.km and 524.63 sq.km, respectively.

In addition, it should be noted that the predicted urban and built-up areas based on logistic regression model has 37% under estimate because this model used only the urban and built-up area in 1986 for prediction of probability data. As in 1986, Suranaree University of Technology had not been yet established, thus logistic regression model could not predict this part.

Table 6.5 Overall accuracy and Kappa hat coefficient of agreement for each probability value.

Threshold	Overall accuracy	Kappa	Kappa (%)
0.12	27.67	0.00	0.00
0.13	27.69	0.00	0.00
0.14	27.73	0.00	0.00
0.15	27.79	0.00	0.00
0.16	27.84	0.00	0.00
0.17	27.94	0.00	0.00
0.18	27.94	0.00	0.00
0.19	28.01	0.00	0.00
0.20	28.01	0.00	0.00
0.21	28.07	0.00	0.00
0.22	28.12	0.00	0.00
0.23	28.17	0.00	0.00
0.24	28.23	0.00	0.00
0.25	28.27	0.00	0.00
0.26	28.30	0.00	0.00
0.27	28.36	0.01	1.00
0.28	28.46	0.01	1.00
0.29	28.64	0.01	1.00
0.30	28.88	0.01	1.00
0.31	29.13	0.01	1.00
0.32	29.40	0.01	1.00
0.33	29.62	0.02	2.00
0.34	29.84	0.02	2.00
0.35	30.01	0.02	2.00

Table 6.5 Overall accuracy and Kappa hat coefficient of agreement for each probability value (Continued).

Threshold	Overall accuracy	Kappa	Kappa (%)
0.36	30.28	0.02	2.00
0.37	30.65	0.02	2.00
0.38	31.11	0.02	2.00
0.39	31.53	0.02	2.00
0.40	31.95	0.03	3.00
0.41	32.40	0.03	3.00
0.42	32.83	0.03	3.00
0.43	33.12	0.03	3.00
0.44	33.24	0.03	3.00
0.45	33.24	0.03	3.00
0.46	33.28	0.03	3.00
0.47	33.33	0.04	4.00
0.48	33.37	0.04	4.00
0.49	33.41	0.04	4.00
0.50	33.45	0.04	4.00
0.51	33.51	0.04	4.00
0.52	33.59	0.04	4.00
0.53	33.67	0.04	4.00
0.54	33.76	0.04	4.00
0.55	33.89	0.04	4.00
0.56	34.03	0.04	4.00
0.57	34.20	0.04	4.00
0.58	34.38	0.04	4.00
0.59	34.62	0.05	5.00
0.60	34.90	0.05	5.00
0.61	35.26	0.05	5.00
0.62	35.73	0.06	6.00
0.63	36.36	0.06	6.00
0.64	37.22	0.07	7.00
0.65	38.47	0.08	8.00
0.66	40.26	0.09	9.00
0.67	42.90	0.11	11.00
0.68	46.86	0.14	14.00
0.69	52.22	0.20	20.00
0.70	59.27	0.27	27.00
0.71	67.78	0.38	38.00
0.72	78.53	0.53	53.00
0.73	87.22	0.67	67.00
0.74	88.57	0.69	69.00
0.75	88.92	0.70	70.00
0.76	88.97	0.70	70.00
0.77	89.10	0.70	70.00
0.78	89.22	0.70	70.00
0.79	89.41	0.71	71.00
0.80	89.26	0.70	70.00
0.81	89.25	0.69	69.00

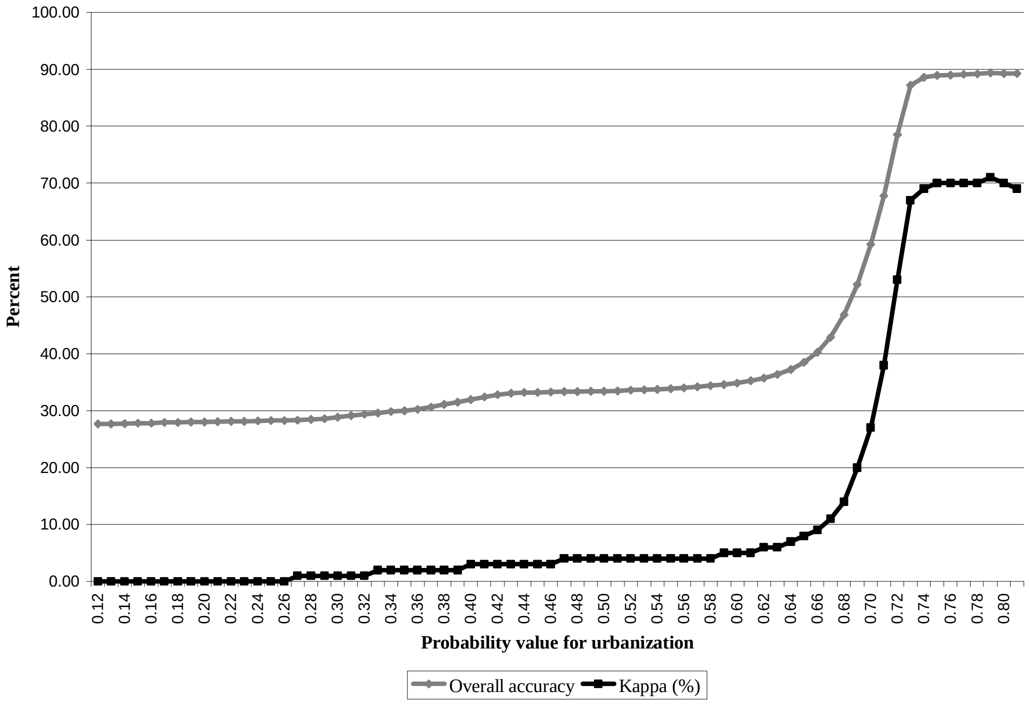


Figure 6.5 Relationship between overall accuracy and kappa hat coefficient (%) of predictive urban and built-up area in 2002 and probability values for urban growth.

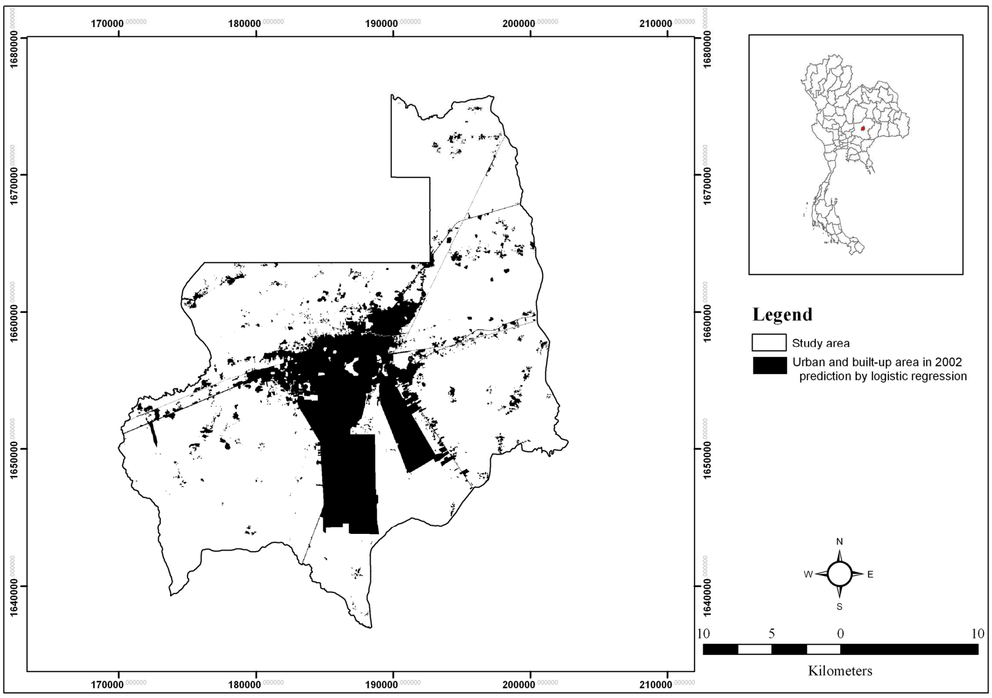


Figure 6.6 Predicted urban and built-up areas in 2002 by logistic regression model.

6.3 Optimum models for urban growth prediction

The predicted urban and built-up areas resulted from CA-Markov and logistic regression model for urban growth prediction in 2010 and 2018 was here justified based on accuracy assessment of predictive urban and built-up area in 2002 from CA-Markov and logistic regression models with an interpreted urban and built-up area in 2002.

It was found that overall accuracy and Kappa hat coefficient of agreement for predictive urban and built-up area in 2002 using CA-Markov model was 93.41% and 0.84, respectively (Table 6.6). At the meantime, overall accuracy and Kappa hat coefficient of agreement for predictive urban and built-up area in 2002 using logistic regression model was 89.41% and 0.71, respectively (Table 6.7). Therefore, CA-Markov model that provides higher overall accuracy and Kappa hat efficient of agreement will be here used for urban growth prediction in 2010 and 2018.

Table 6.6 Accuracy assessment of CA-Markov model for predictive urban growth in 2002.

Unit: sq.km

CA-Markov	**Visual interpretation**		**Total**
	Urban and Built-up area	**Non-Urban and Built-up area**	
Urban and Built-up area	159.67	23.58	**183.25**
Non-Urban and Built-up area	19.00	443.59	**462.59**
Total	**178.67**	**467.17**	**645.84**

Note for accuracy assessment:
1. Overall accuracy = 93.41%
2. Kappa hat coefficient of agreement 0.84

Table 6.7 Accuracy assessment of logistic regression model for predictive urban growth in 2002.

Unit: sq.km

Logistic regression	Visual interpretation		Total
	Urban and Built-up area	Non-Urban and Built-up area	
Urban and Built-up area	115.75	5.46	**121.21**
Non-Urban and Built-up area	62.92	461.71	**524.63**
Total	**178.67**	**467.17**	**645.84**

Note for accuracy assessment:
1. Overall accuracy = 89.41%
2. Kappa hat coefficient of agreement 0.71

6.4 Prediction of urban growth in 2010 and 2018

Refer to section 6.3, CA-Markov model provided higher overall accuracy and Kappa hat coefficient of agreement than logistic regression model, thus CA-Markov is here selected to predict the urban growth in 2010 and 2018, following these steps.

6.4.1 Prediction of urban growth in 2010

In practice, land use types in 1994 and 2002 (see Figure 5.2 and 5.3, respectively) were used to generate a transition areas matrix and a transition probability matrix between 1994 and 2002 (Table 6.8 and Table 6.9, respectively). Then, a transition probability matrix will be applied to create a set of conditional probability data for land use types between 1994 and 2002 (Figure 6.7). Then, derived output of Markov model included transition areas matrix, set of condition probability data between 1994 and 2002, and an original land use types in 2002 were exported into CA-Markov to generate predicted land use types in 2010 based on Markov chain analysis and multi-criteria evaluation/multi-objective land allocation routines (Figure

6.8). Table 6.10 summarized area of predicted land use types in 2010. The predicted urban and built-up area in 2010 covers area of 226.98 sq.km.

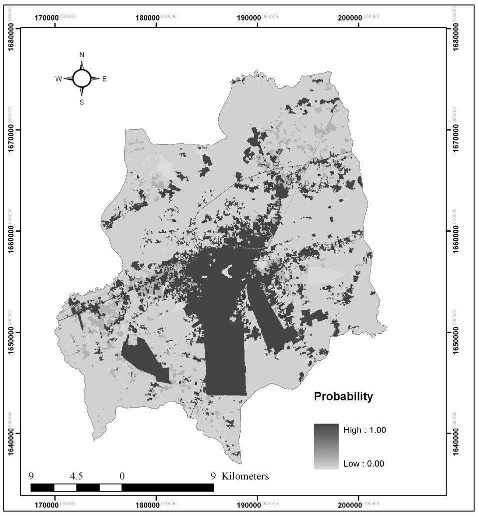
Table 6.8 Transition area matrix for land use change between 1994 and 2002.

Unit: sq.km

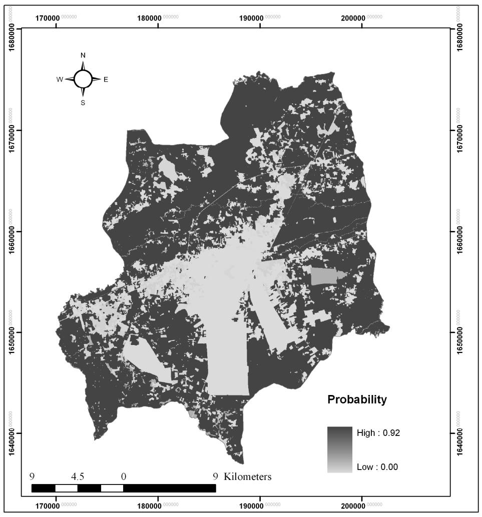
Land use in 2002	Land use types					
	U	**A**	**F**	**W**	**M**	**Total**
Urban and built-up area (U)	190.66	0.00	0.00	0.00	0.00	190.66
Agriculture land (A)	27.24	456.68	0.00	1.78	10.67	496.37
Forest land (F)	0.22	2.49	6.33	0.04	1.83	10.90
Water body (W)	0.00	0.40	0.00	12.44	0.38	13.21
Miscellaneous land (M)	8.85	2.08	0.00	1.15	28.83	40.91
Total	226.98	461.64	6.33	15.40	41.71	752.06

Table 6.9 Transition probability matrix for land use change between 1994 and 2002.

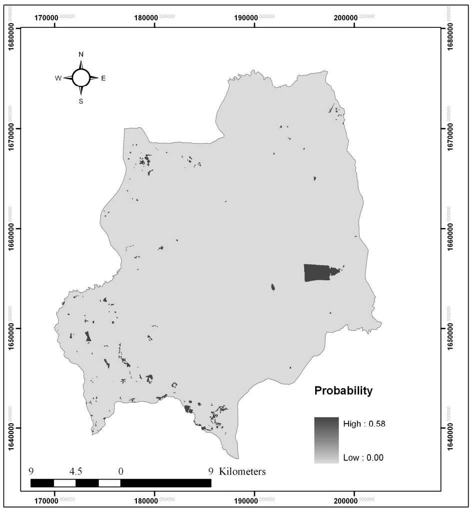
Land use in 2002	Land use types					
	U	**A**	**F**	**W**	**M**	**Total**
Urban and built-up area (U)	1.000	0.000	0.000	0.000	0.000	1.000
Agriculture land (A)	0.055	0.920	0.000	0.004	0.021	1.000
Forest land (F)	0.020	0.228	0.580	0.004	0.168	1.000
Water body (W)	0.000	0.030	0.000	0.942	0.028	1.000
Miscellaneous land (M)	0.216	0.051	0.000	0.028	0.705	1.000



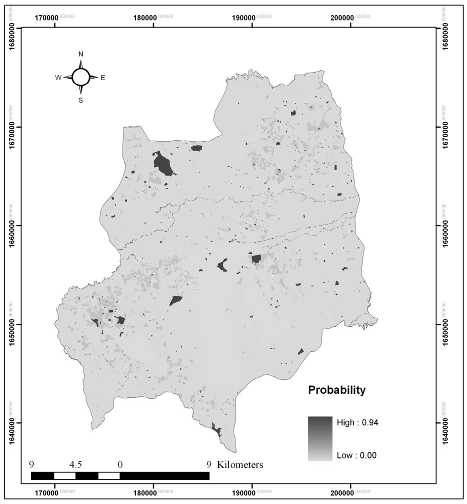
(a) urban and built-up area



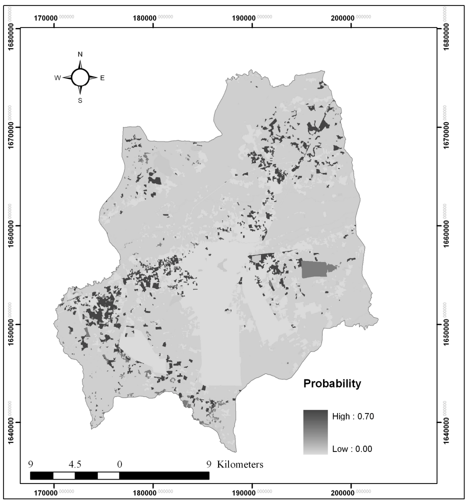
(b) agriculture land



(c) forest land



(d) water body



(e) miscellaneous land

Figure 6.7 Condition probabilities of five land use types (1994-2002).

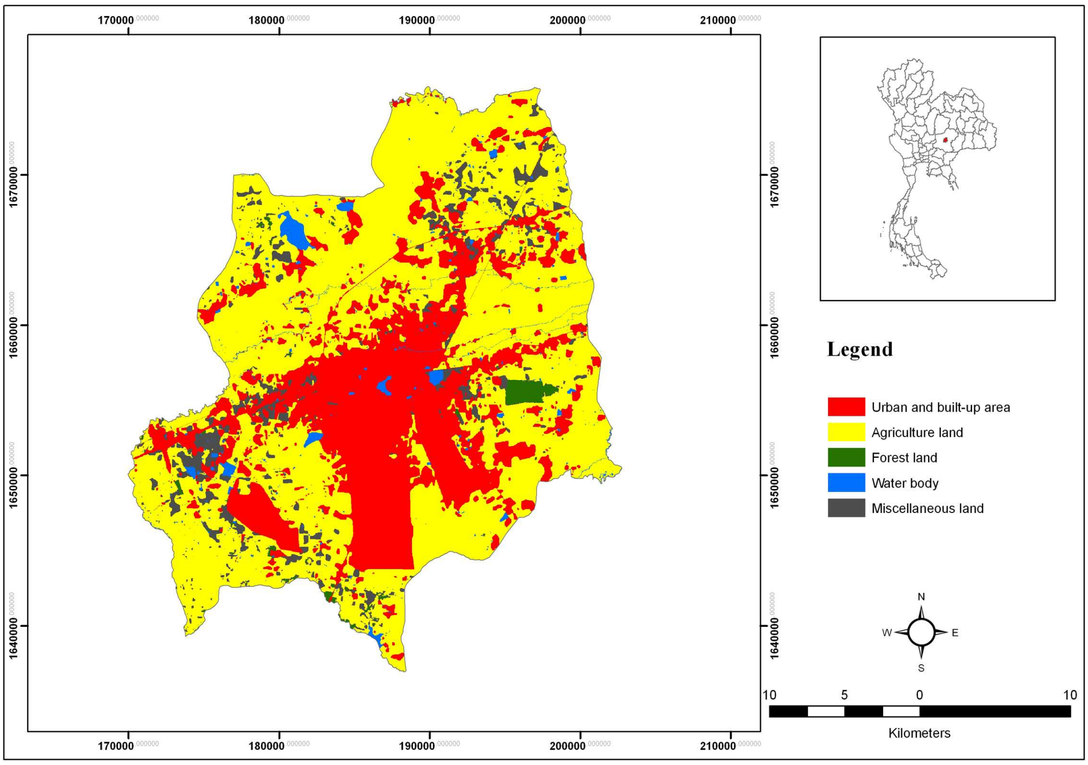


Figure 6.8 Predicted land use types in 2010 by CA-Markov model.

Table 6.10 Area and percentage of predicted land use types in 2010.

Land use types	**Area in sq.km**	**Percentage**
Urban and built-up area	226.98	30.18
Agriculture land	461.64	61.38
Forest land	6.33	0.84
Water body	15.40	2.05
Miscellaneous land	41.71	5.55
Total	**752.06**	**100.00**

Furthermore, accuracy assessment of predicted land use types in 2010 was calculated included overall accuracy and Kappa analysis. Herein, the predicted land use types in 2010 were evaluated with the ground reference data in 2010. There were 127 randomly stratified sampling points based on multinomial distribution theory with desired level of confident 90 percent and a precision of 10 percent (Figure 6.9). The error matrix between predicted land use types in 2010 and the reference land use data from field survey was shown in Table 6.11. It was found that the overall accuracy was 90.55% and Kappa hat coefficient of agreement was 0.86.

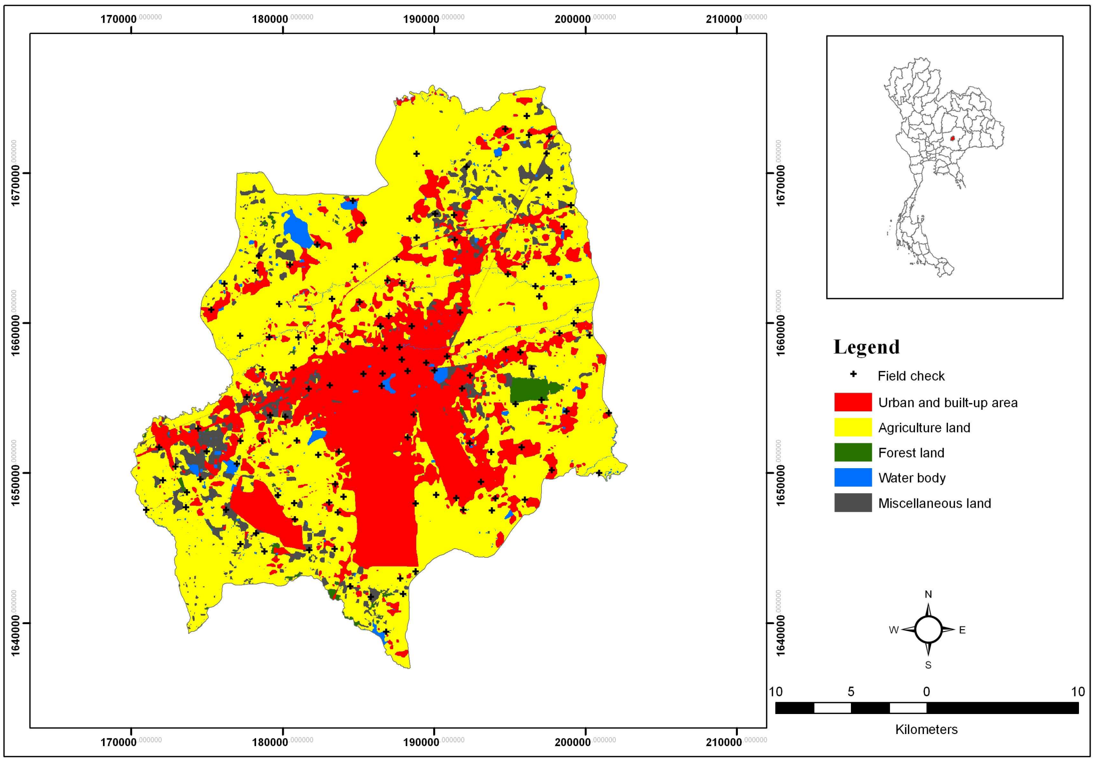


Figure 6.9 Distribution of sampling points over predicted land use types in 2010.

Table 6.11 Error matrix for accuracy assessment of predicted land use types in 2010.

Unit: pixel

Predicted land use types By CA-Markov	Reference Data					
	U	**A**	**F**	**W**	**M**	**Total**
Urban and built-up area (U)	38	3	0	0	6	47
Agriculture land (A)	0	54	0	0	0	54
Forest land (F)	0	0	2	0	0	2
Water body (W)	0	0	0	14	2	16
Miscellaneous land (M)	0	1	0	0	7	8
Total	38	58	2	14	15	127

Note for accuracy assessment: 1. Overall accuracy = 90.55%
2. Kappa hat coefficient of agreement 0.86

6.4.2 Prediction of urban growth in 2018

In practice, land use types in 2002 (see Figure 5.3) and predicted land use types in 2010 (see Figure 6.8) were used to generate a transition areas matrix and a transition probability matrix between 2002 and 2010 (Table 6.12 and Table 6.13, respectively). Then, a transition probability matrix will be applied to create a set of conditional probability data for land use types between 2002 and 2010 (Figure 6.10). Then, derived output of Markov model included transition areas matrix, set of condition probability data between 2002 and 2010 and the predicted land use types in 2010 were exported into CA-Markov to generate the predicted land use types in 2018 based on Markov chain analysis and multi-criteria evaluation/multi-objective land allocation routines (Figure 6.11). Table 6.14 summarized area of predicted land use types in 2018. The predicted urban and built-up area in 2018 covers area of 261.53 sq.km.

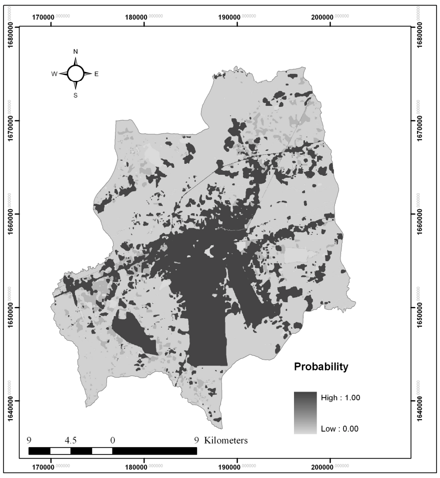
Table 6.12 Transition areas matrix for land use change between 2002 and 2010.

Unit: sq.km

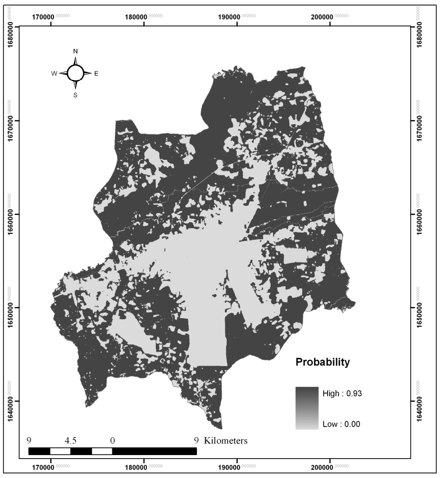
Land use in 2010	**Land use types**					
	U	**A**	**F**	**W**	**M**	**Total**
Urban and built-up area (U)	226.98	0.00	0.00	0.00	0.00	226.98
Agriculture land (A)	25.40	431.55	0.00	0.09	5.86	462.90
Forest land (F)	0.13	0.09	3.67	0.02	2.42	6.33
Water body (W)	0.00	0.00	0.00	14.14	0.00	14.14
Miscellaneous land (M)	9.02	0.00	0.00	0.82	31.88	41.72
Total	261.53	431.63	3.67	15.06	40.17	752.06

Table 6.13 Transition probability matrix for land use change between 2002 and 2010.

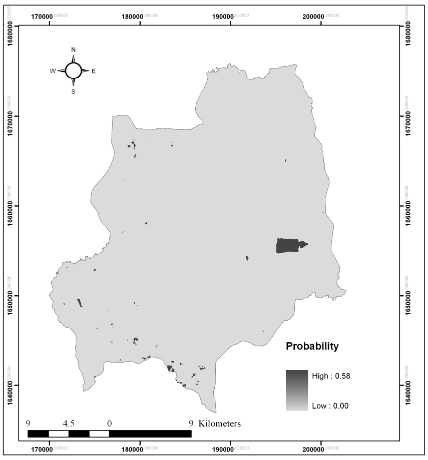
Land use in 2002	**Land use types**					
	U	**A**	**F**	**W**	**M**	**Total**
Urban and built-up area (U)	1.000	0.000	0.000	0.000	0.000	1.000
Agriculture land (A)	0.055	0.920	0.000	0.004	0.021	1.000
Forest land (F)	0.020	0.228	0.580	0.004	0.168	1.000
Water body (W)	0.000	0.030	0.000	0.942	0.028	1.000
Miscellaneous land (M)	0.216	0.051	0.000	0.028	0.705	1.000



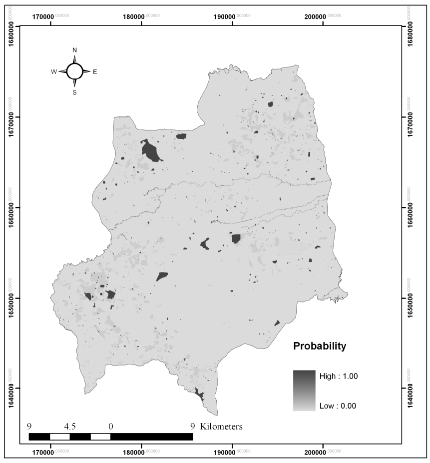
(a) urban and built-up area



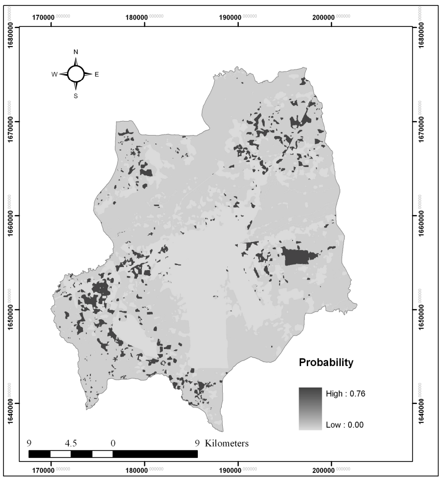
(b) agriculture land



(c) forest land



(d) water body



(e) miscellaneous land

Figure 6.10 Condition probabilities of five land use types (2002-2010).

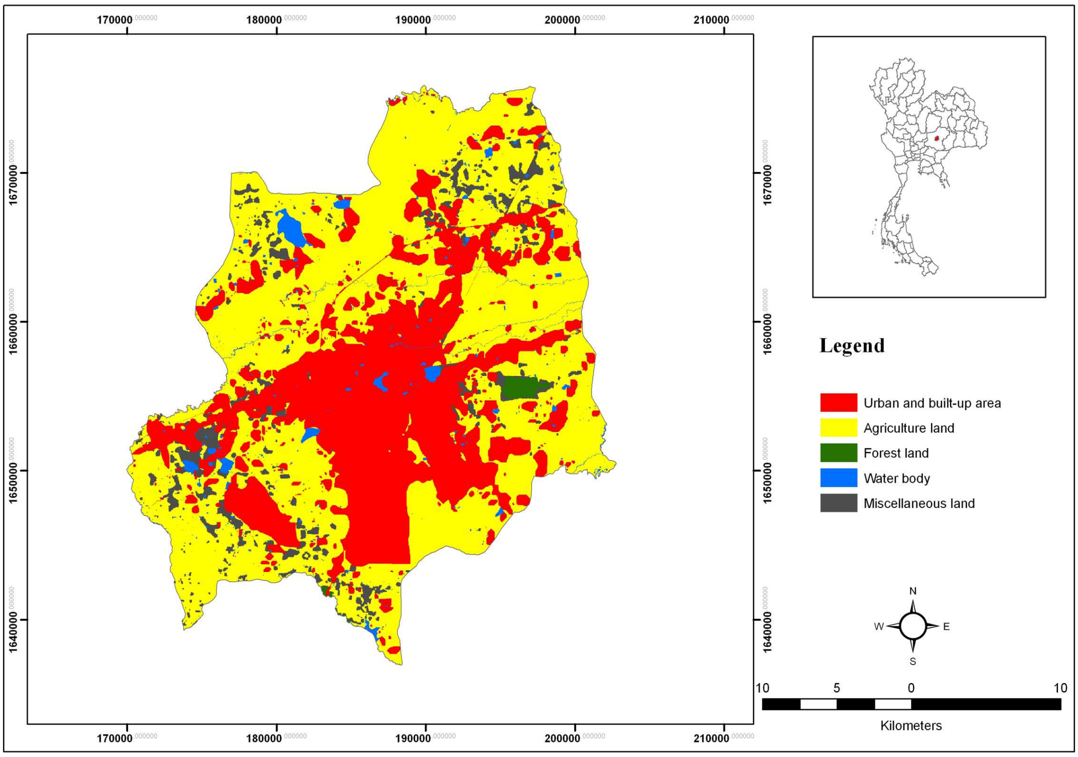


Figure 6.11 Predicted land use types in 2018 using CA-Markov.

Table 6.14 Area and percentage of predicted land use types in 2018.

Land use types	**Area in sq.km**	**Percentage**
Urban and built-up area	261.53	34.78
Agriculture land	431.63	57.39
Forest land	3.67	0.49
Water body	15.06	2.00
Miscellaneous land	40.17	5.34
Total	**752.06**	**100.00**

CHAPTER VII

ASSESSMENT OF QUALITY OF LIFE

In this part, remotely sensed data, socio-economic data and some selected BMN indicators in GIS based form will be integrated to estimate and predict the Quality of Life (QOL). Two methods, factor analysis and regression analysis, will be applied to derive theses three results: (1) QOL index by factor analysis, (2) validation of QOL index, and (3) predictive QOL index by regression analysis.

7.1 Quality of Life index by factor analysis

Basically, QOL index is here extracted based on environment variables (NDVI, surface temperature, and urban and built-up area) and five socioeconomic variables (population density, household density, person per household, per capita income, and per household income) and 18 BMN indicator selected from six measurements (health, housing, education, economy, values, and participation) using factor analysis. According to calculation procedure, we firstly extract related variables, then calculate factor analysis for QOL and finally assess QOL index.

7.1.1 Extraction of variables for factor analysis

7.1.1.1 Extraction of environment variables

Three environment variables for factor analysis on QOL index include NDVI, surface temperature, and urban and built-up area extracted from Landsat TM data acquired on 3 March 2008 and land use data of LDD, respectively. In practice, Landsat TM data was firstly geometric corrected and then calculated NDVI and surface temperature, while urban and built-up area was extracted from LDD's land use. Herein, Landsat data were geometrically rectified using 2002 color orthophotographs of Ministry of Agriculture and Cooperative as reference. We select second order transformation for spatial interpolation and nearest neighbour resampling for intensity interpolation and define acceptable RMS error to be less than 1 pixel. The geocoded Landsat TM has RMS error value of 0.974 pixel or 24.35 m (Figure 7.1).

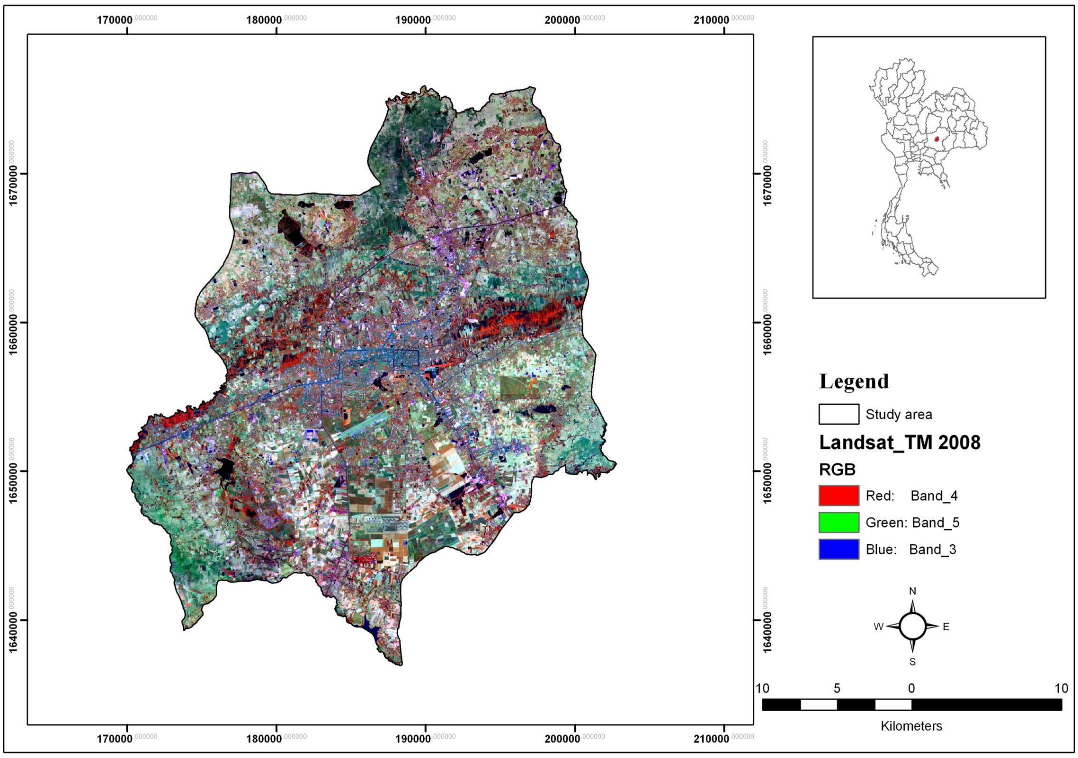


Figure 7.1 Color composite of Landsat-TM in 2008.

Source: Copyright (2008) GISTDA.

(a) Normalized Difference Vegetation Index (NDVI)

We use IDRISI software to calculate NDVI by standard equation (Eq. 4.16) using the red and near infrared bands of Landsat TM. We derive NDVI values as signed 8 bits varying between -0.71 to 0.72 (Figure 7.2). High values represent vegetation areas while low values represent non-vegetation areas.

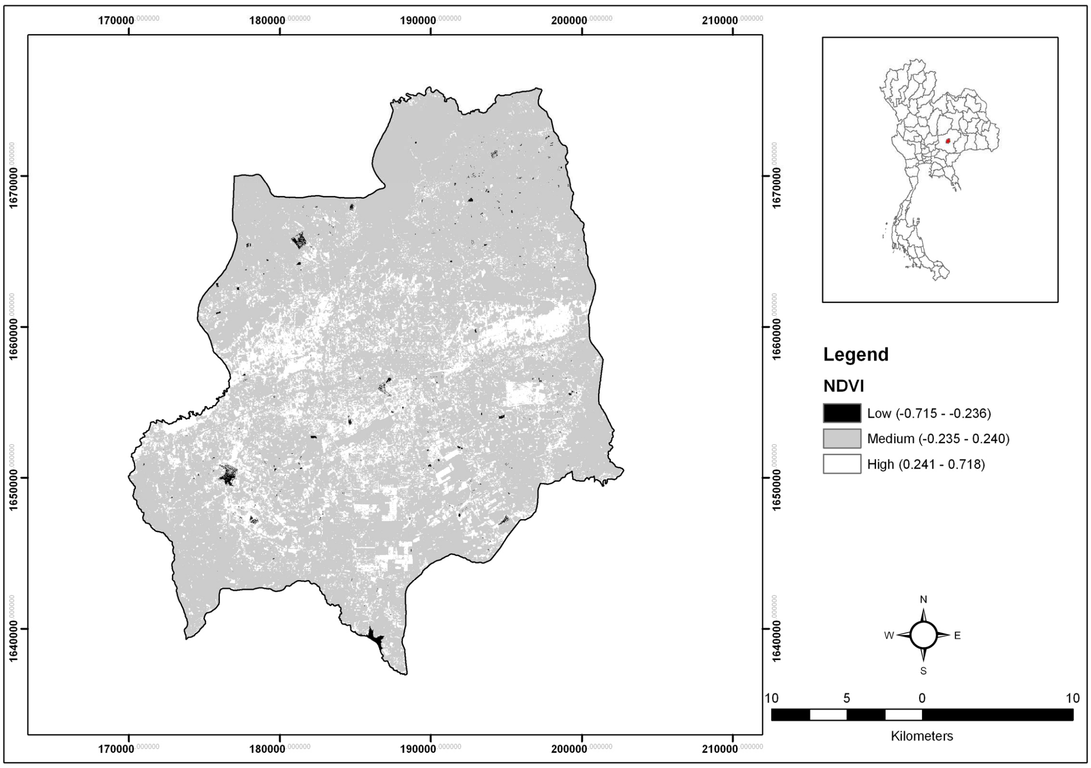


Figure 7.2 Normalized Difference Vegetation Index in 2008.

(b) Surface temperature

In this study, surface temperature is calculated from Landsat-TM based on NASA formula (section 4.2.3.1) and following these three conversion steps: (1) DN to spectral radiance, (2) spectral radiance to effective at-satellite temperature in degree Kelvin, and (3) degree Kelvin to degree Celsius. The surface temperature in the study area varies between 15.00 and 42.28 degree Celsius (Figure 7.3).

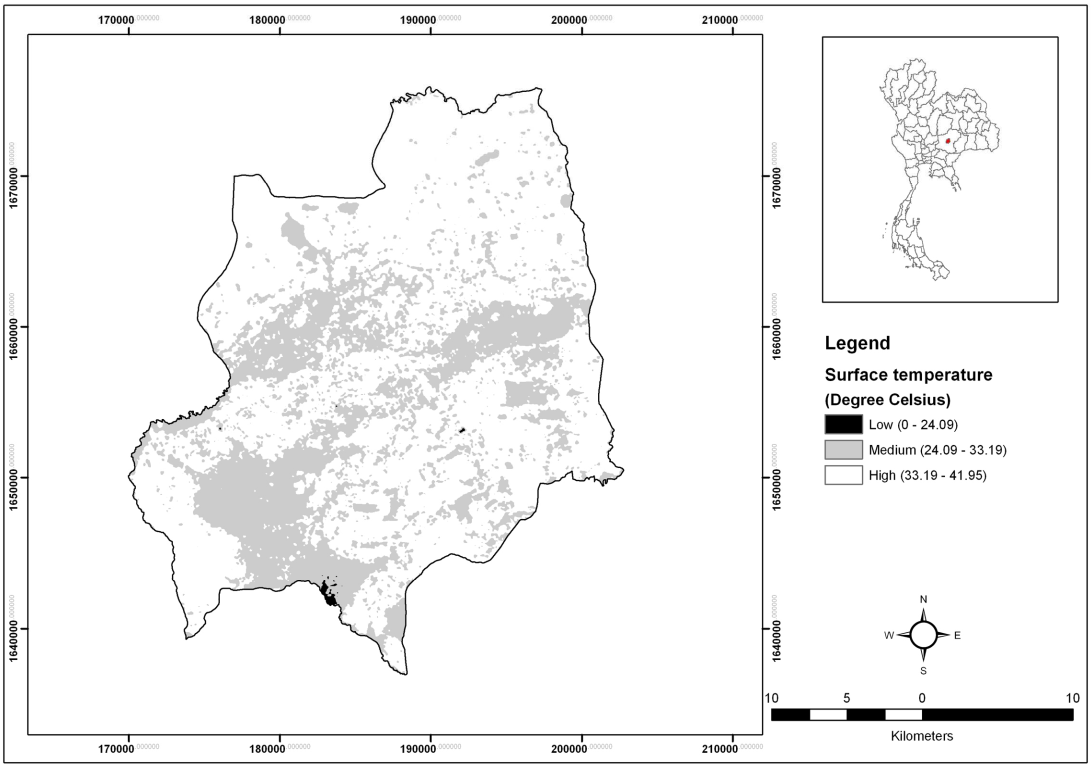


Figure 7.3 Surface temperature in 2008.

(c) Urban and built-up area

Only the urban and built-up area category of the 2007 LDD's land use is selected and labeled as urban and built-up area (Figure 7.4).

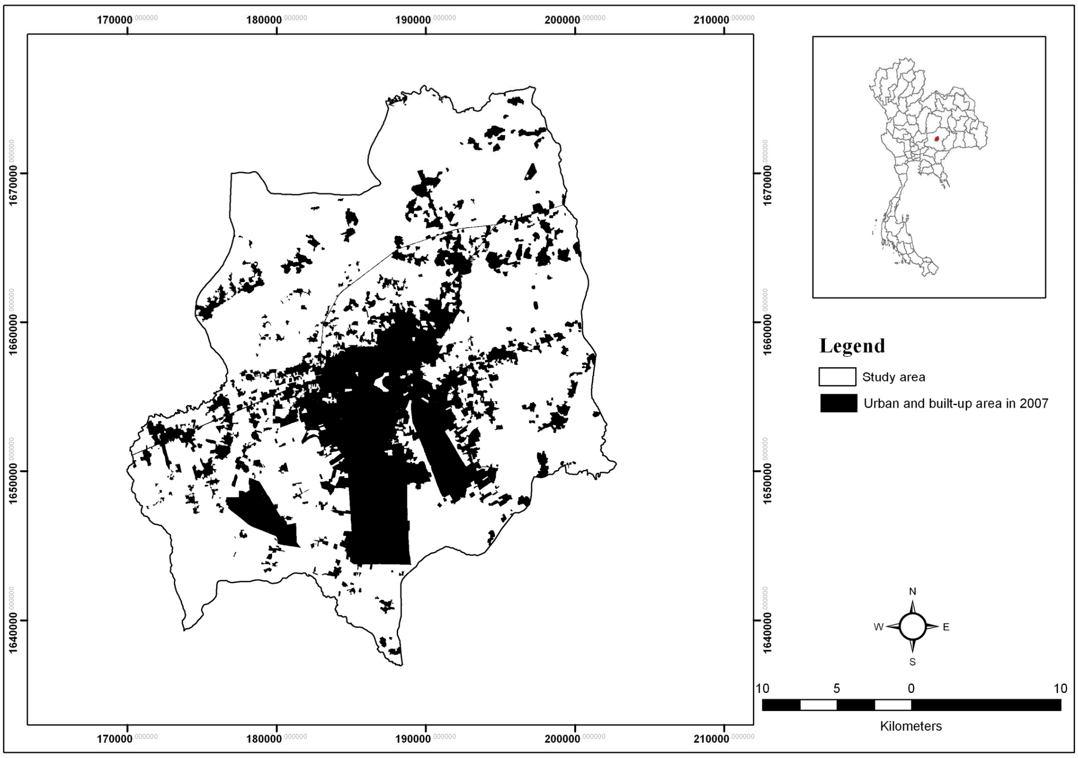


Figure 7.4 Urban and built-up area in 2007.

7.1.1.2 Extraction of socioeconomic variables

We select five BMN socioeconomic indicators in 2008, at village level from the Community Development Department as variables for factor analysis on QOL index. They concern population density, household density, persons per household, per capita income, and per household income (Figures 7.5-7.9).

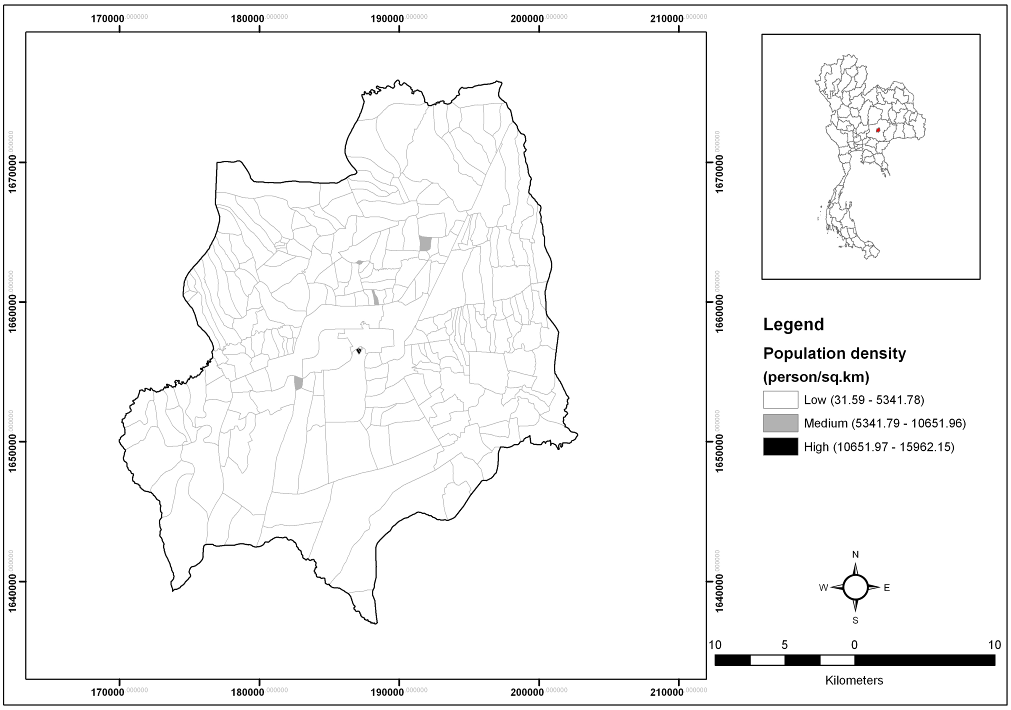


Figure 7.5 Population density in 2008.

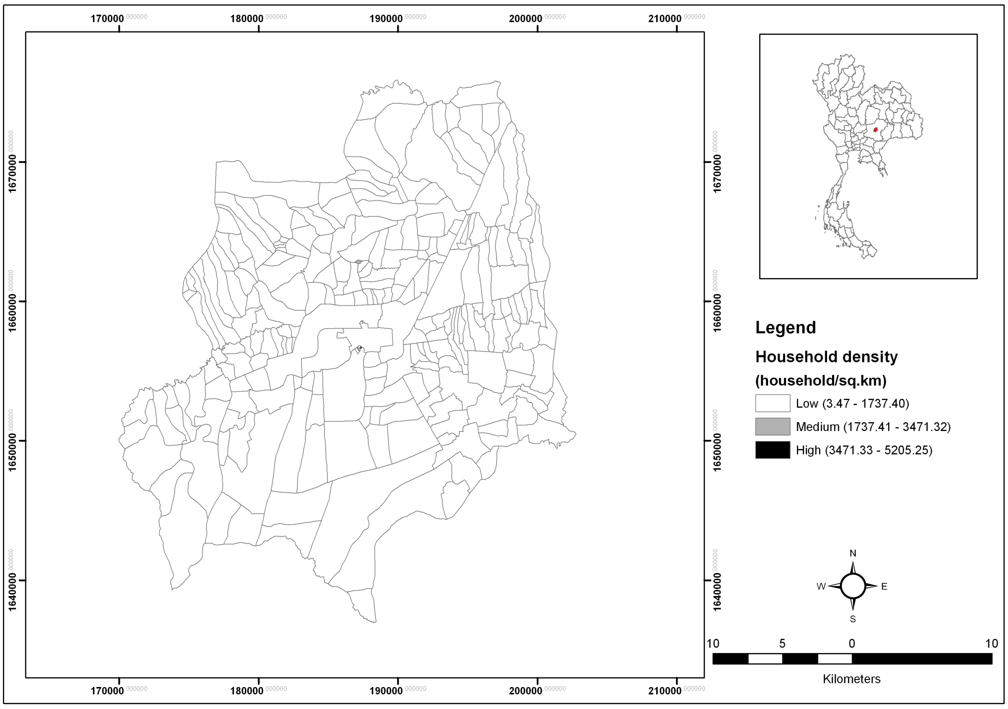


Figure 7.6 Household density in 2008.

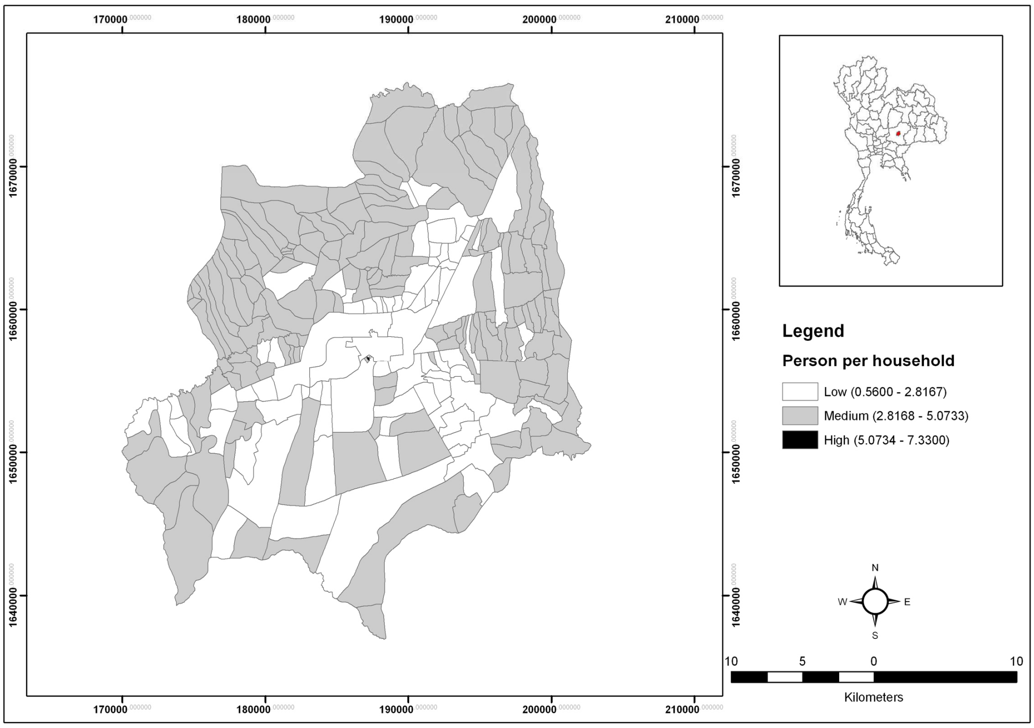


Figure 7.7 Persons per household in 2008

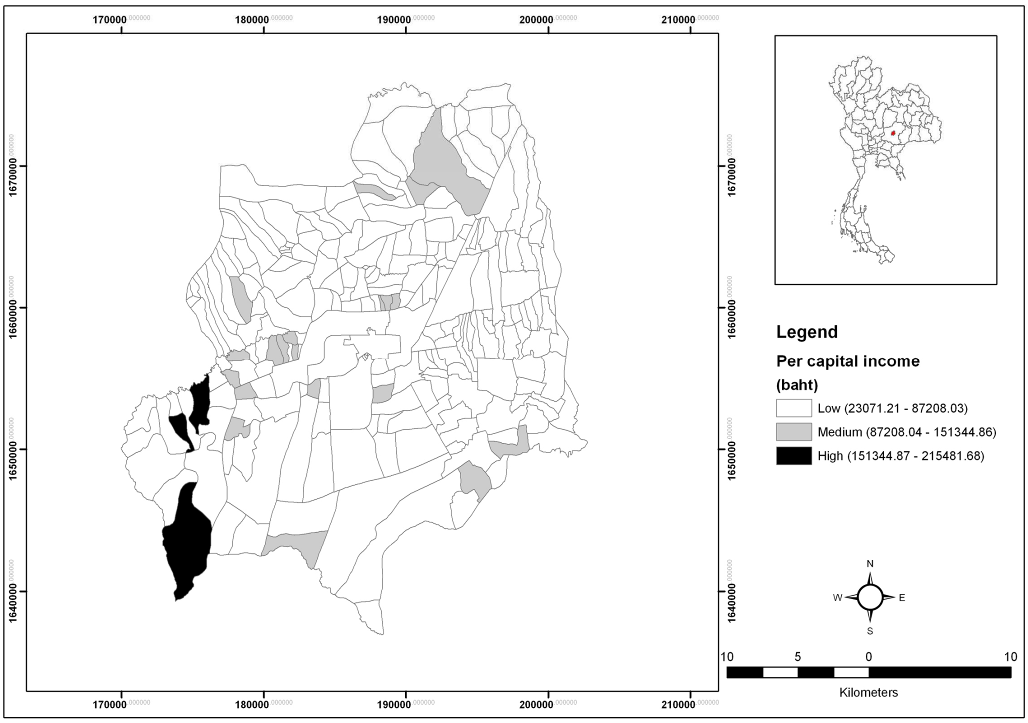


Figure 7.8 Per capital income in 2008.

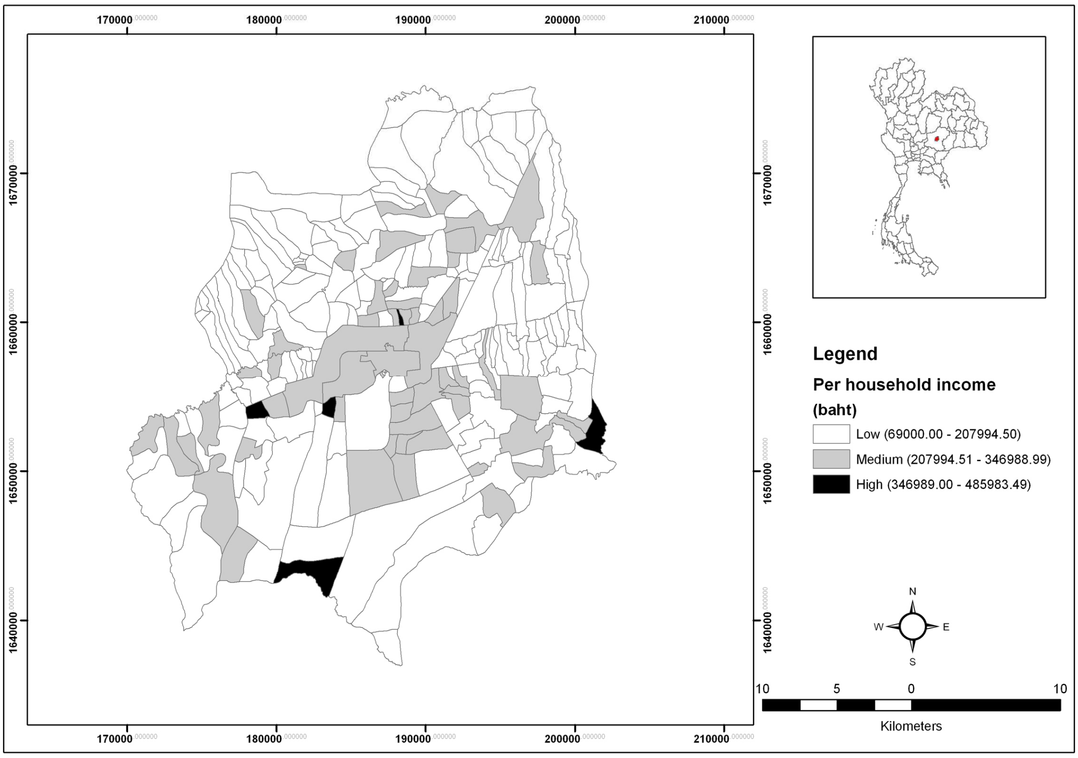


Figure 7.9 Per household income in 2008.

7.1.1.3 Extraction of BMN indicators

In this study, BMN indicators at household level which were fitted with village level were extracted from BMN data in 2008 from Community Development Department. In fact, 18 BMN indicators variables from six measurements (health, housing, education, economy, values, and participation) were used for QOL index as follows:

1) Health measurement

(1) Everybody in a household has quality and standard security

(2) A household correctly knows about medicine usage

2) Housing measurement

(3) Housing is durable at least for 5 years and has tenure security

(4) A household has sufficient water to consume

(5) A household has safe water sufficient to drink

(6) A household area is healthily managed

(7) A household does not bother from pollution

(8) A household knows how to prevent accidents

(9) A household has no harm to lives and properties

(10) A household has warm family

3) Education measurement

(11) A household receives advantageous information at least 5 times a week

4) Economy measurement

(12) A household has regular saving

5) Values measurement

(13) People behave under Thai customs and manner

(14) A household practice religious activities at least one a week

6) Participation measurement

(15) A household belongs to a least one community group

(16) A household participates and shares their thought in community meetings

(17) A household participates in natural conservation activities

(18) A household participates in community activities

Description and coding of 26 variables in three aspects (environment, socioeconomic, and BMN indicators) used in factor analysis for QOL index was summarized as shown in Table 4.3 of Chapter IV.

7.1.2 Factor analysis for QOL index

Extracted variables data in three aspects (environment, socioeconomic, and BMN indicators) which influence QOL were examined and analyzed by factor analysis in SPSS. In fact, the aim of factor analysis is to reduce number of factors with correlation of identified factors. The main results of factor analysis for QOL index can be summarized based on major step of factor analysis as following.

7.1.2.1 Standardization of variable values

As the values of the selected 26 variables for factor analysis still have different ranges and units among them (Table 7.1). Consequently, it is necessary to normalize these values before variable selection for factor analysis, so that the mean value of all variables is set to 0 and their standard deviation value is set to 1 (Table 7.2).

Table 7.1 Descriptive statisticed data of 26 variables before standardization.

Variables	Minimum	Maximum	Mean	Std. Deviation	Unit
G109	45.95	100.00	96.7566	6.3507	Percent
G110	52.70	100.00	97.5641	5.7989	Percent
G214	76.09	100.00	99.3031	2.0893	Percent
G215	85.90	100.00	99.4738	1.4484	Percent
G216	91.93	100.00	99.3100	1.3929	Percent
G217	52.53	100.00	98.4815	4.1421	Percent
G218	14.10	100.00	97.0064	8.7020	Percent
G219	4.61	100.00	98.9333	6.3901	Percent
G220	1.39	100.00	97.1794	10.4691	Percent
G221	90.41	100.00	99.5634	1.1922	Percent
G328	34.75	100.00	97.9897	7.5808	Percent
G431	9.70	100.00	85.2806	18.3535	Percent
G534	54.61	100.00	98.2976	4.7495	Percent
G535	43.26	100.00	95.6062	8.7279	Percent
G638	11.63	100.00	87.4213	17.9903	Percent
G639	45.21	100.00	93.9639	10.5391	Percent
G640	43.86	100.00	94.4067	10.4711	Percent
G641	4.32	100.00	89.0061	18.0090	Percent
Per_HH	0.56	7.33	3.2008	0.8624	Person/household
Pop_den	31.59	15962.15	1013.0248	1718.2344	Person/sq.km
HH_den	3.47	5205.25	152.1670	386.1217	household/sq.km
Pop_income	2.31×10^{4}	2.15×10^{5}	5.5207×10^{4}	2.6531×10^{4}	Baht/person/year
HH_income	6.90×10^{4}	4.86×10^{5}	1.8944×10^{5}	5.5298×10^{4}	Baht/household/year
ST	27.31	37.85	33.6538	1.8001	Degree Celsius
Urban	0.00	1.00	0.2100	0.4090	Bit (0 and 1)
NDVI	-0.16	0.36	0.1619	0.0621	Unit less

Table 7.2 Descriptive statisticed data of 26 variables after standardization.

Variables	Minimum	Maximum	Mean	Standard Deviation
G109	-8.000	0.511	0	1
G110	-7.737	0.420	0	1
G214	-11.110	0.334	0	1
G215	-9.372	0.363	0	1
G216	-5.298	0.495	0	1
G217	-11.092	0.367	0	1
G218	-9.527	0.344	0	1
G219	-14.761	0.167	0	1
G220	-9.150	0.269	0	1
G221	-7.677	0.366	0	1
G328	-8.342	0.265	0	1
G431	-4.118	0.802	0	1
G534	-9.198	0.358	0	1
G535	-5.998	0.503	0	1
G638	-4.213	0.699	0	1
G639	-4.626	0.573	0	1
G640	-4.827	0.534	0	1
G641	-4.702	0.610	0	1
Per_HH	-3.062	4.788	0	1
Pop_den	-0.571	8.700	0	1
HH_den	-0.385	13.087	0	1
Pop_income	-1.211	6.041	0	1
HH_income	-2.178	5.363	0	1
ST	-3.524	2.331	0	1
Urban	-0.517	1.925	0	1
NDVI	-5.275	3.254	0	1

7.1.2.2 Variables selection of factor analysis

For this part, two statistic methods, Kaiser-Meyer-Olkin (KMO) of sampling adequacy and Bartlett's test of sphericity (section 4.4.2), are firstly used to identify significant variables based on correlation matrix and correlation coefficient among them (Table 7.3). As results, KMO of sampling adequacy is 0.771, considered as moderate suitable for factor analysis (Field, 2005), while Bartlett's test of sphericity is 0.000, considered significant ($p < 0.001$) after Li and Weng (2007) (Table 7.4). Thus, all 26 variables are appropriate to use for factor analysis.

Secondly, communality of variables was computed by taking the sum of the squared loadings for all variables. In fact, communality value varies between 0 and 1 and appropriate variables should have communality value more than 0.5 (Field, Online, 2005). Owing to these rules, two communalities are computed. After the first iteration, there are three variables (Persons per household (Per_HH), household participation in community activities (G641), and household having no harm to lives and properties (G220)) being dropped as their communality values are less that 0.5 and dropped factor analysis. Then after the second iteration to test the rest 23 variables, all were significant and appropriate for factor analysis (Table 7.5). Herein, Kaiser-Meyer-Olkin (KMO) of sampling adequacy and Bartlett's test of sphericity were calculated again based on new correlation matrix of the 23 variables (Table 7.6) to verify the previous results. This time, KMO of sampling adequacy increased to 0.779 and Bartlett's test of sphericity was 0.000 and they were considered significant ($p < 0.001$) (Table 7.7). Therefore, the 23 selected variables were ready to use for factor analysis of QOL index.

7.1.2.3 Factor extraction of factor analysis

To extract an initial solution for factor loading, Principal Component Method was firstly applied. Herein, factors whose has eigenvalues greater than 1 were extracted. Then, rotation of initial solution factors was applied using Varimax to clarify the factor pattern in order to better interpret the nature of the components (Table 7.8). Each factor will be explained by percentage of variance as factor loading. It was found that the first seven factors (components) have more than 74.276% of the variance.

Table 7.3 Correlation matrix of 26 variables before variable selection of factor analysis.

	G109	G110	G214	G215	G216	G217	G218	G219	G220	G221	G328	G431	G534	G535	G638	G639	G640	G641	Per_HH	Pop_den	HH_den	Pop_income	HH_income	ST	Urban	NDVI
G109	1.00	0.87	0.26	0.32	0.37	0.35	0.25	0.15	0.22	0.42	0.61	0.26	0.46	0.66	0.44	0.40	0.39	0.22	0.13	-0.03	-0.09	0.04	-0.10	0.02	-0.09	0.01
G110	0.87	1.00	0.29	0.34	0.39	0.37	0.32	0.17	0.26	0.47	0.73	0.32	0.57	0.72	0.50	0.47	0.44	0.13	0.11	-0.04	-0.08	0.04	-0.09	-0.03	-0.07	0.04
G214	0.26	0.29	1.00	0.48	0.33	0.44	0.48	0.13	0.09	0.59	0.17	0.33	0.27	0.31	0.29	0.22	0.24	0.07	0.15	-0.03	-0.08	0.05	0.03	0.05	-0.03	-0.05
G215	0.32	0.34	0.48	1.00	0.52	0.46	0.67	0.11	0.20	0.45	0.27	0.27	0.37	0.42	0.33	0.27	0.26	0.07	0.20	-0.04	-0.10	0.01	-0.06	-0.03	-0.15	-0.05
G216	0.37	0.39	0.33	0.52	1.00	0.52	0.36	0.09	0.30	0.39	0.32	0.21	0.38	0.42	0.34	0.30	0.30	0.09	0.09	-0.03	-0.08	-0.17	-0.14	-0.13	-0.12	0.03
G217	0.35	0.37	0.44	0.46	0.52	1.00	0.41	0.12	0.17	0.49	0.24	0.31	0.43	0.43	0.26	0.24	0.24	0.07	0.09	-0.01	-0.05	0.01	-0.07	-0.02	-0.05	0.04
G218	0.25	0.32	0.48	0.67	0.36	0.41	1.00	0.04	0.08	0.61	0.20	0.30	0.23	0.36	0.40	0.44	0.35	0.10	0.27	-0.05	-0.09	-0.04	-0.11	0.00	-0.14	0.03
G219	0.15	0.17	0.12	0.11	0.09	0.12	0.04	1.00	0.05	0.12	0.13	0.23	0.19	0.41	0.08	0.07	0.07	0.00	0.00	-0.01	-0.02	0.05	0.00	-0.03	-0.01	0.01
G220	0.22	0.26	0.09	0.20	0.30	0.17	0.08	0.05	1.00	0.08	0.21	0.11	0.23	0.26	0.13	0.11	0.11	0.03	-0.12	0.01	0.00	-0.13	-0.17	-0.03	-0.03	0.01
G221	0.43	0.47	0.59	0.45	0.39	0.49	0.61	0.12	0.08	1.00	0.42	0.38	0.36	0.47	0.47	0.47	0.41	0.14	0.24	-0.05	-0.11	0.03	-0.10	0.01	-0.12	0.00
G328	0.61	0.73	0.17	0.27	0.32	0.24	0.20	0.13	0.21	0.42	1.00	0.30	0.66	0.66	0.43	0.45	0.43	0.16	0.06	-0.12	-0.15	-0.01	-0.12	0.01	-0.19	0.01
G431	0.26	0.32	0.33	0.27	0.21	0.31	0.29	0.22	0.11	0.38	0.29	1.00	0.41	0.51	0.41	0.33	0.36	0.02	0.15	-0.03	-0.08	0.03	0.06	-0.12	-0.12	0.07
G534	0.46	0.57	0.27	0.37	0.38	0.43	0.23	0.19	0.23	0.36	0.66	0.41	1.00	0.76	0.47	0.42	0.38	0.12	0.16	-0.11	-0.16	-0.06	-0.05	0.00	-0.11	0.01
G535	0.66	0.72	0.31	0.42	0.42	0.43	0.36	0.41	0.26	0.47	0.66	0.51	0.76	1.00	0.58	0.49	0.47	0.12	0.14	-0.06	-0.11	-0.01	-0.09	-0.03	-0.12	0.02
G638	0.44	0.50	0.29	0.33	0.34	0.26	0.40	0.08	0.13	0.47	0.43	0.42	0.47	0.58	1.00	0.79	0.78	0.28	0.35	-0.18	-0.29	-0.13	-0.18	0.05	-0.27	-0.08
G639	0.41	0.47	0.22	0.27	0.30	0.24	0.45	0.07	0.12	0.48	0.45	0.33	0.42	0.49	0.79	1.00	0.87	0.40	0.27	-0.18	-0.24	-0.13	-0.20	0.03	-0.20	0.01
G640	0.389	0.44	0.24	0.26	0.30	0.24	0.35	0.07	0.11	0.41	0.43	0.36	0.38	0.47	0.78	0.87	1.00	0.43	0.27	-0.16	-0.23	-0.16	-0.22	0.02	-0.23	-0.02
G641	0.22	0.13	0.07	0.07	0.09	0.07	0.10	0.00	0.03	0.14	0.16	0.02	0.12	0.12	0.28	0.40	0.43	1.00	0.24	-0.22	-0.27	-0.11	-0.08	0.01	-0.26	0.11

Table 7.3 Correlation matrix of 26 variables before variable selection of factor analysis (Continued).

	G109	G110	G214	G215	G216	G217	G218	G219	G220	G221	G328	G431	G534	G535	G638	G639	G640	G641	Per_HH	Pop_den	HH_den	Pop_income	HH_income	ST	Urban	NDVI
Per_HH	0.13	0.11	0.15	0.20	0.09	0.09	0.27	-0.00	-0.12	0.24	0.06	0.15	0.16	0.14	0.35	0.27	0.27	0.24	1.00	-0.06	-0.31	-0.19	-0.24	0.03	-0.39	-0.14
Pop_den	-0.03	-0.04	-0.03	-0.03	-0.03	-0.01	-0.05	-0.01	0.01	-0.05	-0.12	-0.03	-0.11	-0.06	-0.18	-0.18	-0.16	-0.22	-0.06	1.00	0.92	0.11	0.15	-0.20	0.48	-0.15
HH_den	-0.09	-0.08	-0.08	-0.10	-0.08	-0.05	-0.09	-0.02	0.00	-0.11	-0.15	-0.08	-0.16	-0.11	-0.29	-0.24	-0.23	-0.27	-0.31	0.92	1.00	0.16	0.23	-0.13	0.60	-0.08
Pop_Income	0.04	0.04	0.05	0.01	-0.17	0.01	-0.04	0.05	-0.13	0.03	-0.01	0.03	-0.06	-0.01	-0.13	-0.13	-0.16	-0.11	-0.19	0.11	0.16	1.00	0.58	-0.03	0.10	0.07
HH_income	-0.09	-0.08	0.03	-0.06	-0.14	-0.07	-0.11	0.00	-0.17	-0.09	-0.12	0.06	-0.05	-0.09	-0.18	-0.20	-0.22	-0.08	-0.24	0.15	0.23	0.58	1.00	-0.10	0.28	0.00
ST	0.02	-0.03	0.05	-0.03	-0.13	-0.02	0.00	-0.03	-0.03	0.01	0.01	-0.12	0.00	-0.03	0.05	0.03	0.02	0.01	0.03	-0.20	-0.14	-0.03	-0.10	1.00	-0.01	-0.60
Urban	-0.09	-0.07	-0.03	-0.15	-0.12	-0.05	-0.14	-0.01	-0.03	-0.12	-0.19	-0.12	-0.11	-0.12	-0.27	-0.20	-0.23	-0.26	-0.39	0.48	0.60	0.10	0.28	-0.01	1.00	0.04
NDVI	0.01	0.04	-0.05	-0.05	0.03	0.04	0.03	0.01	0.01	0.00	0.01	0.07	0.01	0.02	-0.08	0.01	-0.02	0.11	-0.14	-0.15	-0.08	0.07	0.00	-0.60	0.04	1.00

Table 7.4 KMO and Bartlett’s Test with 26 variables.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.771
Bartlett's Test of Sphericity	Approximate Chi-Square	3801.143
	Degree of freedom	325
	Significant	0.000

Table 7.5 Selection of variables based on communality values.

Variables	Description	First Communality 26 variables	Second Communality 23 variables
HH_den	Household density (household/ km^2)	0.926	0.926
Pop_den	Population density (person/km^2)	0.885	0.885
G535	A household does religious activities at least one a week	0.861	0.859
G639	A household participates and shares their thought in community meetings	0.828	0.881
NDVI	Normalized Difference Vegetation Index	0.817	0.808
G640	A household participates in natural conservation activities	0.815	0.860
ST	Surface Temperature	0.808	0.821
G110	A household correctly knows about medicine usage	0.805	0.860
G638	A household belongs to a least one community group	0.767	0.821
Pop_income	Per capita income	0.736	0.783
G328	A household receives advantageous information at least 5 times a week	0.716	0.752
HH_income	Household density (household/ km^2)	0.716	0.746
G109	Everybody in a household has quality and standard security	0.698	0.767
G218	A household does not bother from pollution	0.697	0.704
G215	A household has sufficient water to consume	0.663	0.663
G221	A household has warm family	0.646	0.643
G534	People behave under Thai customs and manner	0.636	0.639
G219	A household knows how to prevent the accidents	0.605	0.759
G214	Housing is durable at least for 5 years and has tenure security	0.601	0.617
G216	A household has safe water sufficient to drink	0.595	0.579
Urban	Urban and built-up area	0.576	0.550
G431	A household has regular saving	0.566	0.586
G217	A household area is healthily managed	0.558	0.577
Per_HH	Persons per household	0.499	
G641	A household participates in community activities	0.456	
G220	A household has no harm to lives and properties	0.444	

Table 7.6 Correlation matrix of 23 Variables after variable selection of factor analysis.

	G109	G110	G214	G215	G216	G217	G218	G219	G221	G328	G431	G534	G535	G638	G639	G640	Pop_den	HH_den	Pop_income	HH_income	ST	Urban	NDVI
G109	1.00	0.87	0.26	0.32	0.37	0.35	0.25	0.15	0.43	0.61	0.26	0.46	0.66	0.44	0.41	0.39	-0.03	-0.09	0.04	-0.09	0.02	-0.09	0.01
G110	0.87	1.00	0.29	0.34	0.39	0.37	0.32	0.17	0.47	0.73	0.32	0.57	0.72	0.50	0.47	0.44	-0.04	-0.08	0.04	-0.08	-0.03	-0.07	0.04
G214	0.26	0.29	1.00	0.48	0.33	0.44	0.48	0.13	0.59	0.17	0.33	0.27	0.31	0.29	0.22	0.24	-0.03	-0.08	0.05	0.03	0.05	-0.03	-0.05
G215	0.32	0.34	0.48	1.00	0.52	0.46	0.67	0.11	0.45	0.27	0.27	0.37	0.42	0.33	0.27	0.26	-0.04	-0.10	0.01	-0.06	-0.03	-0.15	-0.05
G216	0.37	0.39	0.33	0.52	1.00	0.52	0.36	0.09	0.39	0.32	0.21	0.38	0.42	0.34	0.30	0.30	-0.03	-0.08	-0.17	-0.14	-0.13	-0.12	0.03
G217	0.35	0.37	0.44	0.46	0.52	1.00	0.41	0.12	0.49	0.24	0.31	0.43	0.43	0.26	0.24	0.24	-0.01	-0.05	0.01	-0.07	-0.02	-0.05	0.04
G218	0.25	0.32	0.48	0.67	0.36	0.41	1.00	0.04	0.61	0.20	0.30	0.23	0.36	0.40	0.45	0.35	-0.05	-0.09	-0.04	-0.11	0.00	-0.14	0.03
G219	0.15	0.17	0.13	0.11	0.09	0.12	0.04	1.00	0.12	0.13	0.23	0.19	0.41	0.08	0.07	0.07	-0.01	-0.02	0.05	0.00	-0.03	-0.01	0.01
G221	0.43	0.47	0.59	0.45	0.39	0.49	0.61	0.12	1.00	0.42	0.38	0.36	0.47	0.47	0.48	0.41	-0.05	-0.11	0.03	-0.10	0.01	-0.12	0.00
G328	0.61	0.73	0.17	0.27	0.32	0.24	0.20	0.13	0.42	1.00	0.29	0.66	0.66	0.43	0.45	0.43	-0.12	-0.15	-0.01	-0.12	0.01	-0.19	0.01
G431	0.26	0.32	0.33	0.27	0.21	0.31	0.30	0.23	0.38	0.29	1.00	0.41	0.51	0.42	0.33	0.36	-0.03	-0.08	0.03	0.06	-0.12	-0.12	0.07
G534	0.46	0.57	0.27	0.37	0.38	0.43	0.23	0.19	0.36	0.66	0.41	1.00	0.76	0.47	0.42	0.38	-0.11	-0.16	-0.06	-0.05	0.00	-0.11	0.01
G535	0.66	0.72	0.31	0.42	0.42	0.43	0.36	0.41	0.47	0.66	0.51	0.76	1.00	0.58	0.49	0.47	-0.06	-0.11	-0.01	-0.09	-0.03	-0.12	0.02
G638	0.44	0.50	0.29	0.33	0.34	0.26	0.40	0.08	0.47	0.43	0.42	0.47	0.58	1.00	0.79	0.78	-0.18	-0.29	-0.13	-0.18	0.05	-0.27	-0.08
G639	0.41	0.47	0.22	0.27	0.30	0.24	0.45	0.07	0.48	0.45	0.33	0.42	0.49	0.79	1.00	0.87	-0.18	-0.24	-0.13	-0.20	0.03	-0.20	0.01
G640	0.39	0.44	0.24	0.26	0.30	0.24	0.35	0.07	0.41	0.43	0.36	0.38	0.47	0.78	0.87	1.00	-0.16	-0.23	-0.16	-0.22	0.02	-0.23	-0.02
Pop_den	-0.03	-0.04	-0.03	-0.04	-0.03	-0.01	-0.05	-0.01	-0.05	-0.12	-0.03	-0.11	-0.06	-0.18	-0.18	-0.16	1.00	0.92	0.11	0.15	-0.20	0.48	-0.15
HH_den	-0.09	-0.08	-0.08	-0.10	-0.08	-0.05	-0.09	-0.02	-0.11	-0.15	-0.08	-0.16	-0.11	-0.29	-0.24	-0.23	0.92	1.00	0.16	0.23	-0.14	0.60	-0.08
Pop_income	0.04	0.04	0.05	0.01	-0.17	0.01	-0.04	0.05	0.03	-0.01	0.03	-0.06	-0.01	-0.13	-0.13	-0.16	0.11	0.16	1.00	0.58	-0.03	0.10	0.07
HH_income	-0.09	-0.08	0.03	-0.06	-0.14	-0.07	-0.11	0.00	-0.10	-0.12	0.06	-0.05	-0.09	-0.18	-0.20	-0.22	0.15	0.23	0.58	1.00	-0.10	0.28	0.00
ST	0.02	-0.03	0.05	-0.03	-0.13	-0.02	0.00	-0.03	0.01	0.01	-0.12	0.00	-0.03	0.05	0.03	0.02	-0.20	-0.14	-0.03	-0.10	1.00	-0.01	-0.60
Urban	-0.09	-0.07	-0.03	-0.15	-0.12	-0.05	-0.14	-0.01	-0.12	-0.19	-0.12	-0.11	-0.12	-0.27	-0.20	-0.23	0.48	0.60	0.10	0.28	-0.01	1.00	0.04
NDVI	0.01	0.04	-0.05	-0.05	0.03	0.04	0.03	0.01	0.00	0.01	0.07	0.01	0.02	-0.08	0.01	-0.02	-0.15	-0.08	0.07	0.00	-0.60	0.04	1.00

Table 7.7 KMO and Bartlett's Test with 23 variables.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.779
Bartlett's Test of Sphericity	Approximate Chi-Square	3494.273
	Degree of freedom	253
	Significant	0.000

Table 7.8 Rotated factor loading matrix of factor analysis for QOL index.

Variables	Component						
	Factor 1	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**	**Factor 6**	**Factor 7**
G110	**.868**	.233	.223	.008	.033	.025	.010
G109	**.833**	.214	.159	-.005	.024	-.013	-.038
G328	**.825**	.093	.219	-.109	-.021	-.007	.049
G535	**.712**	.286	.283	-.024	-.029	.018	.435
G534	**.671**	.238	.187	-.086	-.045	.004	.296
G215	.194	**.784**	.063	-.059	-.033	-.012	.033
G218	.027	**.769**	.324	-.047	-.021	.020	-.058
G214	.046	**.739**	.127	-.024	.138	-.102	.149
G217	.291	**.686**	-.024	.004	-.054	.042	.127
G221	.262	**.671**	.339	-.037	.062	-.018	.051
G216	.355	**.594**	.017	-.003	-.283	.137	.003
G639	.290	.190	**.858**	-.118	-.098	.004	-.003
G640	.265	.153	**.856**	-.112	-.138	-.004	.032
G638	.326	.234	**.784**	-.160	-.086	-.067	.087
HH_den	-.053	-.039	-.107	**.950**	.083	.012	-.019
Pop_den	-.035	.011	-.039	**.939**	.010	.013	-.003
Urban	-.048	-.077	-.134	**.709**	.144	.003	-.010
Pop_income	.062	.008	-.092	.053	**.876**	.027	-.017
HH_income	-.069	-.028	-.102	.178	**.833**	.038	.051
ST	.011	-.022	-.004	-.156	-.004	**-.891**	-.048
NDVI	.023	-.022	-.028	-.125	.053	**.888**	-.010
G219	.129	.034	-.054	-.004	-.017	-.015	**.859**
G431	.152	.297	.393	-.032	.142	.132	**.530**
Initial eigenvalues	3.721	3.488	2.772	2.442	1.661	1.639	1.360
% of variance	16.179	15.166	12.053	10.618	7.222	7.126	5.912
Cumulative %	**16.179**	**31.345**	**43.398**	**54.016**	**61.238**	**68.364**	**74.276**

7.1.2.4 Synthesis of factor analysis for QOL index

Based on Comrey and Lee (1992), a range of values to interpret the strength of the relationships between variables and factors using factor loading as follows:

Factor loading of 0.71 and higher are considered as excellent relationship;

Factor loading between 0.63-0.70 is considered as very good relationship;

Factor loading of 0.55-0.62 is considered as good relationship;

Factor loading of 0.45-0.54 is considered as fair relationship and;

Factor loading of 0.32-0.44 is considered as poor relationship.

Therefore, synthesis of factor analysis in Table 7.8 can be explained in term QOL indicators based on strengthen of relationship between variables and factor as following.

Factor 1: There are four significant variables of BMN indicators having relationship with this factor, in term of health, education, and values measurement in each village. Four of them having excellent relationship with this factor: (1) A household correctly knows about medicine usage (G110), (2) Everybody in a household has quality and standard security (G109) as health measurement of BMN, (3) A household receives advantageous information at least 5 times a week (G328) as education measurement of BMN, and (4) A household does religious activities at least one a week (G535). And the last one having very good relationship with this factor is People behaving under Thai customs and manner (G534). The factor score of this factor varies between -7.69728 and 2.36708 (Figure 7.10).

Factor 2: It concerns six variables of housing measurement of BMN. The first three of them have excellent relationship with this factor: (1) a household has sufficient water to consume (G215), (2) A household does not bother from pollution (G218), and (3) housing is durable at least for 5 years and has tenure security (G214). The other two have very good relationship: (1) a household area is healthily managed (G217) and (2) a household has warm family (G221). And the last one, a household has safe water sufficient to drink (G216), has good relationship. The factor score of the factor 2 varies between -7.20890 and 1.54839 (Figure 7.11).

Factor 3: The three variables representing participation measurement and having excellent relationship with this factor are (1) a household participates and shares their thought in community meetings (G639), (2) a household participates in natural conservation activities (G640), and (3) a household belongs to a least one community group (G638). The factor score of factor 3 varies between -5.59837 and 2.66769 (Figure 7.12).

Factor 4: For socioeconomic (population) indicators, there are two variables having excellent relationship with this factor: (1) household density (HH_den) and (2) population density (Pop_den). For environment indicator, there is only one variable, urban and built-up area (Urban), also having excellent relationship. These three significant variables will be used to explain QOL index in term of crowdedness in each village. It means that the higher score shows the smaller space for people to live. The factor score of factor 4 varies between -1.00859 and 7.91528 (Figure 7.13).

Factor 5: There are two variables representing socioeconomic (income) indicator which have excellent relationship with this factor: (1) Per capita income

(Pop_income) and (2) Per household income (HH_income). The factor score of factor 5 varies between -2.31118 and 4.75558 (Figure 7.14).

Factor 6: There are two significant variables of environment quality indicator, having excellent relationship with this factor: (1) surface temperature (ST) and (2) Normalized Differencing Vegetation Index (NDVI). Herein, surface temperature has negative relationship while NDVI has positive relationship. Both variables imply about environmental conditions, therefore the higher score in this component shows better environment quality. The factor score of factor 6 varies between -2.14222 and 3.37466 (Figure 7.15).

Factor 7: There are two variables concerning safety and economy (saving) measurements of BMN. The first having excellent relationship with this component is ‘a household knows how to prevent the accidents (G219)’. The second having fair positive relationship is ‘a household has regular saving (G431)’. The factor score of factor 7 varies between -13.00933 and 2.46213 (Figure 7.16).

In summary, factor score of each Factor or Component can be used as indices to represent the QOL in different dimensions (Figures 7.10 to 7.16).

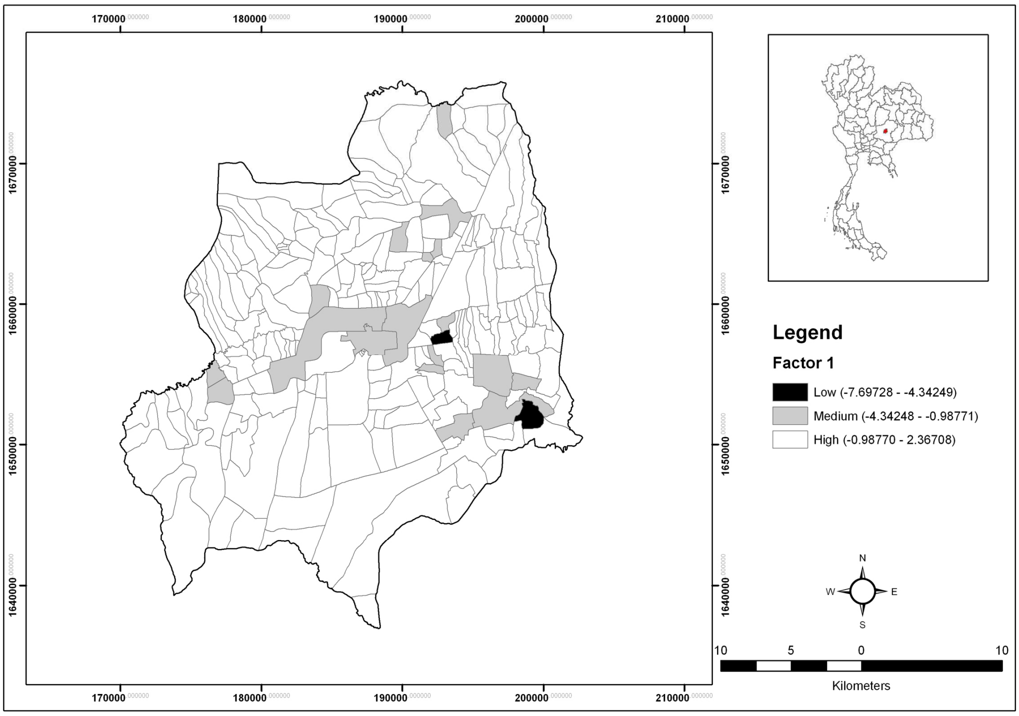


Figure 7.10 Factor 1: Measurement of Health, Education, and Cultural Values in each village.

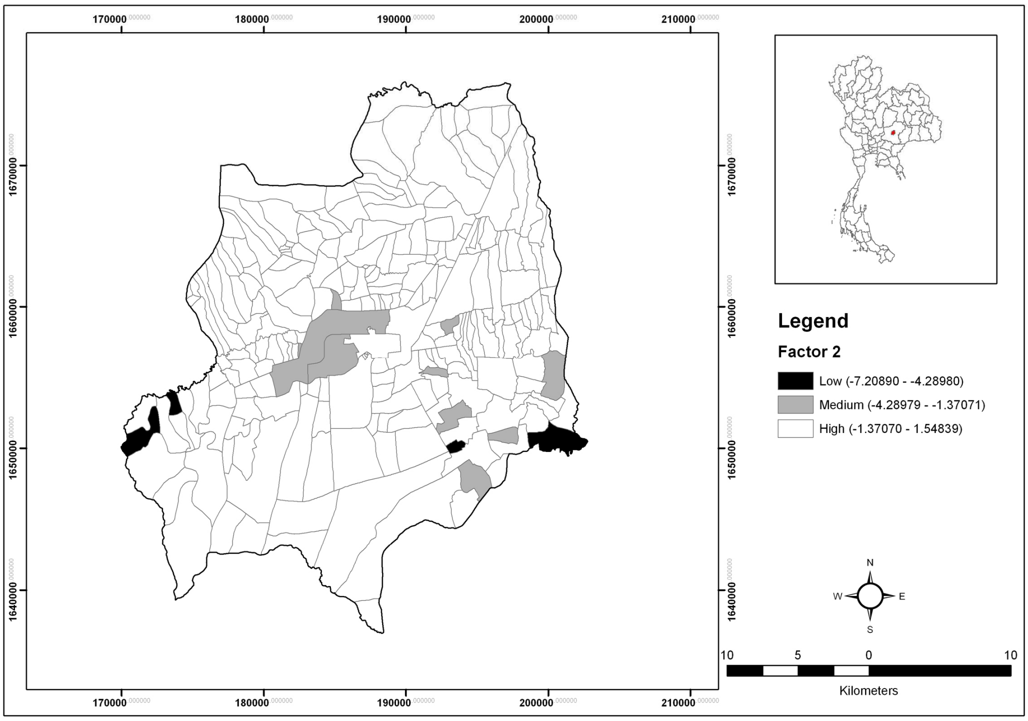


Figure 7.11 Factor 2: Measurement of Housing in each village.

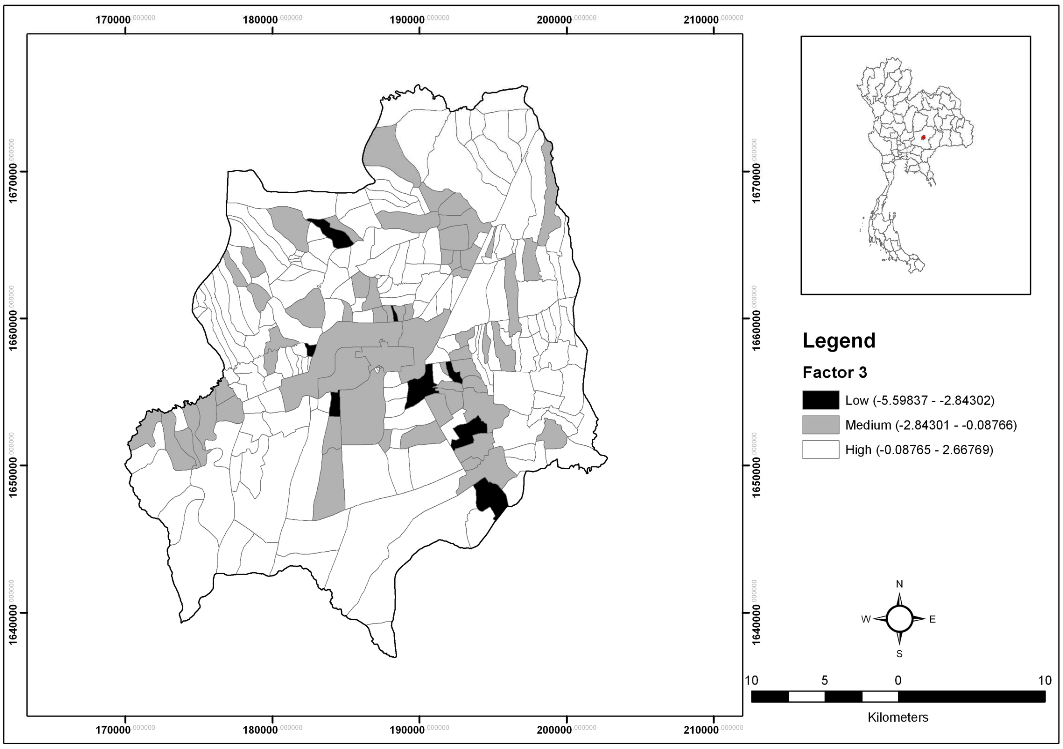


Figure 7.12 Factor 3: Measurement of People Participation in each village.

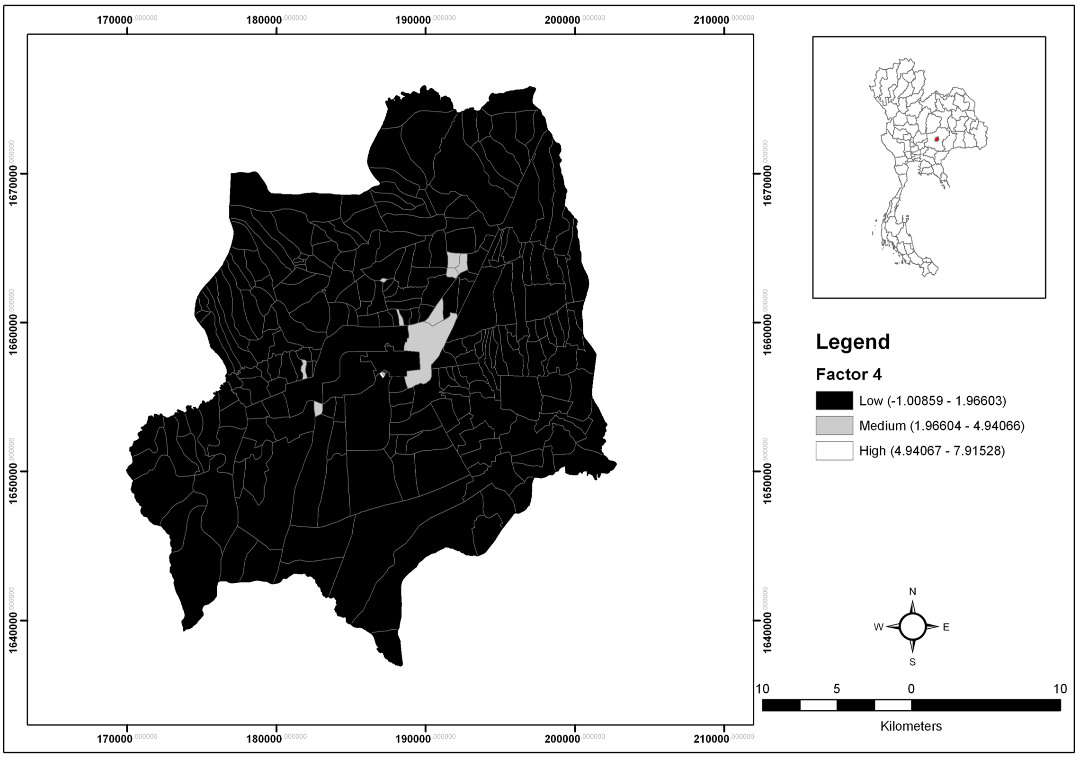


Figure 7.13 Factor 4: Measurement of Crowdedness in each village.

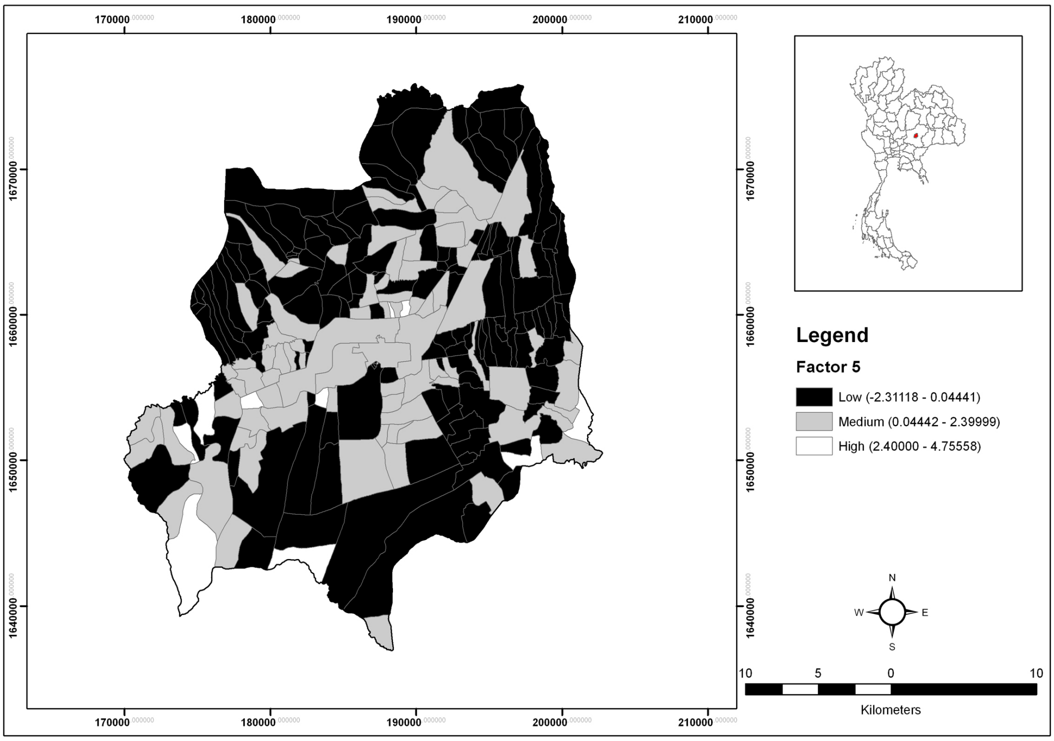


Figure 7.14 Factor 5: Measurement of Income in each village.

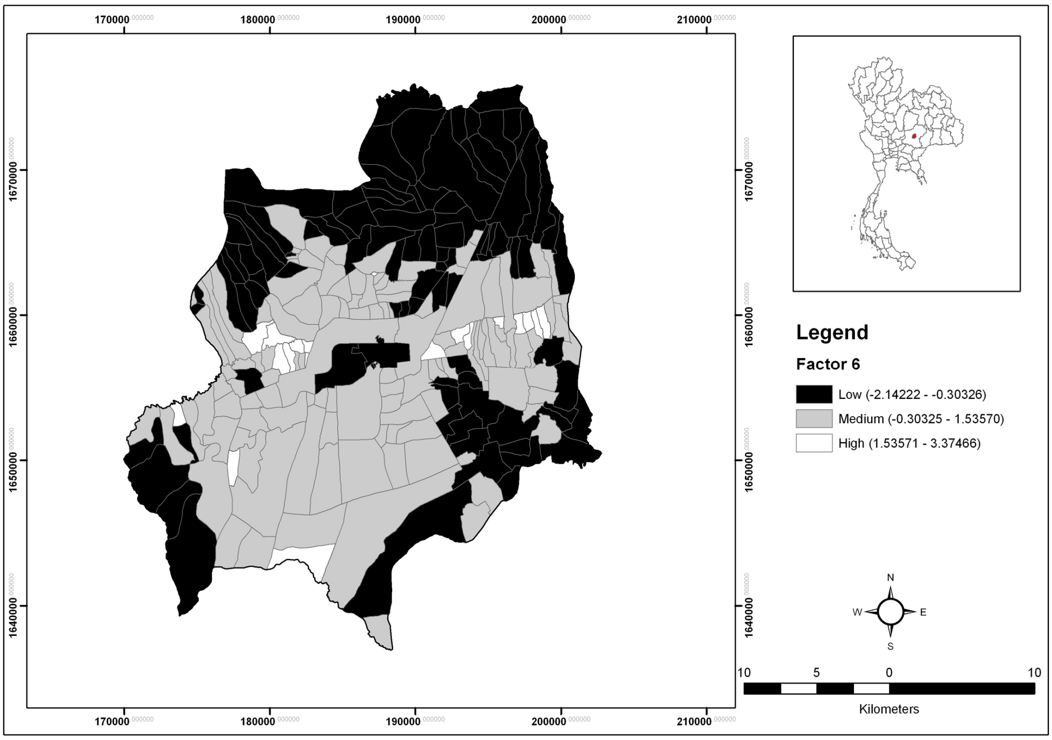


Figure 7.15 Factor 6: Measure of Environment Quality in each village.

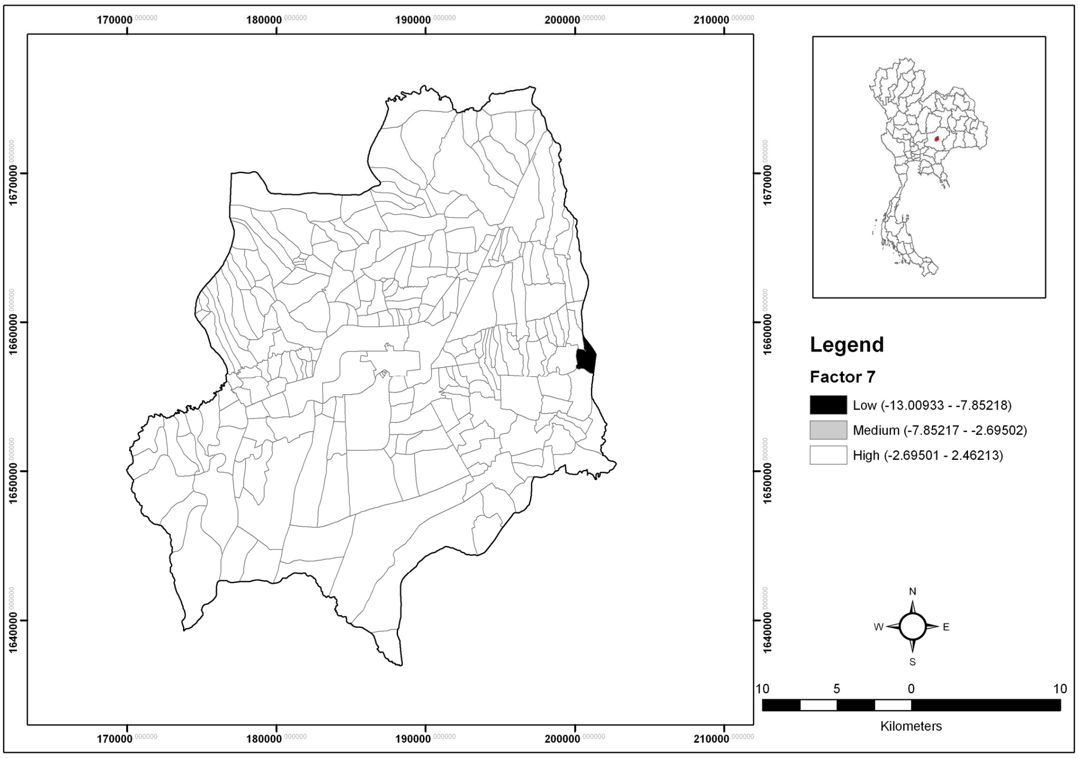


Figure 7.16 Factor 7: Measurement of Safety and saving in each village.

7.1.3 Development of synthetic QOL index

Development of a synthetic QOL index involves the integration of the seven factors or components that represent together different aspects of quality of life. In this study, most of factors have a positive contribution to quality of life except factor 4 (crowdedness) has a negative correlation to quality of life. Then, QOL index is calculated by summation of multiplication between factor score and weight (Eq. 4.20) as follows:

$$\text{QOL index} = (16.179*\text{Factor 1} + 15.166*\text{Factor 2} + 12.053*\text{Factor 3} - 10.618*\text{Factor 4} + 7.222*\text{Factor 5} + 7.126*\text{Factor 6} + 5.912*\text{Factor 7})/100 \quad (7.1)$$

Figure 7.17 shows the distribution of QOL scores ranging from -1.1824 to 0.6262. It is remarkable that most of villages have score between 0.0234 and 0.6262, representing as good QOL index. Number of villages having poor, moderate, and good QOL in 2008 is 15, 85, and 136, respectively. Percentage of good QOL index of villages is about 57.63%. The QOL scores and QOL level of each village and its characteristic are presented in Appendix B.

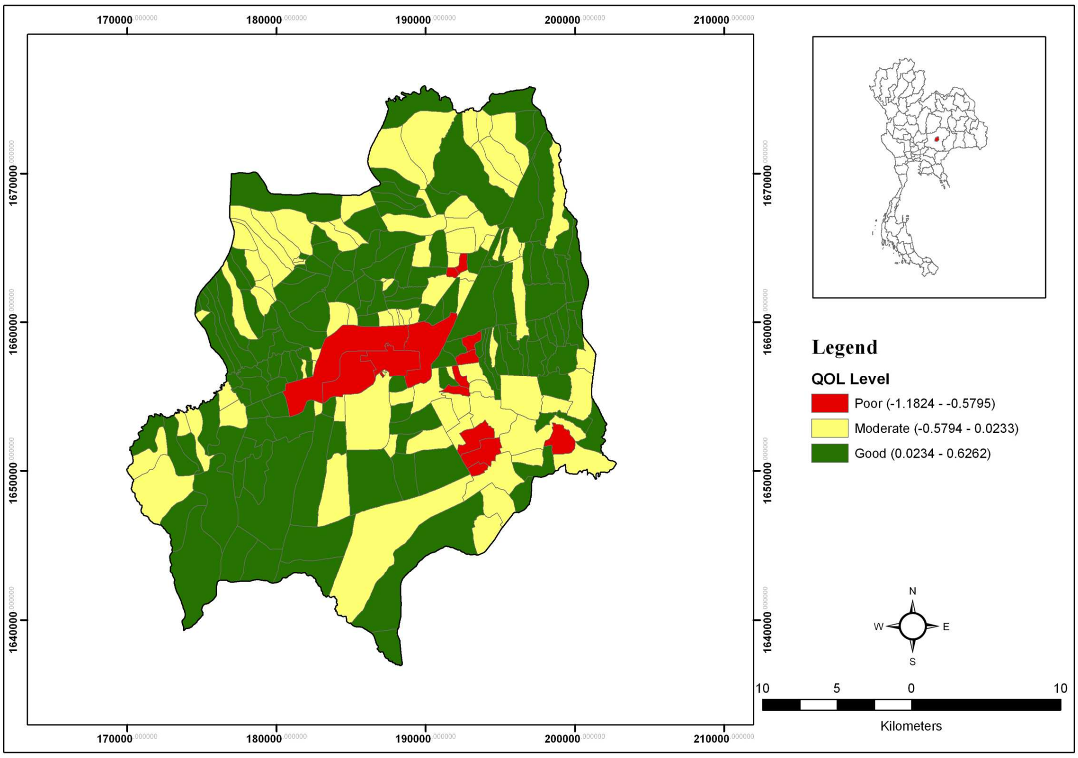


Figure 7.17 Quality of life index in each sub-district of Mueang Nakhon Ratchasima district in 2008.

7.2 Validation of QOL index

QOL index derived from factor analysis (Eq. 7.1) will be validated using the QOL level of Community Development Department as reference. In this study, three priorities for defining a plan to develop QOL of village were assigned by equal interval method as Community Development Department in 2008 for validation of QOL index with following conditions:

(1) If a village fells to pass BMN indicators between 0 and 7 BMN indicators which implies high QOL index, then that village will be represented with good QOL level;

(2) If a village fells to pass BMN indicators between 8 and 14 BMN indicators which implies high QOL index, then that village will be represented with moderate QOL level;

(3) If a village fells to pass BMN indicators between 15 and 21 BMN indicators which implies high QOL index, then that village will be represented with poor QOL level.

Figure 7.18 shows the distribution of QOL level based on BMN data in 2008 as reference data for QOL index validation. At same time, previous derived QOL score based on factor analysis (Figure 7.17) was used as candidate data for QOL data validation.

In this study, contingency matrix between reference and candidate data was created for validation QOL index in term of agreement by using overall accuracy and Kappa analysis. It was found that overall accuracy and Kappa hat coefficient of agreement for QOL level between derived QOL from factor analysis and BMN data was 74.58% and 0.52, respectively (Table 7.9). In fact, there are 176 villages of 236 villages coincide with QOL level. In addition, one village from derived QOL identified as poor level is significantly different from BMN data QOL as it is defined to good level.

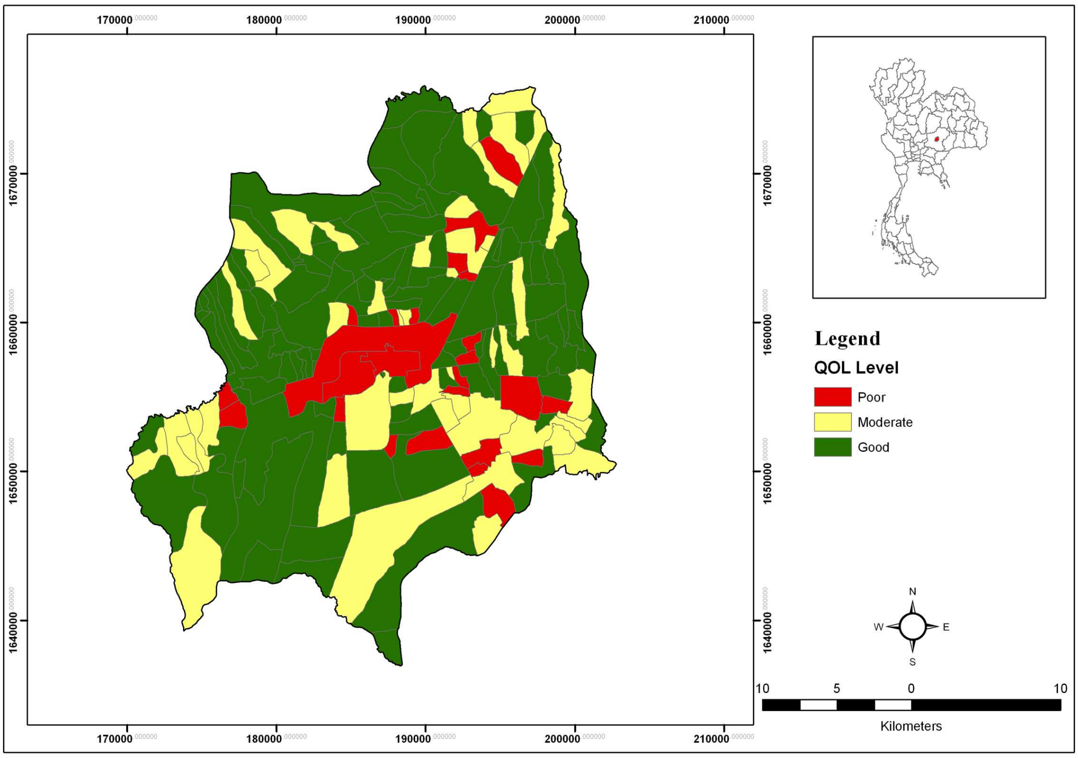


Figure 7.18 Level of QOL based on BMN data.

Table 7.9 Contingency matrix for QOL index validation.

QOL level by Factor Analysis	QOL Level by BMN Data			
	Good	**Moderate**	**Poor**	**Total**
Good	126	10	0	**136**
Moderate	30	39	16	**85**
Poor	1	3	11	**15**
Total	**157**	**52**	**27**	**236**

7.3 Predictive QOL index by regression analysis

After QOL indices were created from factors analysis, regression analysis can be then applied to relate QOL index value to environmental, socioeconomic and BMN indicators variables. In fact, for a specific QOL aspect, factors were regressed against those variables that had high loading (see Table 7.8). In this study, regression model, therefore, are constructed in various QOL aspects based on R^2 as following.

(1) Health, education and cultural values QOL model. Since factor 1 had high correlation with four BMN indicators for QOL measurement including (1) A household correctly knows about medicine usage (code G110), (2) Everybody in a household has quality and standard security (code G109), representing as health measurement of BMN, (3) A household receives advantageous information at least 5 times a week (code G328), representing as education measurement of BMN, and (4) A household does religious activities at least one a week (code G535), representing as values measurement of BMN. These variables were then used as predictor variables in the regression model for health, education, and cultural values QOL model. The derived regression equation for health, education, and cultural values QOL with R^2 = 0.864 is as follows:

$$\text{Health, education and cultural values QOL} = (3.584*10^{-15}) + 0.351*G109 + 0.230*G110 + 0.414*G328 + 0.043*G535 \quad (7.2)$$

(2) Housing QOL model. Since factor 2 had high correlation with three BMN indicators for QOL measurement including (1) A household has sufficient water to

consume (code G215), (2) A household does not bother from pollution (code G218), and (3) Housing is durable at least for 5 years and has tenure security (code G214), representing as housing measurement of BMN. So, these variables will be used as predictor variables in the regression model for housing QOL model. The derived regression equation for housing QOL with $R^2 = 0.843$ is as follows:

$$\text{Housing QOL} = (1.524*10^{-14}) + 0.372*G215 + 0.326*G218 + 0.406*G214 \quad (7.3)$$

(3) Participation QOL model. Since factor 3 had high correlation with three BMN indicators for QOL measurement including (1) A household participates and shares their thought in community meetings (code G639), (2) A household participates in natural conservation activities (code G640), and (3) A household belongs to a least one community group (code G638) representing as participation measurement of BMN. These variables will be then used as predictor variables in the regression model for participation QOL model. The derived regression equation for participation QOL with $R^2 = 0.798$ is as follows:

$$\text{Participation QOL} = (-1.258*10^{-15}) + 0.195*G638 + 0.375*G639 + 0.377*G640 \quad (7.4)$$

(4) Crowdedness QOL model. Since factor 4 had high correlation with three variables for QOL measurement in term of crowdedness including (1) household density (HH_den), (2) population density (Pop_den) representing as socioeconomic

variables, and (3) urban and built-up area (Urban) representing as environment variables. These variables will be used to develop crowdedness QOL model. The derived regression equation for crowdedness QOL with R^2 = 0. 978 is as follows:

$$\text{Crowdedness QOL} = (-7.877*10^{-17}) + 0.536*\text{Pop\_den} + 0.294*\text{HH\_den} + 0.275*\text{Urban} \quad (7.5)$$

(5) Economic QOL model. Since factor 5 had high correlation with two variables for QOL measurement in term of economic including (1) Per capita income (Pop_income) and (2) Per household income (HH_income), representing as socioeconomic variables. In general, these variables should be used as predictor variables in the regression model for economic QOL model. The derived regression equation for economic QOL with R^2 = 0.927 is as follows:

$$\text{Economic QOL} = (7.342*10^{-16}) + 0.592*\text{Pop\_income} + 0.490*\text{HH\_income} \quad (7.6)$$

(6) Environment QOL model. Since factor 6 had high correlation with two variables for environment QOL measurement including (1) surface temperature (ST) and (2) Normalized Differencing Vegetation Index (NDVI), representing as environment indicator. In general, these variables should be used as predictor variables in the regression model for environment QOL model. The derived regression equation for environment QOL with R^2 = 0.988 is as follows:

$$\text{Environment QOL} = (1.535*10^{-15}) - 0.559*\text{ST} + 0.551*\text{NDVI} \quad (7.7)$$

(7) Safety QOL model. Since factor 7 had high correlation with one BMN indicators for QOL measurement, (1) A household knows how to prevent the accidents (code G219), representing as housing measurement of BMN. This variable will be then used as predictor variable in the regression model for safety QOL model. The derived regression equation for safety QOL with $R^2 = 0.738$ is as follows:

$$\text{Safety QOL} = (-7.025*10^{-15}) + 0.859*\text{G219} \quad (7.8)$$

(8) Synthetic QOL Model. Concerning this process, highest significant variables from each factor will be employed with standardized value to develop synthetic QOL by linear regression. The derived regression equation for synthetic QOL index with $R^2 = 0.865$ is as follows:

$$\text{Synthetic QOL} = (2.081*10^{-14}) + 0.395*\text{G110} + 0.276*\text{G215} + 0.309*\text{G639} - 0.346*\text{HH\_den} + 0.263*\text{Pop\_income} - 0.201*\text{ST} + 0.085*\text{G219} \quad (7.9)$$

Detail of regression analysis for predictive QOL index in 7 aspects and synthetic QOL model is presented in Appendix C.

CHAPTER VIII

QUALITY OF LIFE PREDICTION AND ITS CHANGE

The main result in this chapter focuses on prediction of QOL in 2010 and 2018 and compared with QOL assessment in 2008. Herein, synthetic QOL model which was developed based on significant predictors form factor analysis by regression analysis as explanation in section 7.3 of Chapter 7 was used to compare the changes of QOL. In this study, two periods of QOL change, between 2008 and 2010 for short term and between 2008 and 2018 for long term, were explained here in term of gain and loss by transition matrix. Specific results were here separately explained including: (1) assessment of QOL index in 2008 and prediction of QOL index in 2010 and 2018 and (2) QOL changes between 2008 and 2010 and between 2008 and 2018.

8.1 Assessment of QOL index in 2008 and prediction of QOL index in 2010 and 2018

8.1.1 Extraction and estimation of predictors for QOL index

In fact, QOL index in 2008 was assessed and QOL index in 2010 and 2018 were predicted based on synthetic QOL model (Eq. 7.9) to generate QOL score in respectively year. Herein, predictors for synthetic QOL in 2008 was directly extracted from remote sensing, socioeconomic and BMN data in 2008 while predictors for synthetic QOL in 2010 and 2018 were estimated by trend analysis based on historical time series data of remote sensing, socioeconomic and BMN data.

In this study, predictors of synthetic QOL were categorized into 3 groups with 7 predictors including:

(1) Environment data

1) Surface temperature (ST)

(2) Socioeconomic data

2) Per capita income (Pop_income)

3) Household density (HH_den)

(3) BMN indicators

4) A household correctly knows about medicine usage (G110)

5) A household has sufficient water to consume (G215)

6) A household knows how to prevent accidents (G219)

7) A household participates and shares their thought in community meetings (G639)

After that, linear scale transformation with benefit and cost criteria equations (Makczewski, 1999) was applied to original synthetic QOL score to generate level of QOL in respective year. In this study, QOL was categorized into 5 levels: very poor, poor, moderate, good, and very good.

8.1.1.1 Extraction and estimation of surface temperature

Landsat-TM data in 2008 was used to extract surface temperature by standard method of NASA. While two input surface temperature data in 2006, 2008, and 2009 which were derived from Landsat-TM by standard method as mentioned earlier were used to estimate surface temperature data in 2010 and 2018 by trend analysis. In practice, mean value of surface temperature in each village were used in this analysis. It was found that the range of surface temperature data in 2008, 2010, and 2018 were 27.31-37.85, 21.39-28.18, and 26.27-32.50, respectively. The distribution of predictive surface temperature in 2008, 2010, and 2018 were presented in Figure 8.1 a, b, and c, respectively.

8.1.1.2 Extraction and estimation of per capita income

Per capita income from BMN data in 2008 was directly extracted as predictor for synthetic QOL in 2008. At the same time, time series of per capita income from BMN data in 2004, 2006, 2008, and 2009 were used to estimate per capita income data in 2010 and 2018 by trend analysis. It was found that the range of per capita income data in 2008, 2010, and 2018 were 23,071.21-215,481.68, 27,704.61-169,000.00, and 23,256.07-173,337.95 respectively. The distribution of predictive per capita income in 2008, 2010, and 2018 were presented in Figure 8.2a, b, and c, respectively.

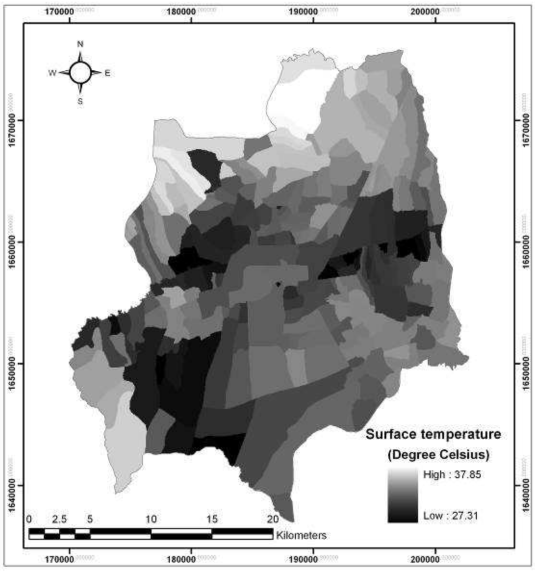
8.1.1.3 Extraction and estimation of household density

Household density from BMN data in 2008 was directly extracted as predictor for synthetic QOL in 2008. At the same time, time series of household density from BMN data in 2004, 2006, 2008, and 2009 were used to estimate household density data in 2010 and 2018 by trend analysis. It was found that the range of household density data in 2008, 2010, and 2018 were 3.47 to 5205.25, 3.83 to 5569.40, and 4.15 to 5959.26, respectively. The distribution of predictive household density in 2008, 2010, and 2018 were presented in Figure 8.3a, b, and c, respectively.

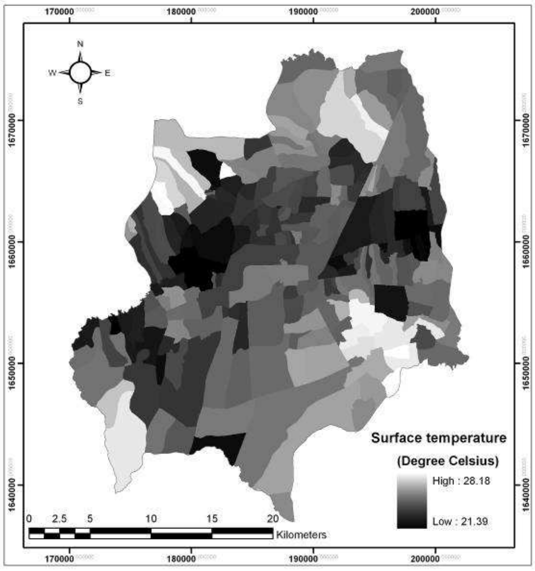
8.1.1.4 Extraction and estimation of predictors of BMN data

Predictors of BMN indicators include (1) A household correctly knows about medicine usage (G110), (2) A household has sufficient water to consume (G215), (3) A household knows how to prevent accidents (G219), and (4) A household participates and shares their thought in community meetings (G639) from BMN data in 2008 were directly extracted for synthetic QOL in 2008. At the same time, time series of these predictors of BMN of from 2004, 2006, 2008, and 2009 were used to estimate 4 predictors of BMN indicators in 2010 and 2018 by trend analysis.

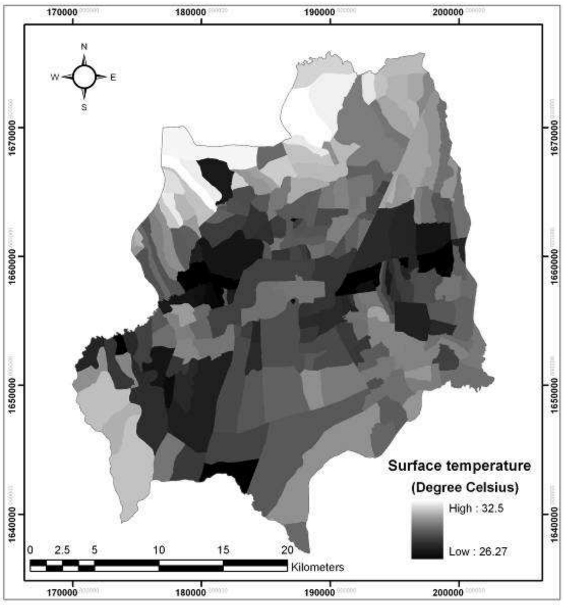
It was found that the range of household correctly knows about medicine usage (G110) in 2008, 2010, and 2018 were 52.70 to 100.00, 36.93 to 100.00, and 0.00 to 100.00, respectively. The distribution of this predictor in 2008, 2010, and 2018 were presented in Figure 8.4a, b, and c, respectively. Also, the range of household had sufficient water to consume (G215) in 2008, 2010, and 2018 were 85.90 to 100.00, 77.83 to 100.00, and 6.87 to 100.00, respectively. The distribution of this predictor in 2008, 2010, and 2018 were presented in Figure 8.5a, b, and c, respectively. While, the range of household knows how to prevent the accidents (G219) in 2008, 2010, and 2018 were 4.61 to 100.00, 0.00 to 100.00, and 0.00 to 100.00, respectively. The distribution of this predictor in 2008, 2010, and 2018 were presented in Figure 8.6a, b, and c, respectively. In addition, the range of household participates and shares their thought in community meetings (G639) in 2008, 2010, and 2018 were 45.21 and 100.00, 20.18 and 100.00, and 0.00 and 100.00, respectively. The distribution of this predictor in 2008, 2010, and 2018 were presented in Figures 8.7a, b, and c, respectively.



(a) Surface temperature in 2008.

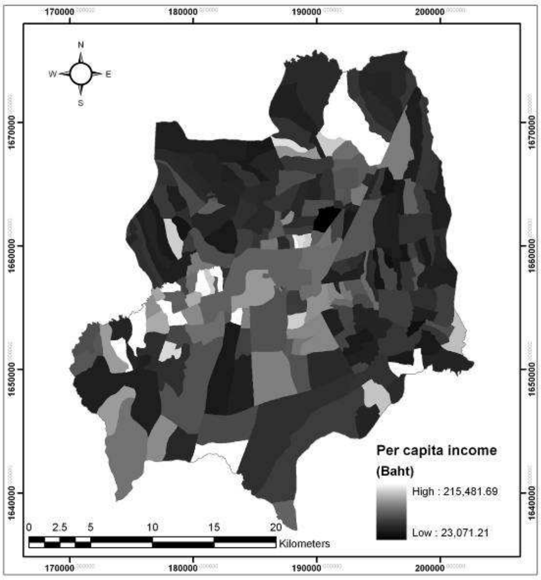


(b) Surface temperature in 2010.

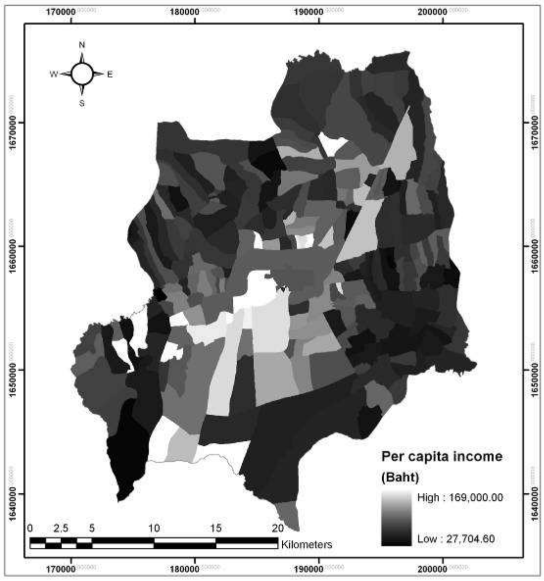


(c) Surface temperature in 2018.

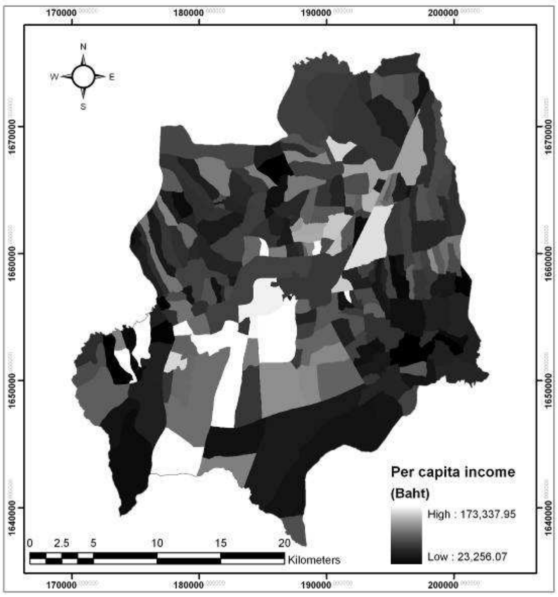
Figure 8.1 Extraction and estimation of surface temperature in 2008, 2010, and 2018.



(a) Per capita income in 2008.

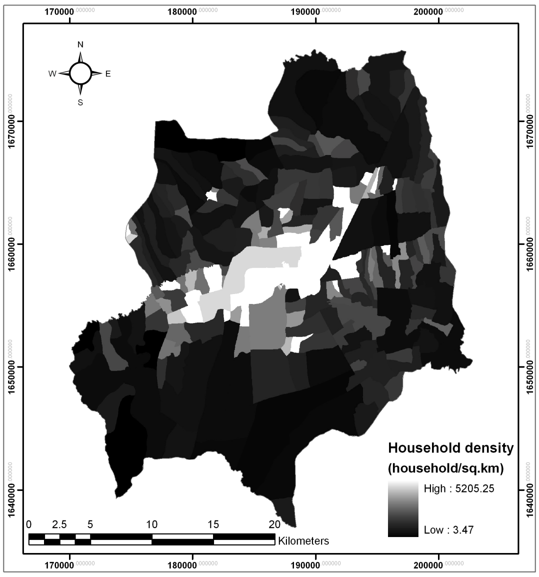


(b) Per capita income in 2010.

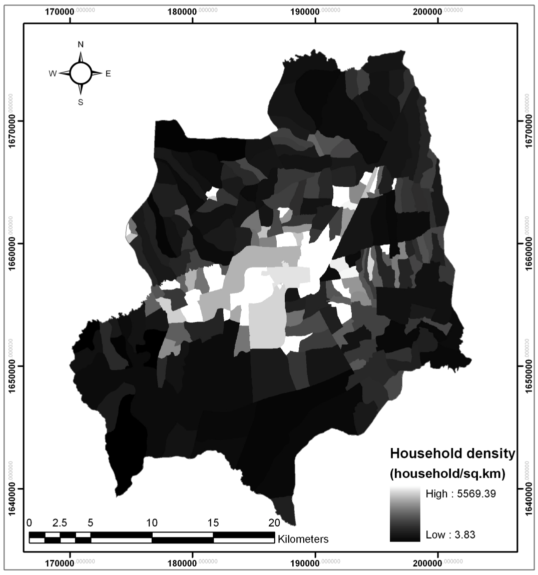


(c) Per capita income in 2018.

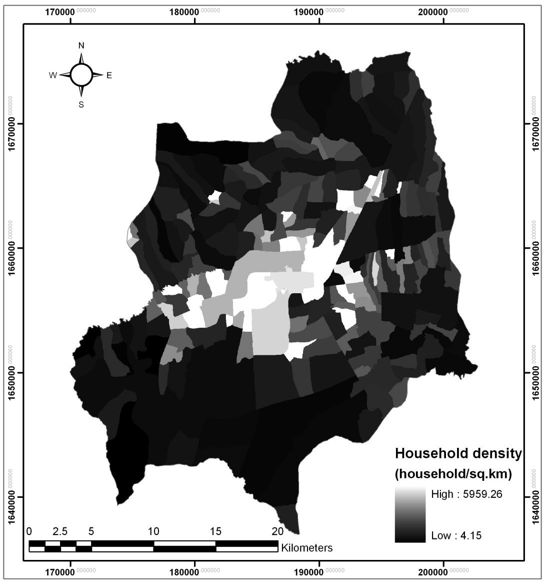
Figure 8.2 Extraction and estimation of per capita income in 2008, 2010, and 2018.



(a) Household density in 2008.

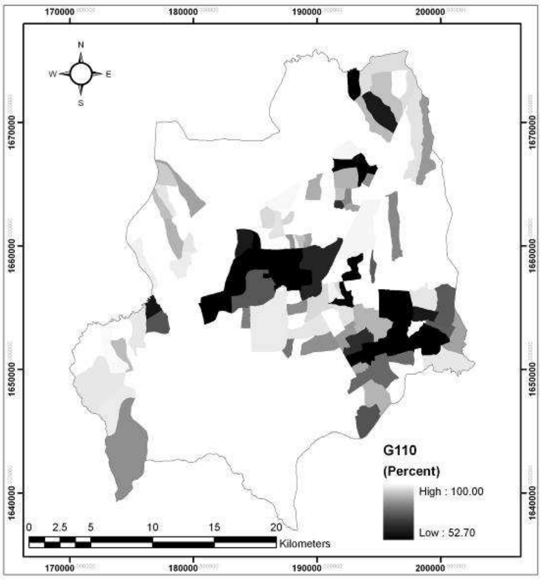


(b) Household density in 2010.

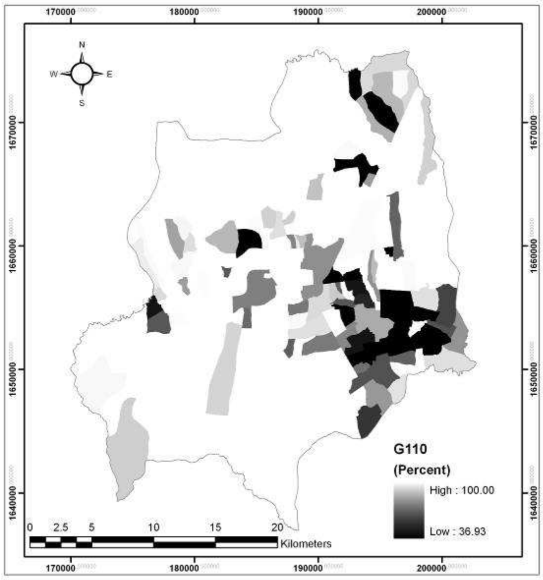


(c) Household density in 2018.

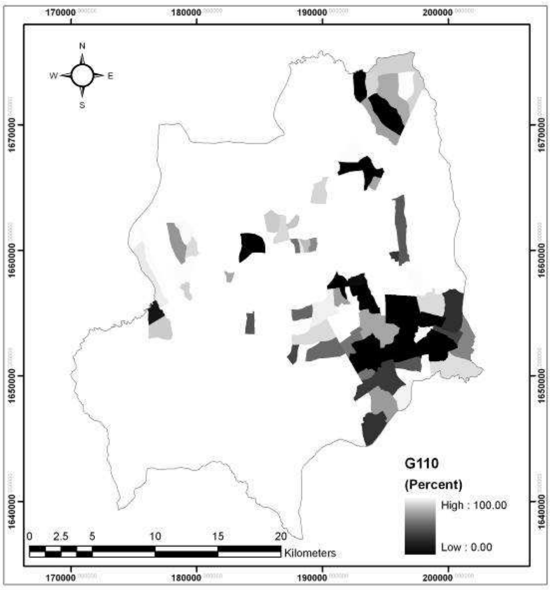
Figure 8.3 Extraction and estimation of household density in 2008, 2010, and 2018.



(a) A household correctly knows about medicine usage in 2008.

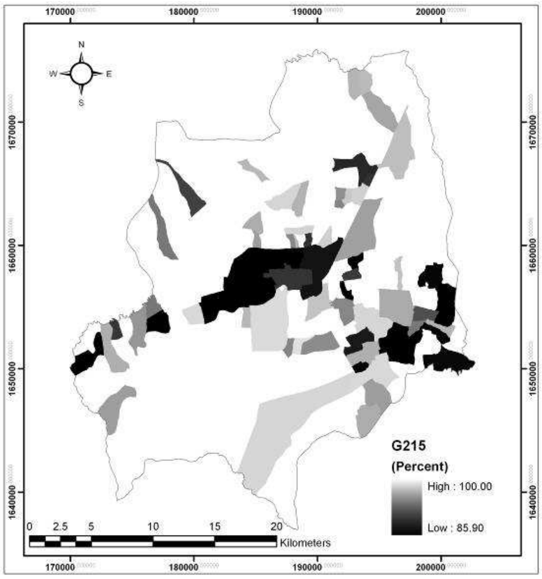


(b) A household correctly knows about medicine usage in 2010.

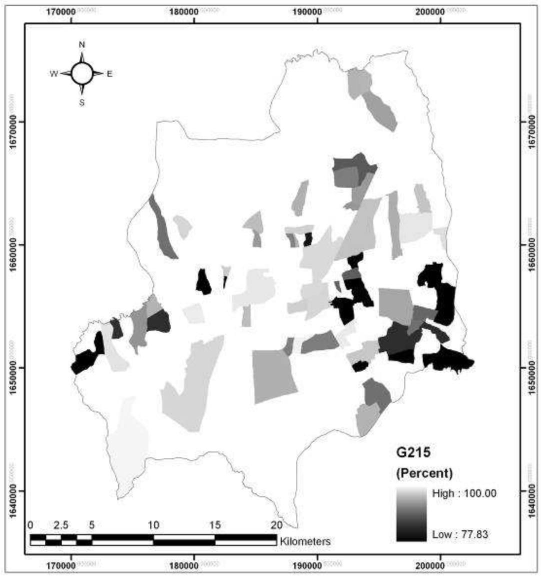


(c) A household correctly knows about medicine usage in 2018.

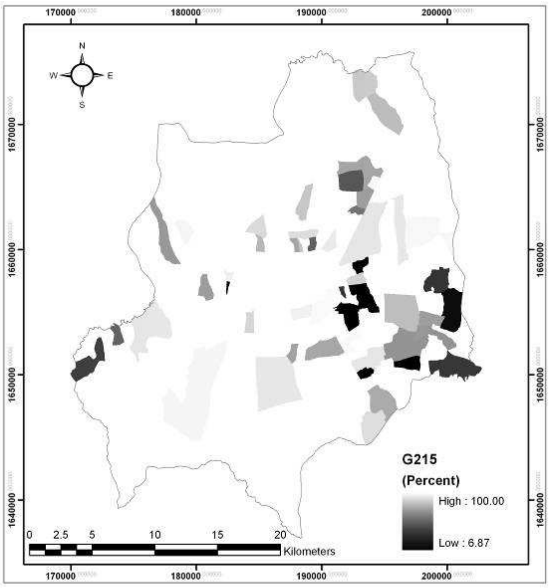
Figure 8.4 Extraction and estimation of a household correctly knows about medicine usage (G110) in 2008, 2010, and 2018.



(a) A household has sufficient water to consume usage in 2008.

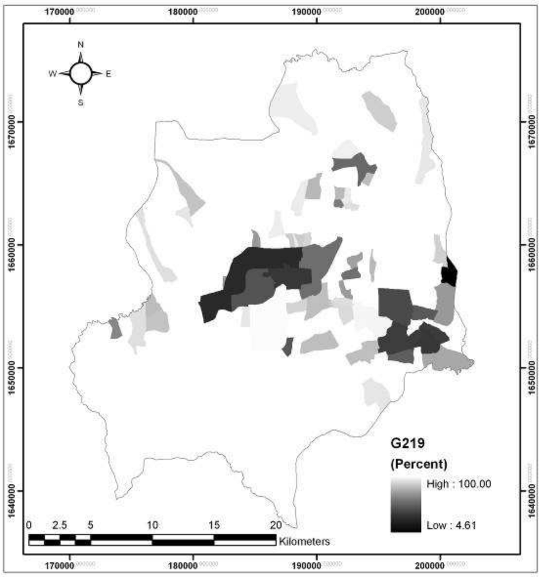


(b) A household has sufficient water to consume usage in 2010.

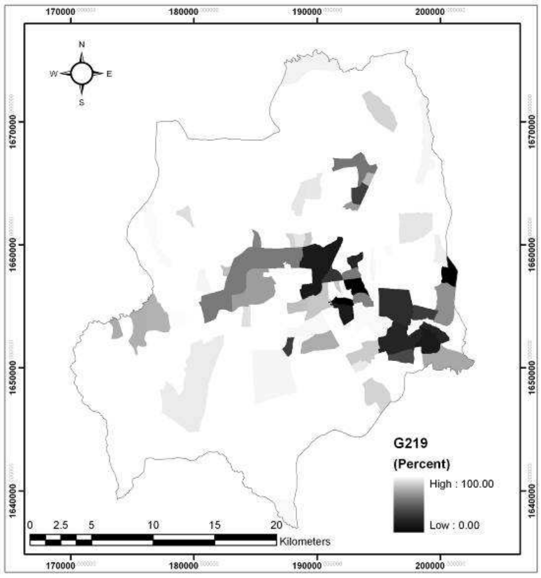


(c) A household has sufficient water to consume in 2018.

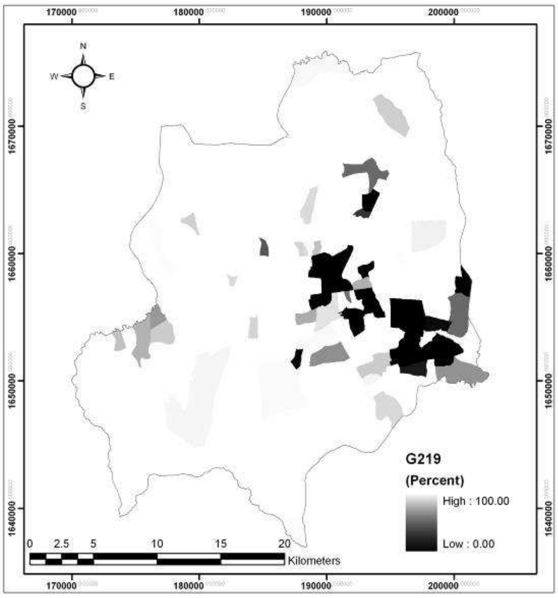
Figure 8.5 Extraction and estimation of a household has sufficient water to consume (G215) in 2008, 2010, and 2018.



(a) A household knows how to prevent the accidents in 2008.

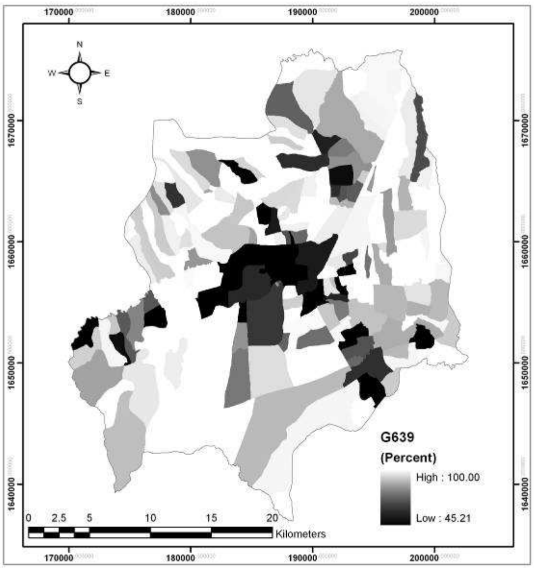


(b) A household knows how to prevent the accidents in 2010.

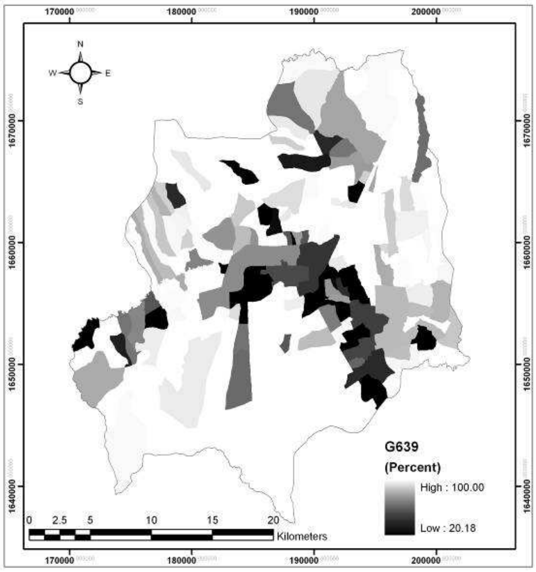


(c) A household knows how to prevent the accidents in 2018.

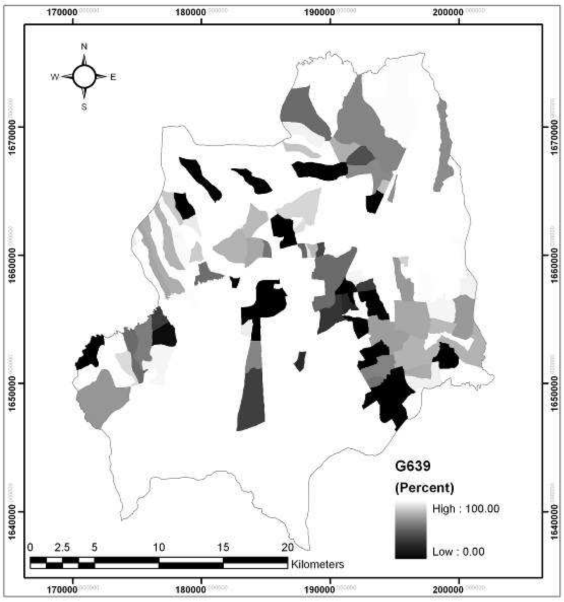
Figure 8.6 Extraction and estimation of a household knows how to prevent the accidents (G219) in 2008, 2010, and 2018.



(a) A household participates and shares their thought in community meetings in 2008.



(b) A household participates and shares their thought in community meetings in 2010.



(c) A household participates and shares their thought in community meetings in 2018.

Figure 8.7 Extraction and estimation of a household participates and shares their thought in community meetings (G639) in 2008, 2010, and 2018.

8.1.2 Assessment of QOL index in 2008

Based on synthetic QOL model (Eq. 7.9), QOL in Muang Nakhon Ratchasima district in 2008 was classified into 5 levels included very poor, poor, moderate, good and very good. It was found that number of villages in each QOL levels: very poor, poor, moderate, good and very good are 3, 8, 32, 169, and 24, respectively (Table 8.1). The distribution of QOL in 2010 is presented in Figure 8.8.

Table 8.1 Number and percentage of villages for each QOL levels in 2008.

Levels	**Number of village**	**Percentage**
Very poor	3	1.27
Poor	8	3.39
Moderate	32	13.56
Good	169	71.61
Very good	24	10.17
Total	**236**	**100.00**

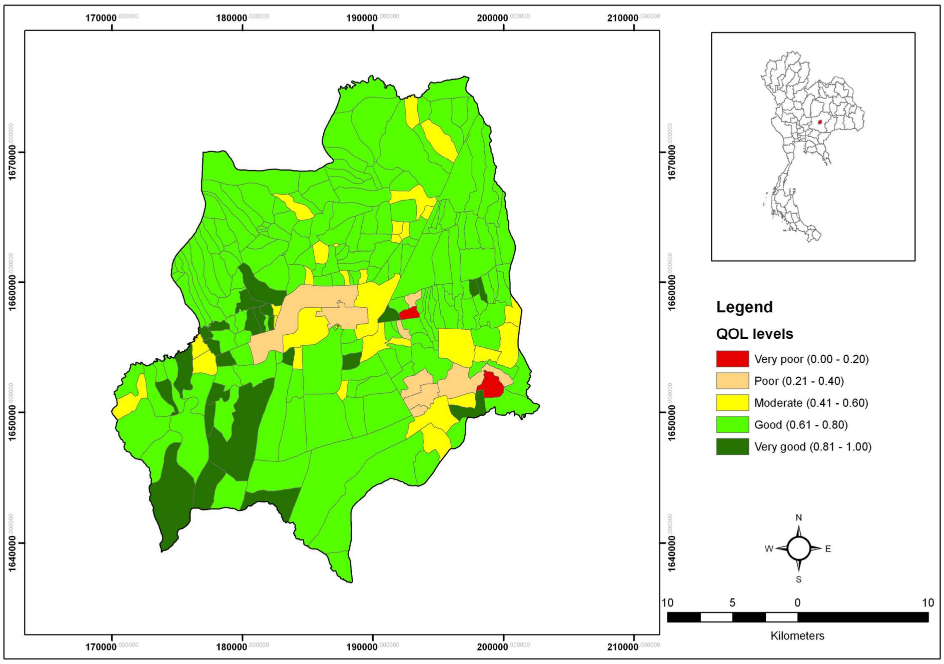


Figure 8.8 Distribution of QOL levels in 2008.

8.1.3 Prediction of QOL index in 2010

Based on standard synthetic QOL model, QOL in Muang Nakhon Ratchasima district in 2010 was classified into 5 levels: very poor, poor, moderate, good, and very good. It was found that number of villages in each QOL levels: very poor, poor, moderate, good, and very good were 2, 3, 19, 170, and 42, respectively (Table 8.2). The distribution of QOL in 2010 was presented in Figure 8.9.

Table 8.2 Number and percentage of villages for each QOL levels in 2010.

Levels	Number of village	Percentage
Very poor	2	0.85
Poor	3	1.27
Moderate	19	8.05
Good	170	72.03
Very good	42	17.80
Total	**100**	**100.00**

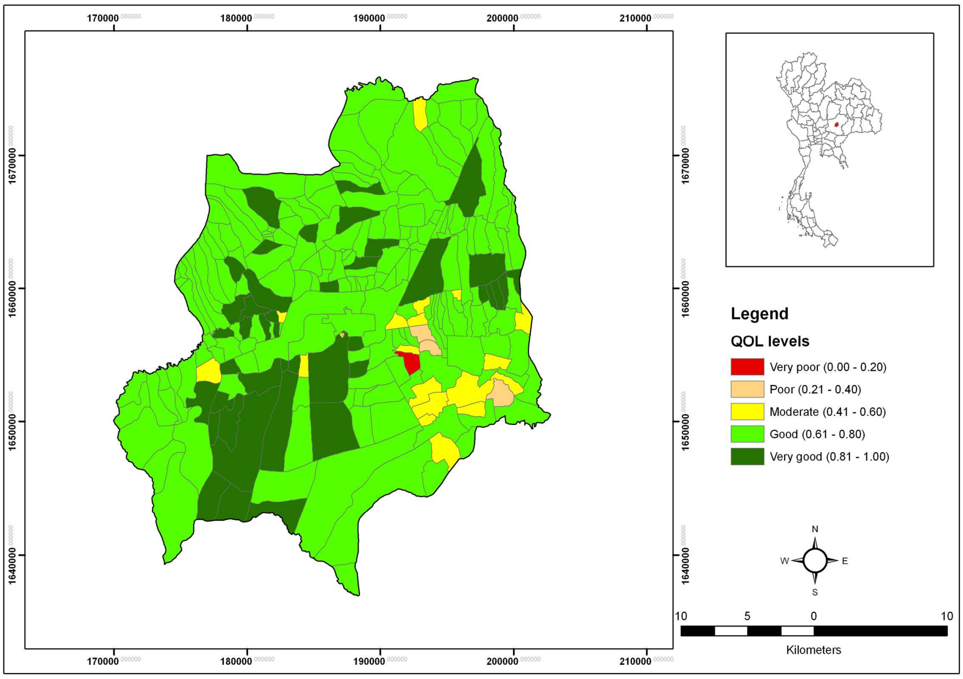


Figure 8.9 Distribution of QOL levels in 2010.

8.1.4 Prediction of QOL index in 2018

Based on standard synthetic QOL model, QOL in Muang Nakhon Ratchasima district in 2018 was classified into 5 levels: very poor, poor, moderate, good, and very good. It was found that number of villages in each QOL level: very poor, poor, moderate, good, and very good were 5, 4, 29, 168, and 30, respectively (Table 8.3). The distribution of QOL in 2018 was shown in Figure 8.10.

Table 8.3 Number and percentage of villages for each QOL levels in 2018.

Levels	Number of village	Percentage
Very poor	5	2.12
Poor	4	1.69
Moderate	29	12.29
Good	168	71.19
Very good	30	12.71
Total	**236**	**100.00**

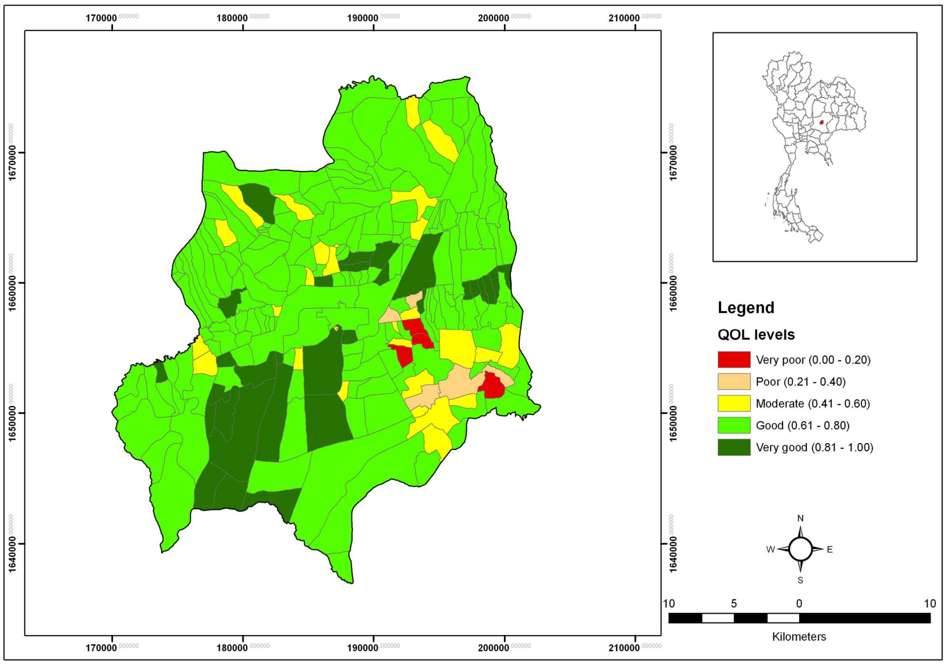


Figure 8.10 Distribution of QOL levels in 2018.

8.2 Change of QOL

Basically, linear scale transformation QOL index in two periods (2008-2010 and 2008-2018) were compared by using transition matrix to explain QOL change in term of gain and loss.

8.2.1 QOL change between 2008 and 2010

Based on transition matrix of QOL between 2008 and 2010 as short term period of urban growth (Table 8.4), it was found that QOL's level of 165 villages from 236 villages in 2010 had same level as in 2008. In addition, QOL's level of 58 villages from 236 villages in 2010 was better than QOL's level in 2008 while QOL's level of 13 villages from 236 villages in 2010 had poorer than QOL's level in 2008. Distribution of QOL change between 2008 and 2010 was shown in Figure 8.11.

Table 8.4 Comparison QOL levels between 2008 and 2010.

QOL 2008	**QOL 2010**					
	Very good	**Good**	**Moderate**	**Poor**	**Very poor**	**Total**
Very good	16	7	1	0	0	**24**
Good	26	138	2	2	1	**169**
Moderate	0	22	10	0	0	**32**
Poor	0	3	5	0	0	**8**
Very poor	0	0	1	1	1	**3**
Total	**42**	**170**	**19**	**3**	**2**	**236**

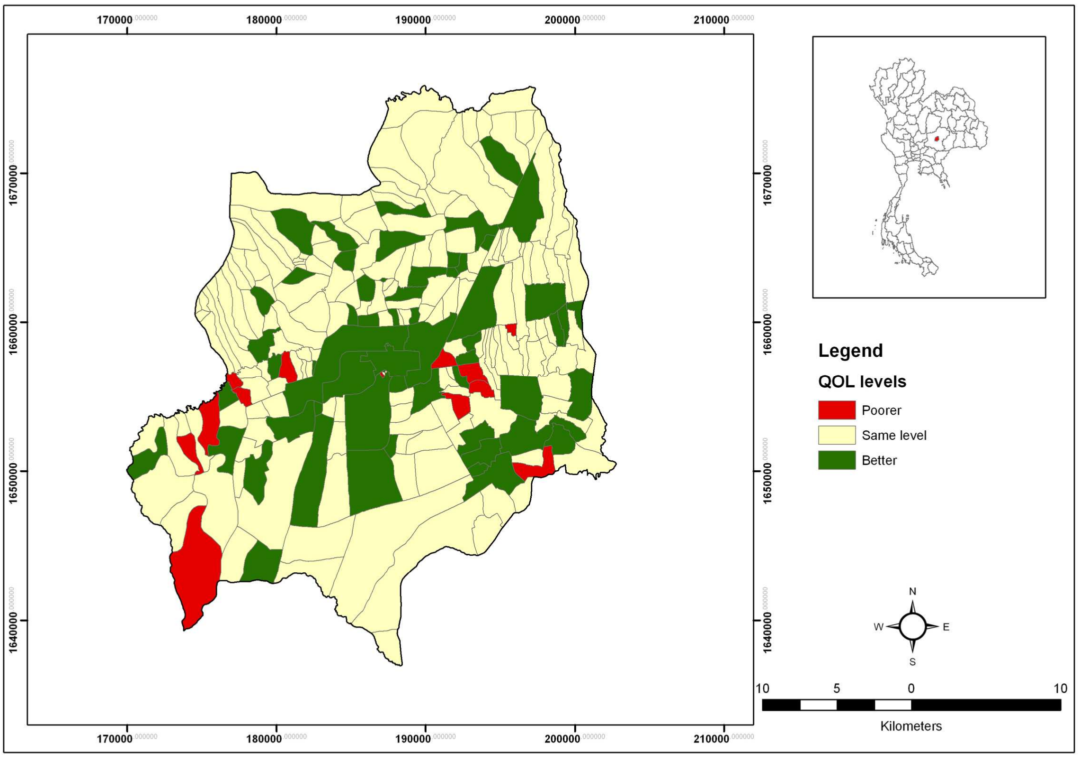


Figure 8.11 Distribution of QOL change between 2008 and 2010.

8.2.2 QOL change between 2008 and 2018

Based on transition matrix of QOL between 2008 and 2018 as long term period of urban growth (Table 8.5), it was found that QOL's level of 171 villages from 236 villages in 2018 had same level as in 2008. In addition, QOL's level of 40 villages from 236 villages in 2018 was better than QOL's level in 2008 while QOL's level of 25 villages from 236 villages in 2018 has poorer than QOL's level in 2008. Distribution of QOL change between 2008 and 2018 was shown in Figure 8.12.

Table 8.5 Comparison QOL levels between 2008 and 2018.

QOL 2008	QOL 2018					
	Very good	Good	Moderate	Poor	Very poor	Total
Very good	8	15	0	1	0	**24**
Good	22	138	6	0	3	**169**
Moderate	0	12	20	0	0	**32**
Poor	0	3	2	3	0	**8**
Very poor	0	0	1	0	2	**3**
Total	**30**	**168**	**29**	**4**	**5**	**236**

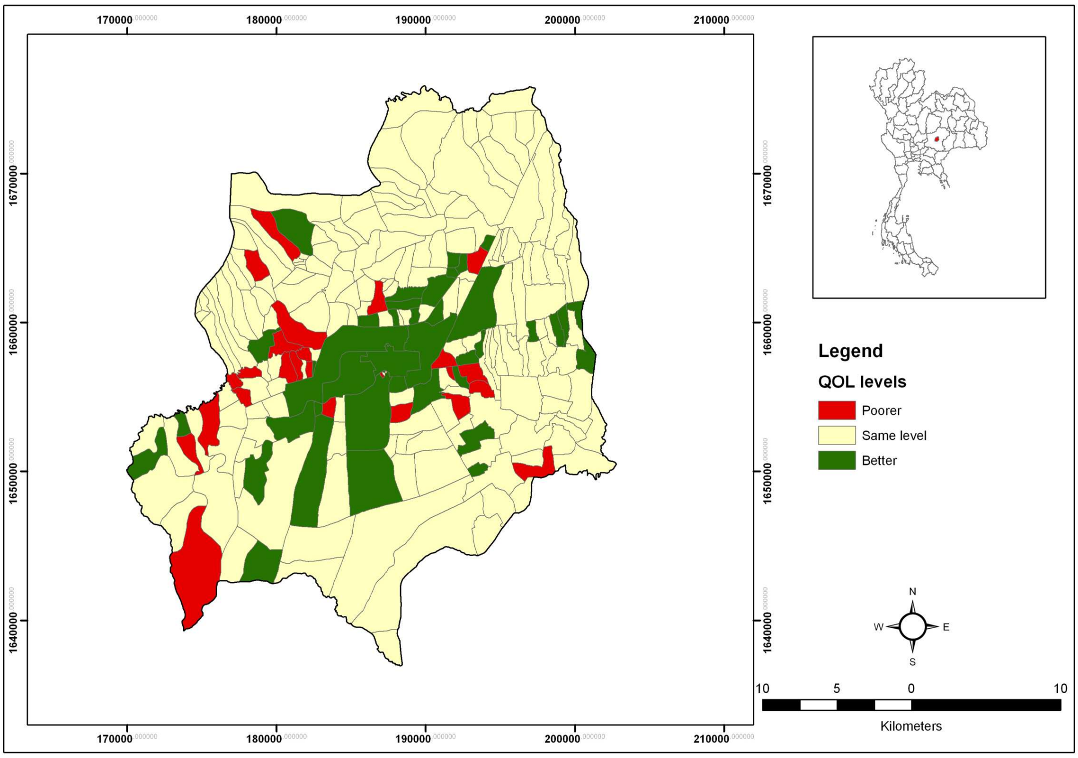


Figure 8.12 Distribution of QOL change between 2008 and 2018.

Detail of QOL change in each village of Mueang Nakhon Ratchasima district in 2008, 2010, and 2018 was presented in Appendix D

CHAPTER IX

CONCLUSION, DISCUSSION AND RECOMMENDATION

There are four main results which are reported in this study including (1) land use assessment and its change and driving force (Chapter V), (2) prediction of urban growth (Chapter VI), (3) assessment of quality of life (Chapter VII), and (4) quality of life prediction and its change (Chapter VIII). For this chapter main results from the last four chapters which consist of (1) assessment of land use and its change and driving force, (2) prediction of urban growth in 2010 and 2018, (3) assessment of quality of life, and (4) quality of life prediction and its change are here separately concluded and discussed with some recommendations.

9.1 Conclusion and discussion

9.1.1 Assessment of land use and its change and driving force

Basically, assessment of land use and its change of Mueang Nakhon Ratchasima district, Nakhon Ratchasima province between 1986 and 2002 were analyzed by using remotely sensed data. In addition, driving force for urban growth was evaluated by stepwise regression analysis, using certain selected factors.

Land use categories in the study area in 1986, 1994, and 2002 were derived from visual interpretation of aerial photographs. They consisted of urban and built-up area, agriculture land, forest land, water body, and miscellaneous land. The development of land use between 1986 and 2002 shown that urban and built-up area, water body and miscellaneous land had continued to increase, while agriculture land and forest land had successively decreased.

In term of long period between 1986 and 2002, it was found that urban and built-up area, water body and miscellaneous land had increased 72.68, 2.46, and 14.41 sq.km or with increasing rates of 11.25%, 0.38%, and 2.23% of the areas in 1986, respectively. Concerning annual increment areas, urban and built-up area, water body and miscellaneous had gained the areas of 4.54, 0.15, and 0.90 sq.km, respectively. In contrast to the former group, during the same period, agriculture land and forest land had lost the areas of 60.99 and 28.56 sq.km, or with decreasing rates of 9.44 and 4.42% of the areas in 1986, respectively. Annual declining areas of agriculture land and forest land were 3.81 and 1.79 sq. km, respectively.

In term of short periods (1986-1994 and 1994-2000), it was found that urban and built-up area, miscellaneous land, and water body had increased with the same annually declining pattern from 4.86 to 4.23 sq.km, from 1.30 to 0.50 sq.km, and from 0.08 to 0.23 sq.km, respectively. In contrast to those previous groups agriculture land had annually decreased with slightly rapid rate from 3.63 to 4.00 sq.km while forest land continued to slowly decrease from 2.61 to 0.96 sq.km. These results implied that during the first period (1986-1994) the pace of urban growth had little impact on land use change, while during the second period (1994-2002), the pace of urban development had much more impact on land use change.

Between 1986 and 2002, it was also found that most of increasing urban and built-up area had been developed from agriculture land, forest land, and miscellaneous land while most of increasing water body had succeeded agriculture land and miscellaneous land had come from agriculture land and forest land. At the same time, most of agriculture land had been changed into urban and built-up area and miscellaneous land while most of forest land had been converted into agriculture land. This land use change then seems to have similar pattern with those found in the researches of Keeratikasikorn, Mongkonsawat, Suwanwerakumtorn and Sutthithan (2007).

In addition, it was found that most of urban expansion in three period (1986-1994, 1994-2002, and 1986-2002) were taken place in all direction within equidistance zone of 500 meter. The annual urban growth rate between 1986 and 2002 was about 0.70, considered to be the urban growth with medium-speed expansion.

Furthermore, the driving force analysis for urban expansion during two short term periods (1986-1994 and 1994-2002) and a long term period (1986-2002) had been calculated by stepwise regression analysis from these selected data: urban land use, population, and infrastructure (road and railway station). It was found that driving forces for urban expansion were agriculture land, miscellaneous land, distance to urban area, forest land, and urban and built-up area from beginning year of two date. These results indicate that the urban expansion in three periods (1986-1994, 1994-2002, and 1986-2002) were driven spontaneously and naturally by socio-economic development such as land use change.

9.1.2 Prediction of urban growth

In principle, two urban growth models, CA-Markov and logistic regression model were firstly applied to predict the urban and built-up area in 2002 and then compared them with the interpreted urban and built-up area in 2002 for identification of optimum model for prediction of urban growth in 2010 and 2018.

In this study, as CA-Markov model could provide higher overall accuracy and Kappa hat coefficient of agreement for urban growth prediction in 2002 than logistic regression model. It was then selected to be the optimum model for urban growth prediction in 2010 and 2018. This result was consistent with the study of Cetin and Demirel (Online, 2010). After simulating urban dynamics of Istanbul Metropolitan with logistic regression and Cellular Automata based Markov models, they found that CA-Markov model was better than the logistic regression model. In addition, Araya and Cabral (2010) mentioned that CA-Markov analysis does not only consider a change from non-built-up to built-up areas, but it could also include any kind of transition among any feature classes.

Under this study, the results of predicted urban and built-up areas in 2002 using logistic regression model was under estimated about 30% because this model used only urban and built-up area in 1986 for prediction of probability data.

For prediction of urban growth in 2010 using CA-Markov model based on land use types in 1994 and 2002, it was found that the area of predicted land use types in 2010 were about 226.98 sq.km. While, for prediction of urban growth in 2018 using CA-Markov model based on interpreted land use types in 2002 and predicted land use types area in 2010, it was found that the area of predicted urban and built-up area in 2018 were about 261.53 sq.km.

We discovered that the urban expansion rates during both short and long term periods had the same pattern, a medium speed expansion. Herewith, when we compared LDD’s urban and built-up area in 2007 and with predicted urban and built-up area in 2010 for short term period, the annual urban growth rate (AGR) was 0.87, representing as medium speed expansion. In the same way, when we compared LDD's urban and built-up area in 2007 with predictive urban and built-up area in 2018 for long term period, we derived the annual urban growth rate (AGR) of 0.65, considered to be also medium speed expansion. However, if there no military bases as barrier that situate adjacency to city, then annual urban growth rate (AGR) might be increase.

9.1.3 Assessment of quality of life

Successively, we integrated remote sensing, socio-economic and BMN data into GIS-based assessment for the Quality of Life (QOL) index using factor analysis and then we applied regression analysis to predict the future QOL.

In this study, we applied factor analysis to extract only seven factors for QOL measurement from the 23 original remote sensing, socio-economic and BMN variables in 2008. The seven factors composed of Factor 1 (health, education and cultural values), Factor 2 (housing), Factor 3 (participation), Factor 4 (crowdedness), Factor 5 (income), Factor 6 (environment quality), and Factor 7 (safety). The QOL index was obtained as follows:

$$\text{QOL index} = (16.179 * \text{Factor 1} + 15.166 * \text{Factor 2} + 12.053 * \text{Factor 3} - 10.618 * \text{Factor 4} + 7.222 * \text{Factor 5} + 7.126 * \text{Factor 6} + 5.912 * \text{Factor 7})/100 \quad (9.1)$$

Regarding the results, the QOL scores in 2008 varied from -1.1824 to 0.6262 and most of villages in Mueang Nakhon Ratchasima district had scores between 0.0234 and 0.6262, considered as good QOL index. There were 15, 85, and 136 villages of 236 villages categorized as poor, moderate, and good QOL, respectively. This result was validated with the level of QOL of Community Development Department. After applying factor analysis and classified QOL using Community Development Department's BMN data in 2008, it was found that overall accuracy and Kappa hat coefficient of agreement for QOL level between derived QOL were 74.58% and 0.52%, respectively.

Furthermore, each factor was regressed against variables with high loading values were constructed for a specific QOL aspect including the QOL models of health, education and cultural values, housing, participation, crowdedness, economy, environment, and safety. In fact, regression equation was built for each QOL aspect and it could be used to explain QOL with concerned factors. In this study, the derived regression equation for synthetic QOL index model, composing of different QOL aspects, was also built for assessment of QOL in 2008 and prediction of QOL in 2010 and 2018 with the following equation:

$$\text{Synthetic QOL} = (2.081*10\text{-}14) + 0.395*G110 + 0.276*G215 + 0.309*G639 - 0.346*HH\_den + 0.263*Pop\_income - 0.201*ST + 0.085*G219 \quad (9.2)$$

where:

G110 A household correctly knows about medicine usage (BMN data);

G215 A household has sufficient water to consume (BMN data);

G639 A household participates and shares their thought in community meetings (BMN data);

HH_den Household density (household/km^2) (BMN data);

Pop_income Per capita income (BMN data);

ST Surface Temperature (Landsat data)

G219 A household knows how to prevent accidents (BMN data);

This study has demonstrated that GIS can provide an effective platform for integrating different data models from different data source such as remote sensing and socio-economic data, and for creating a comprehensive database to assess the quality of life. This would facilitate urban planners and policy makers to formulate urban development plans and strategies. However, several issues raised in the integration of disparate data should be concerned. Li and Weng (2007) stated that remote sensing and socio-economic data were collected for different purposes, at different scales and with different underlying assumptions about the nature of the geographic features. Remote sensing data are digital records of spectral information about ground features with raster format, and often exhibit continuous spatial variation. Socio-economic data usually relate to administrative units and tend to be more discrete in nature with sharp discontinuities between adjacent areas. More often, socio-economic data are integrated into vector GIS as the attributes of its spatial units for various mapping and spatial analysis purposes. Integration between remote sensing and socio-economic data always involves the conversion between data models.

9.1.4 Quality of life prediction and its change

Basically, QOL were firstly extracted in the target years (2008, 2010, and 2018) using synthetic QOL model which was developed based on significant predictors from factor analysis by regression analysis. Then, two QOL periods (2008-2010 and 2008-2018) were used to calculate transition matrix for QOL change in term of gain and loss.

We used synthetic QOL model to extract QOL's levels in 2008, 2010, and 2018. These were classified into 5 levels: very poor, poor, moderate, good and very good. In 2008, there were 3, 8, 32, 169, and 24 villages considered to be very poor, poor, moderate, good, and very good, respectively. In addition, in 2010, we found 2, 3, 19, 170, and 42 classified to be very poor, poor, moderate, good, and very good, respectively. In 2018 there were 5, 4, 29, 168, and 30 villages considered to be very poor, poor, moderate, good, and very good, respectively.

Based on transition matrix of QOL between 2008 and 2010 for short term period of urban growth, among the total 236 villages in the study area, there were 24.6% having better QOL, 5.5% having poorer QOL, and 69.9% having the same QOL.

In the meantime, based on transition matrix of QOL between 2008 and 2018 as long term period of urban growth, among the studied villages, there were 17.0% having better QOL, 10.6% having poorer QOL, and 72.4% having the same QOL.

However, if we compare QOL's level change using different number of villages in term of gain and loss between short term (2008-2010) and long term (2008-2018) periods, it may be concluded that urban growth in long term effects to

QOL's level. In fact, number of gain and loss villages between 2008 and 2010 were 58 and 13 villages, respectively, while number of gain and loss villages between 2008 and 2018 were 40 and 15 villages, respectively.

In conclusion, it appears that integration of derived remotely sensed data with socio-economic and BMN data under GIS environment will be provide information for urban growth modeling and QOL prediction.

9.2 Recommendation

Many objectives were taken into account dealing with assessment of land use and its change and driving force, prediction of urban growth, QOL assessment, and QOL prediction and its change in Mueang Nakhon Ratchasima district. The possibly expected recommendations could be made for further studies as follows:

(1) Land use classification at level II should be applied for urban growth, especially urban and built-up area. This will be provided more detail of urban growth pattern.

(2) To study driving force for urban growth, it should be considered more significant factors such as socio-economic and policy data. In this study, due to a limitation of historical data and difficulty of data collection, the analysis of driving force for urban growth were not included these significant factors.

(3) QOL model should be tested in another area or region for verification and validation of the model. This will be useful for community development.

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APPENDICES

APPENDIX A

LIST OF VILLAGES

Table A-1 List of villages in each sub-district.

Code	Village Number	Village name	Sub-district
30010201	1	Nong Pru	Pho Klang
30010202	2	Nong Phai	Pho Klang
30010203	3	Nong Phluang Noi	Pho Klang
30010204	4	Nong Phluang Manao	Pho Klang
30010205	5	Nong Phutsa	Pho Klang
30010206	6	Nong Bua	Pho Klang
30010207	7	Bung Saen Suk	Pho Klang
30010208	8	Si Somboon	Pho Klang
30010209	9	Khai Suratampitak	Pho Klang
30010210	10	Nong Phai Phatthana	Pho Klang
30010301	1	Tang Ta	Nong Chabok
30010302	2	Krin	Nong Chabok
30010303	3	Thanon Hak	Nong Chabok
30010304	4	Nong Pru	Nong Chabok
30010305	5	Bun Roeng	Nong Chabok
30010401	1	Khok Sung	Khok Sung
30010402	2	Nong Pho	Khok Sung
30010403	3	Song Tai	Khok Sung
30010404	4	Ra-ngom	Khok Sung
30010405	5	Hua Sa	Khok Sung
30010406	6	Ra-ngom Phatthana	Khok Sung
30010407	7	Mamuang Phatthana	Khok Sung
30010408	8	Song Nua	Khok Sung
30010409	9	Lam Choeng Krai	Khok Sung
30010410	10	Samkhan	Khok Sung
30010411	11	Nong Krachai	Khok Sung
30010501	1	Hua Chang	Mareng
30010502	2	Mai	Mareng
30010503	3	Saraphi	Mareng
30010504	4	Phra	Mareng
30010505	5	Bung San	Mareng
30010506	6	Phra	Mareng
30010507	7	Khok	Mareng
30010508	8	Krathon	Mareng
30010601	1	Yong Yaeng	Nong Rawiang
30010602	2	Nong Sai	Nong Rawiang
30010603	3	Nong Muang	Nong Rawiang
30010604	4	Kham Sa Phleng	Nong Rawiang

Table A-1 List of villages in each sub-district (Continued).

Code	Village Number	Village name	Sub-district
30010605	5	Thap Chang	Nong Rawiang
30010606	6	Thap Chang	Nong Rawiang
30010607	7	Map Makha	Nong Rawiang
30010608	8	Cha-om	Nong Rawiang
30010609	9	Cha-om	Nong Rawiang
30010610	10	Tanot	Nong Rawiang
30010611	11	Tanot	Nong Rawiang
30010612	12	Nong Rawiang	Nong Rawiang
30010613	13	Nong Samo	Nong Rawiang
30010614	14	Non Makok	Nong Rawiang
30010615	15	Non Phralan	Nong Rawiang
30010701	1	Khon Chum	Pru Yai
30010702	2	Takhlong Kao	Pru Yai
30010703	3	Nong Hoi	Pru Yai
30010704	4	Wirot Phatthana	Pru Yai
30010705	5	Phop Suk	Pru Yai
30010706	6	Liap	Pru Yai
30010707	7	Saen Suk	Pru Yai
30010801	1	Pra Chok	Muen Wai
30010802	2	Muen Wai	Muen Wai
30010803	3	Non Ta Suk	Muen Wai
30010804	4	Phon Sung	Muen Wai
30010805	5	Khlong Boriboon	Muen Wai
30010806	6	Khok Phai	Muen Wai
30010807	7	Nong Na Lum	Muen Wai
30010808	8	Khon Pha-ngat	Muen Wai
30010809	9	Khlong Phai	Muen Wai
30010901	1	Phol Krang	Phon Krung
30010902	2	Phol Krang	Phon Krung
30010903	3	Phol Krang	Phon Krung
30010904	4	Sakae Krang	Phon Krung
30010905	5	Bu Khi Tun	Phon Krung
30010906	6	Ta Thao	Phon Krung
30010907	7	Bung Tako	Phon Krung
30010908	8	Bung Prasoet	Phon Krung
30011101	1	Hua Thale	Hue Thale
30011102	2	Don Khwang	Hue Thale
30011103	3	Non Farang	Hue Thale
30011104	4	Nong Song Hong	Hue Thale
30011105	5	Pha Lai	Hue Thale
30011106	6	Pha Lai	Hue Thale
30011107	7	Hua Thanon	Hue Thale
30011108	8	Khlong Khoi Ngam	Hue Thale
30011109	9	Tha Krasang	Hue Thale
30011110	10	Nong Song Hong Nua	Hue Thale
30011111	11	Bun Nimit	Hue Thale
30011112	12	Thung Thale Ruam Chai	Hue Thale
30011201	1	Ko	Ban Ko
30011202	2	Ko	Ban Ko
30011203	3	Khanai	Ban Ko

Table A-1 List of villages in each sub-district (Continued).

Code	Village Number	Village name	Sub-district
30011204	4	Khok Phai Noi	Ban Ko
30011205	5	Bung Phaya Prap	Ban Ko
30011301	1	Mai	Ban Mai
30011302	2	Mai	Ban Mai
30011303	3	Hua Sip	Ban Mai
30011304	4	Makham Thao	Ban Mai
30011305	5	Phu Khao Lat	Ban Mai
30011306	6	Samrong Nua	Ban Mai
30011307	7	Sisa La Loeng	Ban Mai
30011308	8	Kamthuat	Ban Mai
30011309	9	Samrong	Ban Mai
30011310	10	Sisa La Loeng	Ban Mai
30011311	11	Yang Noi	Ban Mai
30011312	12	Makham Thao Phatthana	Ban Mai
30011401	1	Maduea	Phut Sa
30011402	2	Phutsa	Phut Sa
30011403	3	Phutsa Rim Bung	Phut Sa
30011404	4	Don Krathing	Phut Sa
30011405	5	Bu Krathin	Phut Sa
30011406	6	Kluai	Phut Sa
30011407	7	Tako	Phut Sa
30011408	8	Lalom Pho	Phut Sa
30011409	9	Sa Pho	Phut Sa
30011410	10	Sisa Chang	Phut Sa
30011411	11	Khwao	Phut Sa
30011412	12	Nong Ya Rak	Phut Sa
30011413	13	Lam Phong	Phut Sa
30011414	14	Noi	Phut Sa
30011415	15	La Lom Nua	Phut Sa
30011416	16	Don Phatthana	Phut Sa
30011417	17	Nong Ya Rak Nua	Phut Sa
30011418	18	Lam Phong Tai	Phut Sa
30011501	1	Yung	Ban Pho
30011502	2	Tanot	Ban Pho
30011503	3	Burana Phanit	Ban Pho
30011504	4	Si Phatthana	Ban Pho
30011505	5	Wang Hin	Ban Pho
30011506	6	Makha	Ban Pho
30011507	7	Saen Mueang	Ban Pho
30011508	8	Nong Bua	Ban Pho
30011509	9	Long Tong	Ban Pho
30011510	10	Makha Phatthana	Ban Pho
30011601	1	Phanao	Cho ho
30011602	2	Kluai	Cho ho
30011603	3	Cho ho	Cho ho
30011604	4	Cho ho	Cho ho
30011605	5	Chong Au	Cho ho
30011606	6	Rakai	Cho ho
30011607	7	Bung Thap Chang	Cho ho
30011608	8	Sa Tammakhan	Cho ho

Table A-1 List of villages in each sub-district (Continued).

Code	Village Number	Village name	Sub-district
30011609	9	Samrong	Cho ho
30011610	10	Nong Ok	Cho ho
30011611	11	Krut	Cho ho
30011612	12	Sa Tarat	Cho ho
30011613	13	Nong Piman	Cho ho
30011614	14	Pun	Cho ho
30011615	15	Nong Kradang Nga	Cho ho
30011701	1	Nong Wa	Khok Kruat
30011702	2	Khok Kruat	Khok Kruat
30011703	3	Don Taew	Khok Kruat
30011704	4	Lalom Mo	Khok Kruat
30011705	5	Prong Malaeng Wan	Khok Kruat
30011706	6	Sra Manora	Khok Kruat
30011707	7	Khlong Krabu	Khok Kruat
30011708	8	Duea	Khok Kruat
30011709	9	Nong Pet Nam	Khok Kruat
30011710	10	Don	Khok Kruat
30011711	11	Nong Khon	Khok Kruat
30011712	12	Nong Rang Ka	Khok Kruat
30011713	13	Nong Kung	Khok Kruat
30011714	14	Khok Phet	Khok Kruat
30011801	1	Chai Mongkhon	Chai Mongkhon
30011802	2	Bu Tan	Chai Mongkhon
30011803	3	Nong Phluang Yai	Chai Mongkhon
30011804	4	Nong Pling	Chai Mongkhon
30011805	5	Nong Sai	Chai Mongkhon
30011901	1	Nong Takhlong	Nong Bua Sala
30011902	2	Nong Talumphuk	Nong Bua Sala
30011903	3	Nong Pling	Nong Bua Sala
30011904	4	Nong Bua Sala	Nong Bua Sala
30011905	5	Ang Nong Nae	Nong Bua Sala
30011906	6	Nong Samong	Nong Bua Sala
30011907	7	Mai Nong Nae	Nong Bua Sala
30011908	8	Nong Ta Khong	Nong Bua Sala
30011909	9	Nong Pling Mai	Nong Bua Sala
30011910	10	Nong Talumphuk Mai	Nong Bua Sala
30012001	1	Ratchasima	Suranaree
30012002	2	Nong Mai Daeng	Suranaree
30012003	3	Yang Yai	Suranaree
30012004	4	Taphao Thong	Suranaree
30012005	5	Nong Bong	Suranaree
30012006	6	Map Uang	Suranaree
30012007	7	Krok Duean Ha	Suranaree
30012008	8	Saphan Hin	Suranaree
30012009	9	Yang Yai Phatthana	Suranaree
30012010	10	Thao Sura	Suranaree
30012101	1	Don	Si Mum
30012102	2	Si Mum	Si Mum
30012103	3	Si Mum	Si Mum
30012104	4	Si Mum	Si Mum

Table A-1 List of villages in each sub-district (Continued).

Code	Village Number	Village name	Sub-district
30012105	5	Si Mum	Si Mum
30012106	6	Si Mum	Si Mum
30012107	7	Mai Charoen Si	Si Mum
30012108	8	Pae	Si Mum
30012109	9	Thung Kradon	Si Mum
30012110	10	Makok	Si Mum
30012201	1	Bu	Talat
30012202	2	Bu	Talat
30012203	3	Talat	Talat
30012204	4	Pho	Talat
30012205	5	Krachot	Talat
30012206	6	Rat Prasong	Talat
30012207	7	Nong Takhlong	Talat
30012208	8	Bu Phatthana	Talat
30012301	1	Maroeng Noi	Pha Nao
30012302	2	Phutsa	Pha Nao
30012303	3	Nong Sai Phrai	Pha Nao
30012304	4	Don In	Pha Nao
30012305	5	Phanao	Pha Nao
30012306	6	Phanao	Pha Nao
30012307	7	Maroeng Yai	Pha Nao
30012308	8	Yong Yaeng	Pha Nao
30012309	9	Mai Yong Yaeng	Pha Nao
30012401	1	Nong Ya Ngam	Nong Krathum
30012402	2	Nong Pho	Nong Krathum
30012403	3	Phra	Nong Krathum
30012404	4	Fai	Nong Krathum
30012405	5	Chong Lom	Nong Krathum
30012406	6	Khok Wua	Nong Krathum
30012407	7	Nong Krathum	Nong Krathum
30012408	8	Som Poi	Nong Krathum
30012409	9	Na Thom	Nong Krathum
30012501	1	Nong Khai Nam Phatthana	Nong Khai Nam
30012502	2	Bung Ri	Nong Khai Nam
30012503	3	Kho Nong Bua	Nong Khai Nam
30012504	4	Sanuan	Nong Khai Nam
30012505	5	Krok Phatthana	Nong Khai Nam
30012506	6	Khok	Nong Khai Nam
30012507	7	Nong Khai Nam	Nong Khai Nam
30012508	8	Kradon	Nong Khai Nam
30017601	1	Bung	Nong Phai Lom
30017602	2	Bung Ta Lua	Nong Phai Lom
30017607	7	Nong Nok Yung	Nong Phai Lom

APPENDIX B

QOL SCORE AND QOL LEVEL

Table B-1 Detail of QOL scores and QOL level of each village.

Code	MOO	Village	Sub-district	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	QOL index	QOL Level
30010101	1	Constituency zone1	Nai Mueang	-1.93	-1.18	-1.45	1.81	0.25	-0.88	-0.75	-0.95	Low
30010102	2	Constituency zone2	Nai Mueang	-2.55	-1.33	-0.25	2.03	0.48	0.38	-0.70	-0.84	Low
30010103	3	Constituency zone3	Nai Mueang	-0.63	-1.91	-0.67	1.87	1.20	-0.48	-0.93	-0.67	Low
30010104	4	Constituency zone4	Nai Mueang	-2.74	-2.83	-1.08	1.73	0.45	0.14	-0.65	-1.18	Low
30010201	1	Nong Pru	Pho Klang	-0.24	-0.17	0.44	1.00	0.40	0.94	0.42	0.00	Medium
30010202	2	Nong Phai	Pho Klang	0.32	0.28	0.75	1.27	0.74	0.33	0.26	0.14	High
30010203	3	Nong Phluang Noi	Pho Klang	0.35	0.31	0.38	0.22	-0.50	-0.15	0.15	0.09	High
30010204	4	Nong Phluang Manao	Pho Klang	0.37	0.31	0.47	0.37	0.30	-0.17	0.08	0.14	High
30010205	5	Nong Phutsa	Pho Klang	-0.60	-0.30	-0.28	0.68	0.67	0.44	-0.30	-0.19	Medium
30010206	6	Nong Bua	Pho Klang	0.33	0.32	0.37	0.66	-0.31	1.17	0.19	0.15	High
30010207	7	Bung Saen Suk	Pho Klang	0.31	0.21	0.76	0.58	1.81	0.47	0.22	0.29	High
30010208	8	Si Somboon	Pho Klang	0.24	0.34	0.63	1.02	0.81	-0.15	0.26	0.12	High
30010209	9	Khai Suratampitak	Pho Klang	0.36	0.39	0.08	0.10	0.73	0.05	0.12	0.18	High
30010210	10	Nong Phai Phatthana	Pho Klang	-0.17	0.01	-0.50	0.07	1.23	0.08	0.15	0.01	Medium
30010301	1	Tang Ta	Nong Chabok	-0.73	-1.46	-0.33	-0.37	-0.97	0.31	-0.05	-0.39	Medium
30010302	2	Krin	Nong Chabok	-1.10	-0.84	0.62	-0.54	-0.15	0.96	0.97	-0.06	Medium
30010303	3	Thanon Hak	Nong Chabok	0.44	0.60	-1.20	-0.53	-0.82	0.04	-0.33	0.00	Medium
30010304	4	Nong Pru	Nong Chabok	0.39	0.53	-0.67	0.74	-0.13	0.88	0.36	0.06	High
30010305	5	Bun Roeng	Nong Chabok	0.45	0.55	-3.70	1.68	0.70	0.78	0.26	-0.35	Medium
30010401	1	Khok Sung	Khok Sung	0.42	0.58	-0.78	-0.52	-0.74	-2.14	0.43	-0.06	Medium
30010402	2	Nong Pho	Khok Sung	0.39	0.27	0.17	-0.50	-0.39	-2.13	0.23	0.01	Medium
30010403	3	Song Tai	Khok Sung	0.48	0.30	0.28	0.64	-0.88	-0.79	-0.23	-0.04	Medium
30010404	4	Ra-ngom	Khok Sung	0.25	0.41	0.23	-0.33	-0.49	-1.56	0.33	0.04	High
30010405	5	Hua Sa	Khok Sung	0.65	0.71	-1.73	-0.66	-0.26	-1.45	0.31	-0.03	Medium
30010406	6	Ra-ngom Phatthana	Khok Sung	0.37	0.43	0.12	-0.49	0.28	-1.61	0.19	0.11	High
30010407	7	Mamuang Phatthana	Khok Sung	0.31	0.38	0.47	-0.55	0.98	-1.41	0.25	0.21	High
30010408	8	Song Nua	Khok Sung	0.29	0.41	0.17	-0.47	-0.18	-1.98	0.31	0.04	High

Table B-1 Detail of QOL scores and QOL level of each village (Continued).

Code	MOO	Village	Sub-district	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	QOL index	QOL Level
30010409	9	Lam Choeng Krai	Khok Sung	0.26	0.36	0.39	-0.46	-0.75	-1.58	0.37	0.05	High
30010410	10	Samkhan	Khok Sung	0.60	0.69	-1.34	-0.51	1.27	-0.78	0.34	0.15	High
30010411	11	Nong Krachai	Khok Sung	0.45	0.44	0.04	-0.69	0.92	-1.14	0.16	0.21	High
30010501	1	Hua Chang	Mareng	0.26	0.41	-0.07	-0.41	-0.43	1.77	0.31	0.25	High
30010502	2	Mai	Mareng	0.24	0.36	0.58	-0.33	1.07	0.28	0.27	0.31	High
30010503	3	Saraphi	Mareng	0.16	0.35	0.55	-0.12	-0.31	0.76	0.34	0.21	High
30010504	4	Phra	Mareng	-0.14	0.54	-1.10	-0.16	-0.59	1.13	-0.75	-0.06	Medium
30010505	5	Bung San	Mareng	0.44	0.31	-0.69	-0.52	-0.30	0.63	-0.69	0.07	High
30010506	6	Phra	Mareng	0.04	0.35	0.50	-0.32	-0.96	0.94	0.36	0.17	High
30010507	7	Khok	Mareng	0.20	0.33	0.47	-0.22	-1.20	0.68	0.35	0.14	High
30010508	8	Krathon	Mareng	-0.03	0.37	0.49	0.10	-1.02	2.64	0.42	0.24	High
30010601	1	Yong Yaeng	Nong Rawiang	0.19	0.38	0.43	-0.43	-0.48	-0.28	0.01	0.13	High
30010602	2	Nong Sai	Nong Rawiang	0.14	-0.25	0.69	-0.43	-0.59	-0.41	0.35	0.06	High
30010603	3	Nong Muang	Nong Rawiang	-2.17	-0.70	0.61	-0.49	-0.61	0.23	-1.51	-0.45	Medium
30010604	4	Kham Sa Phleng	Nong Rawiang	-0.37	-4.44	2.67	-0.53	0.28	-1.00	-1.58	-0.50	Medium
30010605	5	Thap Chang	Nong Rawiang	-7.08	1.45	-1.20	-1.01	-0.97	0.18	2.46	-0.87	Low
30010606	6	Thap Chang	Nong Rawiang	-2.10	-0.84	0.94	-0.63	0.35	-0.38	0.41	-0.26	Medium
30010607	7	Map Makha	Nong Rawiang	-1.84	-0.48	0.53	-0.75	0.10	1.17	-0.33	-0.16	Medium
30010608	8	Cha-om	Nong Rawiang	0.00	-0.07	0.73	-0.32	-0.82	0.23	0.52	0.10	High
30010609	9	Cha-om	Nong Rawiang	-0.53	0.18	0.38	-0.36	0.55	-0.52	-0.08	0.02	High
30010610	10	Tanot	Nong Rawiang	0.01	0.45	0.14	-0.53	-0.47	0.12	0.41	0.14	High
30010611	11	Tanot	Nong Rawiang	-0.92	-1.39	1.15	-0.62	0.63	-0.51	0.22	-0.13	Medium
30010612	12	Nong Rawiang	Nong Rawiang	0.64	1.07	1.33	-0.45	0.24	0.11	-13.01	-0.27	Medium
30010613	13	Nong Samo	Nong Rawiang	-0.83	-2.94	1.25	-0.51	0.00	-0.83	0.40	-0.41	Medium
30010614	14	Non Makok	Nong Rawiang	-0.55	-0.20	0.85	-0.74	2.77	-1.47	0.30	0.18	High
30010615	15	Non Phralan	Nong Rawiang	0.28	0.41	0.58	-0.67	3.09	-0.37	0.11	0.45	High
30010701	1	Khon Chum	Pru Yai	0.21	0.35	0.39	-0.47	0.07	1.41	0.20	0.30	High
30010702	2	Takhlong Kao	Pru Yai	0.45	0.40	-0.36	-0.49	-0.81	1.44	-0.17	0.18	High
30010703	3	Nong Hoi	Pru Yai	0.50	-1.71	1.24	0.09	-0.89	1.62	0.07	0.02	Medium
30010704	4	Wirot Phatthana	Pru Yai	0.01	0.40	0.90	0.81	3.25	0.17	0.32	0.35	High
30010705	5	Phop Suk	Pru Yai	0.23	0.37	1.01	3.61	-0.40	0.21	0.32	-0.17	Medium
30010706	6	Liap	Pru Yai	1.26	1.27	-5.60	-0.84	-1.03	2.19	-0.14	-0.12	Medium
30010707	7	Saen Suk	Pru Yai	0.20	0.34	0.45	-0.40	-0.99	0.42	0.36	0.16	High
30010801	1	Pra Chok	Muen Wai	0.22	0.21	0.41	-0.01	0.33	-0.01	0.35	0.16	High
30010802	2	Muen Wai	Muen Wai	0.34	0.32	0.60	1.41	-0.50	0.21	0.12	0.01	Medium
30010803	3	Non Ta Suk	Muen Wai	0.37	0.02	-0.56	1.18	1.12	-0.52	-0.12	-0.09	Medium

Table B-1 Detail of QOL scores and QOL level of each village (Continued).

Code	MOO	Village	Sub-district	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	QOL index	QOL Level
30010804	4	Phon Sung	Muen Wai	0.35	0.34	0.26	-0.34	-0.54	-0.06	-0.21	0.12	High
30010805	5	Khlong Boriboon	Muen Wai	0.09	0.28	0.57	-0.20	1.42	-0.03	0.32	0.27	High
30010806	6	Khok Phai	Muen Wai	0.17	-0.06	-1.30	1.47	0.22	0.27	0.22	-0.25	Medium
30010807	7	Nong Na Lum	Muen Wai	0.25	0.37	0.94	3.63	-0.62	2.03	0.21	-0.06	Medium
30010808	8	Khon Pha-ngat	Muen Wai	-0.23	-1.31	-0.14	1.02	2.46	-1.08	0.51	-0.23	Medium
30010809	9	Khlong Phai	Muen Wai	1.20	0.68	-3.76	2.61	2.43	0.43	0.33	-0.21	Medium
30010901	1	Phol Krang	Phon Krung	0.67	0.29	-0.23	-0.46	-1.42	-0.60	-1.17	-0.04	Medium
30010902	2	Phol Krang	Phon Krung	0.28	0.53	-0.56	-0.61	-0.20	-0.95	0.08	0.05	High
30010903	3	Phol Krang	Phon Krung	0.21	0.42	0.13	-0.64	0.87	-0.34	-0.20	0.21	High
30010904	4	Sakae Krang	Phon Krung	0.24	0.38	0.24	-0.52	-0.37	-1.10	-0.01	0.08	High
30010905	5	Bu Khi Tun	Phon Krung	0.37	-0.35	0.10	-0.51	-0.89	-0.75	-0.02	-0.05	Medium
30010906	6	Ta Thao	Phon Krung	-0.24	-0.33	0.72	-0.42	0.03	-1.03	0.23	-0.02	Medium
30010907	7	Bung Tako	Phon Krung	0.75	0.54	-1.51	-0.54	-1.02	-1.15	-0.75	-0.12	Medium
30010908	8	Bung Prasoet	Phon Krung	0.22	-1.08	0.75	-0.56	-0.59	-1.34	0.27	-0.10	Medium
30011101	1	Hua Thale	Hue Thale	0.86	0.41	-3.48	0.82	0.85	-0.08	0.09	-0.24	Medium
30011102	2	Don Khwang	Hue Thale	0.52	0.28	0.22	0.89	0.56	0.48	-0.70	0.09	High
30011103	3	Non Farang	Hue Thale	-3.23	-0.41	-2.89	0.48	0.63	-0.16	-0.82	-1.00	Low
30011104	4	Nong Song Hong	Hue Thale	0.74	-0.35	-1.03	0.83	0.00	-0.46	-0.78	-0.22	Medium
30011105	5	Pha Lai	Hue Thale	0.94	0.26	-0.25	0.87	-0.48	-0.72	-1.65	-0.12	Medium
30011106	6	Pha Lai	Hue Thale	-7.70	1.55	-0.77	-0.27	-0.77	1.08	-1.46	-1.14	Low
30011107	7	Hua Thanon	Hue Thale	0.23	0.32	0.49	0.06	-0.72	1.94	0.02	0.23	High
30011108	8	Khlong Khoi Ngam	Hue Thale	0.48	0.33	-0.03	-0.48	-0.64	1.11	-0.50	0.18	High
30011109	9	Tha Krasang	Hue Thale	-2.32	-2.92	-0.23	-0.93	-0.41	2.20	0.22	-0.61	Low
30011110	10	Nong Song Hong Nua	Hue Thale	-3.26	-1.39	-1.22	0.75	0.78	-0.38	0.52	-0.91	Low
30011111	11	Bun Nimit	Hue Thale	0.85	0.28	-0.21	0.27	-0.85	-0.68	-1.55	-0.07	Medium
30011112	12	Thung Thale Ruam Chai	Hue Thale	-0.47	0.74	-0.59	0.98	-0.76	0.01	-1.79	-0.30	Medium
30011201	1	Ko	Ban Ko	0.02	0.22	0.92	2.09	0.88	0.12	0.45	0.02	Medium
30011202	2	Ko	Ban Ko	-0.09	0.40	0.39	0.16	-1.35	-0.63	0.57	-0.03	Medium
30011203	3	Khanai	Ban Ko	-0.08	0.38	0.47	-0.27	-1.72	-0.82	0.55	-0.02	Medium
30011204	4	Khok Phai Noi	Ban Ko	-0.23	0.40	0.73	0.59	0.26	-0.55	0.59	0.06	High
30011205	5	Bung Phaya Prap	Ban Ko	0.17	0.17	0.55	0.54	0.39	-0.60	0.14	0.06	High
30011301	1	Mai	Ban Mai	0.35	0.39	0.06	-0.20	-0.53	0.88	0.05	0.17	High
30011302	2	Mai	Ban Mai	0.33	0.40	-0.10	0.04	0.56	1.18	0.21	0.23	High
30011303	3	Hua Sip	Ban Mai	0.34	0.33	0.42	-0.37	0.22	1.28	-0.12	0.29	High
30011304	4	Makham Thao	Ban Mai	0.38	0.38	0.49	0.19	1.22	0.75	-0.07	0.30	High
30011305	5	Phu Khao Lat	Ban Mai	0.39	0.40	0.35	0.48	0.49	-0.22	0.05	0.14	High

Table B-1 Detail of QOL scores and QOL level of each village (Continued).

Code	MOO	Village	Sub-district	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	QOL index	QOL Level
30011306	6	Samrong Nua	Ban Mai	0.41	0.35	0.34	-0.40	1.10	1.83	-0.09	0.41	High
30011307	7	Sisa La Loeng	Ban Mai	0.42	0.35	0.64	0.13	1.84	1.34	-0.06	0.41	High
30011308	8	Kamthuat	Ban Mai	0.35	0.33	0.55	-0.12	0.90	2.38	-0.09	0.41	High
30011309	9	Samrong	Ban Mai	0.37	0.35	0.44	0.34	0.66	1.82	-0.05	0.30	High
30011310	10	Sisa La Loeng	Ban Mai	0.36	0.30	0.64	2.51	-0.07	0.28	0.17	-0.06	Medium
30011311	11	Yang Noi	Ban Mai	0.41	0.36	0.47	-0.37	1.19	-0.05	-0.01	0.30	High
30011312	12	Makham Thao Phatthana	Ban Mai	0.40	0.40	0.00	-0.45	0.09	-0.67	0.06	0.14	High
30011401	1	Maduea	Phut Sa	0.42	0.14	0.16	-0.56	-0.56	-1.43	-0.25	0.01	Medium
30011402	2	Phutsa	Phut Sa	0.35	0.34	0.25	-0.35	-0.64	-0.04	-0.04	0.12	High
30011403	3	Phutsa Rim Bung	Phut Sa	0.09	-0.18	0.95	0.74	-0.34	0.97	0.47	0.10	High
30011404	4	Don Krathing	Phut Sa	0.18	0.14	0.49	-0.47	-0.52	-1.17	0.21	0.05	High
30011405	5	Bu Krathin	Phut Sa	0.41	0.22	0.24	-0.51	-0.49	-1.84	-0.16	0.01	Medium
30011406	6	Kluai	Phut Sa	0.27	0.36	0.48	-0.42	0.28	-0.37	0.27	0.21	High
30011407	7	Tako	Phut Sa	0.25	0.36	0.58	0.00	0.50	0.01	0.27	0.22	High
30011408	8	Lalom Pho	Phut Sa	0.26	0.34	0.39	-0.45	-0.61	0.48	0.18	0.19	High
30011409	9	Sa Pho	Phut Sa	0.52	0.11	0.11	1.15	-0.53	-0.33	0.18	-0.06	Medium
30011410	10	Sisa Chang	Phut Sa	1.01	-0.18	-2.05	-0.56	-1.26	0.17	-0.27	-0.15	Medium
30011411	11	Khwao	Phut Sa	0.34	0.16	0.41	-0.52	-0.39	-1.25	0.32	0.08	High
30011412	12	Nong Ya Rak	Phut Sa	1.02	1.02	-4.00	-0.78	-0.49	-0.65	0.52	-0.13	Medium
30011413	13	Lam Phong	Phut Sa	0.17	0.38	0.44	-0.41	-0.52	-1.49	0.42	0.06	High
30011414	14	Noi	Phut Sa	-0.11	-0.97	0.69	-0.62	0.20	-1.24	0.28	-0.07	Medium
30011415	15	La Lom Nua	Phut Sa	0.30	0.33	0.56	1.07	-0.72	-0.14	0.32	0.01	Medium
30011416	16	Don Phatthana	Phut Sa	0.08	0.38	0.45	-0.42	-0.92	0.03	0.26	0.12	High
30011417	17	Nong Ya Rak Nua	Phut Sa	0.60	0.27	-0.47	-0.39	-0.94	-0.90	-0.65	-0.05	Medium
30011418	18	Lam Phong Tai	Phut Sa	0.46	0.33	0.03	-0.36	-1.07	-0.96	-0.76	-0.02	Medium
30011501	1	Yung	Ban Pho	0.25	0.33	0.43	-0.33	-0.64	-0.55	0.33	0.11	High
30011502	2	Tanot	Ban Pho	0.21	0.36	0.46	-0.38	-0.51	-0.80	0.37	0.11	High
30011503	3	Burana Phanit	Ban Pho	0.21	0.35	0.45	-0.32	-0.73	-0.15	0.37	0.14	High
30011504	4	Si Phatthana	Ban Pho	0.27	0.18	0.53	-0.51	0.66	-1.06	0.28	0.18	High
30011505	5	Wang Hin	Ban Pho	-0.07	0.31	0.31	-0.52	-0.54	1.11	0.02	0.17	High
30011506	6	Makha	Ban Pho	0.27	0.36	0.40	-0.37	-0.12	-0.08	0.22	0.18	High
30011507	7	Saen Mueang	Ban Pho	0.01	0.37	0.28	-0.44	-0.66	-0.73	0.39	0.06	High
30011508	8	Nong Bua	Ban Pho	0.23	-0.16	-1.33	-0.59	-0.47	-0.75	-0.43	-0.20	Medium
30011509	9	Long Tong	Ban Pho	0.16	0.30	0.45	-0.39	0.01	-0.40	0.33	0.16	High
30011510	10	Makha Phatthana	Ban Pho	0.23	0.55	-0.42	-0.48	0.41	-0.44	0.11	0.13	High
30011601	1	Phanao	Cho ho	-0.17	0.29	-0.46	0.25	-0.79	0.09	-0.05	-0.12	Medium
30011602	2	Kluai	Cho ho	-1.08	0.03	0.39	-0.38	0.06	-0.37	-0.62	-0.14	Medium
30011603	3	Cho ho	Cho ho	-1.71	0.59	-0.83	2.27	-0.16	-0.57	-0.56	-0.61	Low

Table B-1 Detail of QOL scores and QOL level of each village (Continued).

Code	MOO	Village	Sub-district	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	QOL index	QOL Level
30011604	4	Cho ho	Cho ho	0.17	0.41	-0.91	-0.46	0.30	0.09	0.15	0.07	High
30011605	5	Chong Au	Cho ho	-1.51	-0.27	0.53	2.59	-0.99	-0.49	-1.24	-0.68	Low
30011606	6	Rakai	Cho ho	0.13	0.36	0.62	0.56	-0.26	-0.73	0.35	0.04	High
30011607	7	Bung Thap Chang	Cho ho	0.31	0.32	-0.87	-0.49	0.30	-1.11	-0.45	-0.04	Medium
30011608	8	Sa Tammakhan	Cho ho	-0.87	-1.33	0.77	0.35	-0.94	0.01	-0.75	-0.40	Medium
30011609	9	Samrong	Cho ho	0.16	0.36	0.51	-0.52	0.26	0.12	0.34	0.25	High
30011610	10	Nong Ok	Cho ho	0.21	0.37	0.51	-0.40	0.53	-1.01	0.35	0.18	High
30011611	11	Krut	Cho ho	0.17	0.35	0.22	-0.37	-0.20	0.02	0.31	0.15	High
30011612	12	Sa Tarat	Cho ho	0.01	-0.50	0.62	-0.53	0.18	-0.33	0.39	0.07	High
30011613	13	Nong Piman	Cho ho	-0.09	0.26	-0.95	3.94	-0.09	-0.74	-0.04	-0.57	Medium
30011614	14	Pun	Cho ho	-0.02	0.83	-2.25	-0.63	0.07	-0.80	-0.03	-0.14	Medium
30011615	15	Nong Kradang Nga	Cho ho	-1.50	-1.23	-0.48	-0.68	0.21	-0.62	-0.69	-0.48	Medium
30011701	1	Nong Wa	Khok Kruat	0.39	-0.21	-2.03	-0.69	3.93	-0.60	-0.45	0.08	High
30011702	2	Khok Kruat	Khok Kruat	0.67	-0.38	-1.41	-0.66	0.82	1.26	0.27	0.12	High
30011703	3	Don Taew	Khok Kruat	0.10	0.43	0.11	-0.42	-0.55	0.72	-0.21	0.14	High
30011704	4	Lalom Mo	Khok Kruat	0.86	-0.69	-1.47	-0.46	-1.09	0.86	-0.85	-0.16	Medium
30011705	5	Prong Malaeng Wan	Khok Kruat	0.25	0.10	0.51	-0.55	0.69	-0.89	0.17	0.17	High
30011706	6	Sra Manora	Khok Kruat	2.26	-4.93	-0.06	0.26	-2.31	2.81	-1.53	-0.47	Medium
30011707	7	Khlong Krabu	Khok Kruat	0.67	-5.29	1.49	-0.63	0.74	-0.84	0.65	-0.41	Medium
30011708	8	Duea	Khok Kruat	0.00	0.10	-0.23	-0.99	3.82	0.70	-1.11	0.35	High
30011709	9	Nong Pet Nam	Khok Kruat	-1.41	-1.02	-0.73	-0.51	-0.13	0.39	-0.64	-0.44	Medium
30011710	10	Don	Khok Kruat	-1.20	-1.31	-1.95	-0.88	1.36	-0.08	-1.44	-0.53	Medium
30011711	11	Nong Khon	Khok Kruat	0.42	0.33	-0.61	-0.47	0.55	0.83	-1.21	0.12	High
30011712	12	Nong Rang Ka	Khok Kruat	-0.03	0.12	-0.06	-0.55	-0.31	-0.93	0.46	0.00	Medium
30011713	13	Nong Kung	Khok Kruat	-0.42	-0.41	0.55	-0.99	2.92	-1.87	-0.07	0.12	High
30011714	14	Khok Phet	Khok Kruat	0.26	0.37	0.27	-0.40	0.06	0.59	0.18	0.23	High
30011801	1	Chai Mongkhon	Chai Mongkhon	0.00	0.17	0.12	0.16	-0.64	0.09	0.33	0.00	Medium
30011802	2	Bu Tan	Chai Mongkhon	0.24	0.33	0.41	-0.46	0.26	-0.16	0.23	0.21	High
30011803	3	Nong Phluang Yai	Chai Mongkhon	-0.12	0.37	0.33	-0.57	-0.33	-0.37	0.36	0.11	High
30011804	4	Nong Pling	Chai Mongkhon	-0.04	0.27	0.61	-0.43	-0.18	0.24	0.44	0.18	High
30011805	5	Nong Sai	Chai Mongkhon	-0.54	0.48	1.02	-0.56	4.11	1.77	0.58	0.63	High
30011901	1	Nong Takhlong	Nong Bua Sala	0.24	0.10	-0.16	0.38	-0.84	-0.26	-0.33	-0.10	Medium
30011902	2	Nong Talumphuk	Nong Bua Sala	0.73	-3.83	-3.55	-0.66	-1.30	-0.41	1.50	-0.85	Low
30011903	3	Nong Pling	Nong Bua Sala	-2.72	-0.37	-0.45	-0.51	-0.82	-0.57	-0.28	-0.61	Low
30011904	4	Nong Bua Sala	Nong Bua Sala	0.18	-0.17	-1.78	-0.57	-0.64	-0.41	0.01	-0.23	Medium
30011905	5	Ang Nong Nae	Nong Bua Sala	1.75	-3.05	-3.78	-0.87	0.75	0.15	-0.28	-0.49	Medium

Table B-1 Detail of QOL scores and QOL level of each village (Continued).

Code	MOO	Village	Sub-district	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	QOL index	QOL Level
30011906	6	Nong Samong	Nong Bua Sala	-0.65	0.03	0.43	-0.48	-0.79	0.14	0.34	-0.02	Medium
30011907	7	Mai Nong Nae	Nong Bua Sala	0.33	0.23	0.06	-0.39	-0.37	-0.42	0.35	0.10	High
30011908	8	Nong Ta Khong	Nong Bua Sala	0.05	0.21	-0.32	-0.20	-0.93	-0.34	0.20	-0.05	Medium
30011909	9	Nong Pling Mai	Nong Bua Sala	2.37	-7.21	-0.34	0.64	-0.11	0.25	0.97	-0.75	Low
30011910	10	Nong Talumphuk Mai	Nong Bua Sala	0.06	-0.03	0.29	0.18	-0.13	-0.35	-0.37	-0.04	Medium
30012001	1	Ratchasima	Suranaree	0.28	0.23	0.63	-0.11	0.89	0.14	0.25	0.26	High
30012002	2	Nong Mai Daeng	Suranaree	0.24	0.30	0.53	-0.42	0.38	-0.22	0.27	0.22	High
30012003	3	Yang Yai	Suranaree	0.25	0.35	0.51	-0.25	0.15	-0.19	0.29	0.20	High
30012004	4	Taphao Thong	Suranaree	0.15	0.34	0.55	-0.29	-0.34	1.76	0.29	0.29	High
30012005	5	Nong Bong	Suranaree	0.09	0.15	0.65	-0.36	0.08	0.81	0.44	0.24	High
30012006	6	Map Uang	Suranaree	0.17	0.35	0.54	-0.40	0.03	1.10	0.32	0.29	High
30012007	7	Krok Duean Ha	Suranaree	0.17	0.35	0.51	-0.33	-0.54	0.75	0.38	0.22	High
30012008	8	Saphan Hin	Suranaree	0.26	0.37	0.53	-0.55	1.11	-0.15	0.27	0.31	High
30012009	9	Yang Yai Phatthana	Suranaree	0.37	0.40	0.78	-0.20	4.76	-0.21	0.04	0.57	High
30012010	10	Thao Sura	Suranaree	0.29	0.36	0.59	-0.21	1.21	0.75	0.17	0.35	High
30012101	1	Don	Si Mum	0.10	0.32	0.20	-0.47	-0.41	0.27	0.18	0.14	High
30012102	2	Si Mum	Si Mum	0.22	0.43	0.08	-0.51	-0.17	-0.28	0.37	0.15	High
30012103	3	Si Mum	Si Mum	0.23	0.34	0.44	-0.46	-0.60	-0.19	0.33	0.15	High
30012104	4	Si Mum	Si Mum	0.35	0.12	0.18	-0.50	-0.87	0.28	0.28	0.12	High
30012105	5	Si Mum	Si Mum	0.27	0.36	0.34	-0.27	-0.65	-0.66	0.31	0.09	High
30012106	6	Si Mum	Si Mum	0.36	0.10	0.41	0.70	-0.56	-0.46	0.34	-0.01	Medium
30012107	7	Mai Charoen Si	Si Mum	0.07	0.46	0.00	0.03	-0.60	-0.27	0.37	0.04	High
30012108	8	Pae	Si Mum	0.20	0.50	-0.21	-0.57	1.40	2.81	0.16	0.45	High
30012109	9	Thung Kradon	Si Mum	0.16	0.32	0.42	-0.48	-0.78	2.25	0.28	0.30	High
30012110	10	Makok	Si Mum	0.22	0.40	0.16	-0.43	-0.21	1.23	0.27	0.25	High
30012201	1	Bu	Talat	0.39	0.27	0.34	-0.11	-0.62	-0.71	-0.03	0.06	High
30012202	2	Bu	Talat	0.35	0.34	0.30	-0.27	-0.18	-0.53	-0.18	0.11	High
30012203	3	Talat	Talat	0.27	-0.43	0.51	-0.54	0.31	0.49	0.18	0.17	High
30012204	4	Pho	Talat	0.18	0.34	0.47	-0.50	-0.51	0.77	0.29	0.23	High
30012205	5	Krachot	Talat	-0.55	0.02	-0.39	-0.66	-0.78	0.70	0.72	-0.03	Medium
30012206	6	Rat Prasong	Talat	0.44	0.35	0.00	-0.43	-0.87	-0.97	-0.40	0.01	Medium
30012207	7	Nong Takhlong	Talat	0.36	0.35	0.43	0.60	-0.74	-1.01	-0.03	-0.03	Medium
30012208	8	Bu Phatthana	Talat	0.56	0.40	-0.44	0.37	-0.24	-0.74	-0.21	-0.02	Medium
30012301	1	Maroeng Noi	Pha Nao	0.18	0.30	0.55	-0.53	0.02	3.37	0.21	0.45	High
30012302	2	Phutsa	Pha Nao	0.17	0.32	0.52	-0.18	-1.06	2.28	0.31	0.26	High
30012303	3	Nong Sai Phrai	Pha Nao	0.21	0.35	0.48	-0.38	-0.44	0.24	0.34	0.19	High
30012304	4	Don In	Pha Nao	0.22	0.23	0.53	-0.19	-0.87	0.59	0.35	0.15	High

Table B-1 Detail of QOL scores and QOL level of each village (Continued).

Code	MOO	Village	Sub-district	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	QOL index	QOL Level
30012305	5	Phanao	Pha Nao	0.18	0.31	0.51	-0.43	-0.64	2.55	0.27	0.33	High
30012306	6	Phanao	Pha Nao	0.15	0.24	0.62	-0.32	0.13	0.45	0.35	0.23	High
30012307	7	Maroeng Yai	Pha Nao	0.12	0.23	0.59	-0.33	-0.60	2.03	0.34	0.28	High
30012308	8	Yong Yaeng	Pha Nao	0.16	0.21	0.58	-0.39	-0.09	1.28	0.34	0.28	High
30012309	9	Mai Yong Yaeng	Pha Nao	0.18	0.34	0.50	-0.34	-0.53	1.07	0.29	0.23	High
30012401	1	Nong Ya Ngam	Nong Krathum	0.23	0.36	0.62	-0.17	1.20	0.49	0.27	0.32	High
30012402	2	Nong Pho	Nong Krathum	0.37	0.35	-0.25	1.18	-0.46	0.53	0.36	-0.02	Medium
30012403	3	Phra	Nong Krathum	0.23	0.37	0.47	-0.08	-0.05	-0.15	0.34	0.16	High
30012404	4	Fai	Nong Krathum	0.15	0.37	0.49	-0.46	-0.05	-0.62	0.40	0.16	High
30012405	5	Chong Lom	Nong Krathum	0.17	0.40	-0.85	-0.59	-0.20	0.18	0.79	0.09	High
30012406	6	Khok Wua	Nong Krathum	0.13	0.09	0.64	-0.19	-0.44	0.46	0.43	0.16	High
30012407	7	Nong Krathum	Nong Krathum	0.10	0.15	-0.49	-0.54	1.23	-0.18	0.62	0.15	High
30012408	8	Som Poi	Nong Krathum	0.20	0.36	0.50	-0.46	0.10	-0.15	0.36	0.21	High
30012409	9	Na Thom	Nong Krathum	0.28	0.42	0.01	-0.50	-0.24	0.59	0.36	0.21	High
30012501	1	Nong Khai Nam Phatthana	Nong Khai Nam	0.21	0.23	0.17	-0.35	-1.00	-1.58	-0.37	-0.08	Medium
30012502	2	Bung Ri	Nong Khai Nam	-0.97	-0.78	0.64	-0.60	-1.01	-1.10	-0.31	-0.31	Medium
30012503	3	Kho Nong Bua	Nong Khai Nam	0.16	0.20	0.39	-0.39	-0.40	-0.80	-0.15	0.05	High
30012504	4	Sanuan	Nong Khai Nam	0.23	0.28	0.26	-0.46	-0.56	-1.04	0.06	0.05	High
30012505	5	Krok Phatthana	Nong Khai Nam	-0.70	0.10	0.60	-0.52	-0.33	-1.09	0.56	-0.04	Medium
30012506	6	Khok	Nong Khai Nam	-1.01	0.28	0.27	-0.50	-0.53	-1.51	0.60	-0.15	Medium
30012507	7	Nong Khai Nam	Nong Khai Nam	-0.31	0.33	0.09	-0.52	-0.91	-1.07	-0.82	-0.12	Medium
30012508	8	Kradon	Nong Khai Nam	0.37	0.39	0.03	-0.44	-0.55	-1.08	-0.20	0.04	High
30017601	1	Bung	Nong Phai Lom	0.20	0.09	-0.45	1.02	1.00	-0.64	0.36	-0.07	Medium
30017602	2	Bung Ta Lua	Nong Phai Lom	0.40	0.19	0.22	4.08	-1.40	-1.71	0.67	-0.50	Medium
30017607	7	Nong Nok Yung	Nong Phai Lom	0.35	0.54	1.28	7.92	-0.56	-0.80	0.45	-0.62	Low
30017699	0	institutional area	Nong Phai Lom	0.41	0.32	-0.74	0.88	-0.05	0.20	0.43	-0.03	Medium

APPENDIX C

STATISTICCAL DATA FROM THE REGRESSION ANALYSIS

Table C-1 Coefficient of regression analysis for Factor 1: Health, education and cultural values QOL.

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	3.584×10^{-15}	0.024		0.000	1.000
G109	0.351	0.050	0.351	7.065	0.000
G110	0.230	0.058	0.230	3.931	0.000
G328	0.414	0.037	0.414	11.076	0.000
G535	0.043	0.037	0.043	1.181	0.239

Note: Dependent Variable: Factor 1.

Table C-2 Coefficient of regression analysis for Factor 2: Housing QOL.

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	1.524×10^{-15}	0.026		0.000	1.000
G215	0.372	0.036	0.372	10.324	0.000
G218	0.326	0.036	0.326	9.050	0.000
G214	0.406	0.030	0.406	13.355	0.000

Note: Dependent Variable: Factor 2.

Table C-3 Coefficient of regression analysis for Factor 3: Participation QOL.

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	-1.258×10^{-15}	0.029		0.000	1.000
G638	0.195	0.050	0.195	3.871	0.000
G639	0.375	0.065	0.375	5.762	0.000
G640	0.377	0.064	0.377	5.926	0.000

Note: Dependent Variable: Factor 3.

Table C-4 Coefficient of regression analysis for Factor 4: Crowdedness QOL.

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	-7.877×10^{-15}	0.010		0.000	1.000
Pop_den	0.536	0.025	0.536	21.408	0.000
HH_den	0.294	0.027	0.294	10.781	0.000
Urban	0.275	0.012	0.275	22.172	0.000

Note: Dependent Variable: Factor 4.

Table C-5 Coefficient of regression analysis for Factor 5: Economic QOL.

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	7.342×10^{-15}	0.018		0.000	1.000
Pop_income	0.592	0.022	0.592	27.225	0.000
HH_income	0.490	0.022	0.490	22.552	0.000

Note: Dependent Variable: Factor 5.

Table C-6 Coefficient of regression analysis for Factor 6: Environment QOL.

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	1.535×10^{-15}	0.007		0.000	1.000
ST	-0.559	0.009	-0.559	-61.378	0.000
NDVI	0.551	0.009	0.551	60.497	0.000

Note: Dependent Variable: Factor 6.

Table C-7 Coefficient of regression analysis for Factor 7: Safety QOL.

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	-7.025×10^{-15}	0.033		0.000	1.000
G219	0.859	0.033	0.859	25.669	0.000

Note: Dependent Variable: Factor 7.

Table C-8 Coefficient of regression analysis for Synthetic QOL.

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	2.081×10^{-15}	0.024		0.000	1.000
G110	0.395	0.029	0.395	13.623	0.000
G215	0.276	0.026	0.276	10.527	0.000
G639v	0.309	0.029	0.309	10.732	0.000
HH_den	-0.346	0.026	-0.346	-13.561	0.000
Pop_income	0.263	0.025	0.263	10.561	0.000
ST	-0.201	0.025	-0.201	-8.158	0.000
G219	0.085	0.025	0.085	3.431	0.001

Note: Dependent Variable: QOL score.

APPENDIX D

QOL CHANGE

Table D-1 QOL change in each village of Mueang Nakhon Ratchasima district in 2008, 2010, and 2018.

Code	MOO	Village	Sub-district	QOL 2008	QOL 2010	QOL 2018
30017601	1	Bung	Nong Phai Lom	Very poor	Very poor	Very poor
30010605	5	Thap Chang	Nong Rawiang	Very poor	Poor	Very poor
30011106	6	Pha Lai	Hue Thale	Very poor	Moderate	Moderate
30010606	6	Thap Chang	Nong Rawiang	Poor	Moderate	Poor
30011109	9	Tha Krasang	Hue Thale	Poor	Moderate	Poor
30011903	3	Nong Pling	Nong Bua Sala	Poor	Moderate	Poor
30011902	2	Nong Talumphuk	Nong Bua Sala	Poor	Moderate	Moderate
30011909	9	Nong Pling Mai	Nong Bua Sala	Poor	Moderate	Moderate
30010101	1	Constituency zone1	Nai Mueang	Poor	Good	Good
30010104	4	Constituency zone4	Nai Mueang	Poor	Good	Good
30011103	3	Non Farang	Hue Thale	Poor	Good	Good
30010305	5	Bun Roeng	Nong Chabok	Moderate	Moderate	Moderate
30010603	3	Nong Muang	Nong Rawiang	Moderate	Moderate	Moderate
30010613	13	Nong Samo	Nong Rawiang	Moderate	Moderate	Moderate
30010706	6	Liap	Pru Yai	Moderate	Moderate	Moderate
30011110	10	Nong Song Hong Nua	Hue Thale	Moderate	Moderate	Moderate
30011710	10	Don	Khok Kruat	Moderate	Moderate	Moderate
30011905	5	Ang Nong Nae	Nong Bua Sala	Moderate	Moderate	Moderate
30012506	6	Khok	Nong Khai Nam	Moderate	Moderate	Moderate
30017602	2	Bung Ta Lua	Nong Phai Lom	Moderate	Moderate	Moderate
30010612	12	Nong Rawiang	Nong Rawiang	Moderate	Moderate	Good
30010205	5	Nong Phutsa	Pho Klang	Moderate	Good	Moderate
30010301	1	Tang Ta	Nong Chabok	Moderate	Good	Moderate
30010607	7	Map Makha	Nong Rawiang	Moderate	Good	Moderate
30010611	11	Tanot	Nong Rawiang	Moderate	Good	Moderate
30010807	7	Nong Na Lum	Muen Wai	Moderate	Good	Moderate
30011412	12	Nong Ya Rak	Phut Sa	Moderate	Good	Moderate
30011615	15	Nong Kradang Nga	Cho ho	Moderate	Good	Moderate
30011709	9	Nong Pet Nam	Khok Kruat	Moderate	Good	Moderate
30011904	4	Nong Bua Sala	Nong Bua Sala	Moderate	Good	Moderate
30012405	5	Chong Lom	Nong Krathum	Moderate	Good	Moderate
30012502	2	Bung Ri	Nong Khai Nam	Moderate	Good	Moderate
30010102	2	Constituency zone2	Nai Mueang	Moderate	Good	Good

Table D-1 QOL change in each village of Mueang Nakhon Ratchasima district in 2008, 2010, and 2018 (Continued).

Code	MOO	Village	Sub-district	QOL 2008	QOL 2010	QOL 2018
30010103	3	Constituency zone3	Nai Mueang	Moderate	Good	Good
30010703	3	Nong Hoi	Pru Yai	Moderate	Good	Good
30010806	6	Khok Phai	Muen Wai	Moderate	Good	Good
30010808	8	Khon Pha-ngat	Muen Wai	Moderate	Good	Good
30011101	1	Hua Thale	Hue Thale	Moderate	Good	Good
30011603	3	Cho ho	Cho ho	Moderate	Good	Good
30011605	5	Chong Au	Cho ho	Moderate	Good	Good
30011608	8	Sa Tammakhan	Cho ho	Moderate	Good	Good
30011613	13	Nong Piman	Cho ho	Moderate	Good	Good
30011707	7	Khlong Krabu	Khok Kruat	Moderate	Good	Good
30011104	4	Nong Song Hong	Hue Thale	Good	Very poor	Very poor
30011105	5	Pha Lai	Hue Thale	Good	Poor	Very poor
30011111	11	Bun Nimit	Hue Thale	Good	Poor	Very poor
30017607	7	Nong Nok Yung	Nong Phai Lom	Good	Moderate	Moderate
30010508	8	Krathon	Mareng	Good	Moderate	Good
30010907	7	Bung Tako	Phon Krung	Good	Good	Moderate
30011112	12	Thung Thale Ruam Chai	Hue Thale	Good	Good	Moderate
30011401	1	Maduea	Phut Sa	Good	Good	Moderate
30011604	4	Cho ho	Cho ho	Good	Good	Moderate
30012407	7	Nong Krathum	Nong Krathum	Good	Good	Moderate
30010201	1	Nong Pru	Pho Klang	Good	Good	Good
30010202	2	Nong Phai	Pho Klang	Good	Good	Good
30010203	3	Nong Phluang Noi	Pho Klang	Good	Good	Good
30010204	4	Nong Phluang Manao	Pho Klang	Good	Good	Good
30010208	8	Si Somboon	Pho Klang	Good	Good	Good
30010210	10	Nong Phai Phatthana	Pho Klang	Good	Good	Good
30010302	2	Krin	Nong Chabok	Good	Good	Good
30010303	3	Thanon Hak	Nong Chabok	Good	Good	Good
30010304	4	Nong Pru	Nong Chabok	Good	Good	Good
30010401	1	Khok Sung	Khok Sung	Good	Good	Good
30010402	2	Nong Pho	Khok Sung	Good	Good	Good
30010403	3	Song Tai	Khok Sung	Good	Good	Good
30010404	4	Ra-ngom	Khok Sung	Good	Good	Good
30010405	5	Hua Sa	Khok Sung	Good	Good	Good
30010406	6	Ra-ngom Phatthana	Khok Sung	Good	Good	Good
30010408	8	Song Nua	Khok Sung	Good	Good	Good
30010409	9	Lam Choeng Krai	Khok Sung	Good	Good	Good
30010410	10	Samkhan	Khok Sung	Good	Good	Good
30010411	11	Nong Krachai	Khok Sung	Good	Good	Good
30010502	2	Mai	Mareng	Good	Good	Good
30010503	3	Saraphi	Mareng	Good	Good	Good
30010504	4	Phra	Mareng	Good	Good	Good
30010505	5	Bung San	Mareng	Good	Good	Good
30010506	6	Phra	Mareng	Good	Good	Good
30010507	7	Khok	Mareng	Good	Good	Good
30010601	1	Yong Yaeng	Nong Rawiang	Good	Good	Good

Table D-1 QOL change in each village of Mueang Nakhon Ratchasima district in 2008, 2010, and 2018 (Continued).

Code	MOO	Village	Sub-district	QOL 2008	QOL 2010	QOL 2018
30010602	2	Nong Sai	Nong Rawiang	Good	Good	Good
30010604	4	Kham Sa Phleng	Nong Rawiang	Good	Good	Good
30010608	8	Cha-om	Nong Rawiang	Good	Good	Good
30010609	9	Cha-om	Nong Rawiang	Good	Good	Good
30010610	10	Tanot	Nong Rawiang	Good	Good	Good
30010614	14	Non Makok	Nong Rawiang	Good	Good	Good
30010702	2	Takhlong Kao	Pru Yai	Good	Good	Good
30010802	2	Muen Wai	Muen Wai	Good	Good	Good
30010803	3	Non Ta Suk	Muen Wai	Good	Good	Good
30010805	5	Khlong Boriboon	Muen Wai	Good	Good	Good
30010809	9	Khlong Phai	Muen Wai	Good	Good	Good
30010902	2	Phol Krang	Phon Krung	Good	Good	Good
30010903	3	Phol Krang	Phon Krung	Good	Good	Good
30010904	4	Sakae Krang	Phon Krung	Good	Good	Good
30010905	5	Bu Khi Tun	Phon Krung	Good	Good	Good
30010906	6	Ta Thao	Phon Krung	Good	Good	Good
30010908	8	Bung Prasoet	Phon Krung	Good	Good	Good
30011102	2	Don Khwang	Hue Thale	Good	Good	Good
30011108	8	Khlong Khoi Ngam	Hue Thale	Good	Good	Good
30011202	2	Ko	Ban Ko	Good	Good	Good
30011204	4	Khok Phai Noi	Ban Ko	Good	Good	Good
30011205	5	Bung Phaya Prap	Ban Ko	Good	Good	Good
30011301	1	Mai	Ban Mai	Good	Good	Good
30011305	5	Phu Khao Lat	Ban Mai	Good	Good	Good
30011310	10	Sisa La Loeng	Ban Mai	Good	Good	Good
30011312	12	Makham Thao Phatthana	Ban Mai	Good	Good	Good
30011402	2	Phutsa	Phut Sa	Good	Good	Good
30011403	3	Phutsa Rim Bung	Phut Sa	Good	Good	Good
30011404	4	Don Krathing	Phut Sa	Good	Good	Good
30011405	5	Bu Krathin	Phut Sa	Good	Good	Good
30011407	7	Tako	Phut Sa	Good	Good	Good
30011408	8	Lalom Pho	Phut Sa	Good	Good	Good
30011409	9	Sa Pho	Phut Sa	Good	Good	Good
30011411	11	Khwao	Phut Sa	Good	Good	Good
30011413	13	Lam Phong	Phut Sa	Good	Good	Good
30011414	14	Noi	Phut Sa	Good	Good	Good
30011415	15	La Lom Nua	Phut Sa	Good	Good	Good
30011416	16	Don Phatthana	Phut Sa	Good	Good	Good
30011417	17	Nong Ya Rak Nua	Phut Sa	Good	Good	Good
30011418	18	Lam Phong Tai	Phut Sa	Good	Good	Good
30011501	1	Yung	Ban Pho	Good	Good	Good
30011502	2	Tanot	Ban Pho	Good	Good	Good
30011503	3	Burana Phanit	Ban Pho	Good	Good	Good
30011506	6	Makha	Ban Pho	Good	Good	Good

Table D-1 QOL change in each village of Mueang Nakhon Ratchasima district in 2008, 2010, and 2018 (Continued).

Code	MOO	Village	Sub-district	QOL 2008	QOL 2010	QOL 2018
30011507	7	Saen Mueang	Ban Pho	Good	Good	Good
30011508	8	Nong Bua	Ban Pho	Good	Good	Good
30011509	9	Long Tong	Ban Pho	Good	Good	Good
30011510	10	Makha Phatthana	Ban Pho	Good	Good	Good
30011601	1	Phanao	Cho ho	Good	Good	Good
30011602	2	Kluai	Cho ho	Good	Good	Good
30011606	6	Rakai	Cho ho	Good	Good	Good
30011607	7	Bung Thap Chang	Cho ho	Good	Good	Good
30011611	11	Krut	Cho ho	Good	Good	Good
30011612	12	Sa Tarat	Cho ho	Good	Good	Good
30011614	14	Pun	Cho ho	Good	Good	Good
30011702	2	Khok Kruat	Khok Kruat	Good	Good	Good
30011704	4	Lalom Mo	Khok Kruat	Good	Good	Good
30011705	5	Prong Malaeng Wan	Khok Kruat	Good	Good	Good
30011711	11	Nong Khon	Khok Kruat	Good	Good	Good
30011712	12	Nong Rang Ka	Khok Kruat	Good	Good	Good
30011714	14	Khok Phet	Khok Kruat	Good	Good	Good
30011801	1	Chai Mongkhon	Chai Mongkhon	Good	Good	Good
30011802	2	Bu Tan	Chai Mongkhon	Good	Good	Good
30011803	3	Nong Phluang Yai	Chai Mongkhon	Good	Good	Good
30011804	4	Nong Pling	Chai Mongkhon	Good	Good	Good
30011901	1	Nong Takhlong	Nong Bua Sala	Good	Good	Good
30011906	6	Nong Samong	Nong Bua Sala	Good	Good	Good
30011907	7	Mai Nong Nae	Nong Bua Sala	Good	Good	Good
30011908	8	Nong Ta Khong	Nong Bua Sala	Good	Good	Good
30011910	10	Nong Talumphuk Mai	Nong Bua Sala	Good	Good	Good
30012001	1	Ratchasima	Suranaree	Good	Good	Good
30012003	3	Yang Yai	Suranaree	Good	Good	Good
30012101	1	Don	Si Mum	Good	Good	Good
30012102	2	Si Mum	Si Mum	Good	Good	Good
30012103	3	Si Mum	Si Mum	Good	Good	Good
30012104	4	Si Mum	Si Mum	Good	Good	Good
30012105	5	Si Mum	Si Mum	Good	Good	Good
30012106	6	Si Mum	Si Mum	Good	Good	Good
30012107	7	Mai Charoen Si	Si Mum	Good	Good	Good
30012110	10	Makok	Si Mum	Good	Good	Good
30012201	1	Bu	Talat	Good	Good	Good
30012202	2	Bu	Talat	Good	Good	Good
30012204	4	Pho	Talat	Good	Good	Good
30012205	5	Krachot	Talat	Good	Good	Good
30012206	6	Rat Prasong	Talat	Good	Good	Good
30012207	7	Nong Takhlong	Talat	Good	Good	Good
30012208	8	Bu Phatthana	Talat	Good	Good	Good
30012303	3	Nong Sai Phrai	Pha Nao	Good	Good	Good
30012304	4	Don In	Pha Nao	Good	Good	Good
30012306	6	Phanao	Pha Nao	Good	Good	Good

Table D-1 QOL change in each village of Mueang Nakhon Ratchasima district in 2008, 2010, and 2018 (Continued).

Code	MOO	Village	Sub-district	QOL 2008	QOL 2010	QOL 2018
30012402	2	Nong Pho	Nong Krathum	Good	Good	Good
30012403	3	Phra	Nong Krathum	Good	Good	Good
30012404	4	Fai	Nong Krathum	Good	Good	Good
30012406	6	Khok Wua	Nong Krathum	Good	Good	Good
30012409	9	Na Thom	Nong Krathum	Good	Good	Good
30012501	1	Nong Khai Nam Phatthana	Nong Khai Nam	Good	Good	Good
30012503	3	Kho Nong Bua	Nong Khai Nam	Good	Good	Good
30012504	4	Sanuan	Nong Khai Nam	Good	Good	Good
30012505	5	Krok Phatthana	Nong Khai Nam	Good	Good	Good
30012507	7	Nong Khai Nam	Nong Khai Nam	Good	Good	Good
30012508	8	Kradon	Nong Khai Nam	Good	Good	Good
30010501	1	Hua Chang	Mareng	Good	Good	Very good
30010801	1	Pra Chok	Muen Wai	Good	Good	Very good
30011201	1	Ko	Ban Ko	Good	Good	Very good
30011203	3	Khanai	Ban Ko	Good	Good	Very good
30011706	6	Sra Manora	Khok Kruat	Good	Good	Very good
30012302	2	Phutsa	Pha Nao	Good	Good	Very good
30010407	7	Mamuang Phatthana	Khok Sung	Good	Very good	Good
30010901	1	Phol Krang	Phon Krung	Good	Very good	Good
30011302	2	Mai	Ban Mai	Good	Very good	Good
30011406	6	Kluai	Phut Sa	Good	Very good	Good
30011504	4	Si Phatthana	Ban Pho	Good	Very good	Good
30011505	5	Wang Hin	Ban Pho	Good	Very good	Good
30011609	9	Samrong	Cho ho	Good	Very good	Good
30011610	10	Nong Ok	Cho ho	Good	Very good	Good
30011703	3	Don Taew	Khok Kruat	Good	Very good	Good
30012408	8	Som Poi	Nong Krathum	Good	Very good	Good
30010206	6	Nong Bua	Pho Klang	Good	Very good	Very good
30010209	9	Khai Suratampitak	Pho Klang	Good	Very good	Very good
30010705	5	Phop Suk	Pru Yai	Good	Very good	Very good
30010707	7	Saen Suk	Pru Yai	Good	Very good	Very good
30010804	4	Phon Sung	Muen Wai	Good	Very good	Very good
30011410	10	Sisa Chang	Phut Sa	Good	Very good	Very good
30012002	2	Nong Mai Daeng	Suranaree	Good	Very good	Very good
30012005	5	Nong Bong	Suranaree	Good	Very good	Very good
30012007	7	Krok Duean Ha	Suranaree	Good	Very good	Very good
30012109	9	Thung Kradon	Si Mum	Good	Very good	Very good
30012203	3	Talat	Talat	Good	Very good	Very good
30012307	7	Maroeng Yai	Pha Nao	Good	Very good	Very good
30012308	8	Yong Yaeng	Pha Nao	Good	Very good	Very good
30012309	9	Mai Yong Yaeng	Pha Nao	Good	Very good	Very good
30012401	1	Nong Ya Ngam	Nong Krathum	Good	Very good	Very good
30017699	0	institutional area	Nong Phai Lom	Good	Very good	Very good
30011107	7	Hua Thanon	Hue Thale	Very good	Moderate	Poor
30010615	15	Non Phralan	Nong Rawiang	Very good	Good	Good
30011303	3	Hua Sip	Ban Mai	Very good	Good	Good

Table D-1 QOL change in each village of Mueang Nakhon Ratchasima district in 2008, 2010, and 2018 (Continued).

Code	MOO	Village	Sub-district	QOL 2008	QOL 2010	QOL 2018
30011306	6	Samrong Nua	Ban Mai	Very good	Good	Good
30011311	11	Yang Noi	Ban Mai	Very good	Good	Good
30011701	1	Nong Wa	Khok Kruat	Very good	Good	Good
30011708	8	Duea	Khok Kruat	Very good	Good	Good
30011713	13	Nong Kung	Khok Kruat	Very good	Good	Good
30010207	7	Bung Saen Suk	Pho Klang	Very good	Very good	Good
30010701	1	Khon Chum	Pru Yai	Very good	Very good	Good
30010704	4	Wirot Phatthana	Pru Yai	Very good	Very good	Good
30011304	4	Makham Thao	Ban Mai	Very good	Very good	Good
30011307	7	Sisa La Loeng	Ban Mai	Very good	Very good	Good
30011308	8	Kamthuat	Ban Mai	Very good	Very good	Good
30011309	9	Samrong	Ban Mai	Very good	Very good	Good
30012108	8	Pae	Si Mum	Very good	Very good	Good
30011805	5	Nong Sai	Chai Mongkhon	Very good	Very good	Very good
30012004	4	Taphao Thong	Suranaree	Very good	Very good	Very good
30012006	6	Map Uang	Suranaree	Very good	Very good	Very good
30012008	8	Saphan Hin	Suranaree	Very good	Very good	Very good
30012009	9	Yang Yai Phatthana	Suranaree	Very good	Very good	Very good
30012010	10	Thao Sura	Suranaree	Very good	Very good	Very good
30012301	1	Maroeng Noi	Pha Nao	Very good	Very good	Very good
30012305	5	Phanao	Pha Nao	Very good	Very good	Very good

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