APPLICATION OF MARKOV-CELLULAR AUTOMATA AND SOCIAL MODELS FOR LAND USE PREDICTION IN CENTRAL PETCHABURI WATERSHED, THAILAND

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entitled

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Kitsanai Charoenjit

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APPLICATION OF MARKOV-CELLULAR AUTOMATA AND SOCIAL MODELS FOR LAND USE PREDICTION IN CENTRAL PETCHABURI WATERSHED, THAILAND

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ABSTRACT

This study aims to apply Markov, Cellular Automata, and Social models to identify land use change between the years 2003 and 2008 and also predict land use pattern of central Petchaburi watershed, Thailand in 2013.

It was found that the land use patterns which increased were included water bodies (131.00%), field crop (18.21%), urban/built up land (2.10%), disturbed forest (1.44%), and orchard/horticulture (1.13%). The land use patterns which decreased included paddy field (40.52%) and forest land (10.97%). The predicted land use in 2013, using CA-Markov model, was identified as the incretion of water bodies since the reservoir was constructed and completed within the study period. Hence, it was affected the analysis. Meanwhile, the predicted land use using CA-Social model, was incretion of forest land through alteration from disturbed forest area. The comparison of CA-Markov and CA-Social models showed the substantial agreement (Kappa Index = 0.76) and a similarity index of 85 percent. In addition, these two models have been accepted for use as land use predict ors in the study area. However, the CA-Social seems to play a better role since it could consistently identify within the real phenomenon trends of utilization in the study area.

KEY WORDS : LAND USE CHANGE/ CELLULAR AUTOMATA/ MARKOV/ SOCIAL/ CENTRAL PETCHABURI WATERSHED

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การประยุกต์ใช้แบบจำลองทางสังคมและ มาร์คอฟ-เซลลูลาร์ออโตมาตา เพื่อคาดการณ์การใช้ที่ดิน บริเวณลุ่มน้ำเพชรบุรีตอนกลาง ประเทศไทย

APPLICATION OF MARKOV-CELLULAR AUTOMATA AND SOCIAL MODELS FOR LAND USE PREDICTION IN CENTRAL PETCHABURI WATERSHED, THAILAND

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บทคัดย่อ

การศึกษานี้เป็นการประยุกต์ใช้แบบจำลองมาร์คอฟ (Markov) แบบจำลองเซลลูลาออโตมาตา (Cellular Automata) และแบบจำลองทางสังคม เพื่อจำแนกรูปแบบและการเปลี่ยนแปลงการใช้ที่ดินช่วงปี พ.ศ.2546-2551 และคาดการณ์รูปแบบการใช้ที่ดินปี พ.ศ.2556 ของลุ่มน้ำเพชรบุรีตอนกลาง ประเทศไทย

ผลการศึกษา พบว่า รูปแบบการใช้ที่ดินในช่วงปี พ.ศ.2546-2551ที่มีการเปลี่ยนแปลงเพิ่มขึ้น ได้แก่ แหล่งน้ำ พืชไร่ ชุมชนและสิ่งปลูกสร้าง ป่าเสื่อมโทรม ไม้ผลและพืชสวน โดยมีพื้นที่เพิ่มขึ้นร้อยละ 131, 18.21, 2.10, 1.44, และ 1.13 ตามลำดับ ในขณะที่ นาข้าว และป่าไม้ มีพื้นที่ลดลงร้อยละ 40.52 และ 10.97 ตามลำดับ การคาดการณ์การใช้ที่ดินในปี พ.ศ.2556 ด้วยแบบจำลองมาร์คอฟผสมผสานกับแบบจำลองเซลลูลาออโตมาตา (CA-Markov) พบว่า แหล่งน้ำจะมีพื้นที่เพิ่มมากขึ้น ทั้งนี้เนื่องจากมีการสร้างอ่างเก็บน้ำในช่วงระยะเวลาที่ศึกษา จึงทำให้ส่งผลต่อการวิเคราะห์ ส่วนการคาดการณ์ด้วยแบบจำลองทางสังคมผสมผสานกับแบบจำลองเซลลูลาออโตมาตา (CA-Social) พบว่า ป่าไม้จะมีพื้นที่เพิ่มมากขึ้น โดยเปลี่ยนแปลงมาจากพื้นที่ป่าเสื่อมโทรมที่มีการทดแทนเป็นพื้นที่ป่าเป็นส่วนใหญ่ เมื่อเปรียบเทียบการคาดการณ์การใช้ที่ดินระหว่างแบบจำลอง CA-Markov กับ CA-Social พบว่าแบบจำลองทั้งสองมีความสอดคล้องกันที่ร้อยละ 85.00 และมีการยอมรับอยู่ในระดับมาก (Kappa = 0.76) ดังนั้น แบบจำลองทั้งสองสามารถนำมาใช้ในการคาดการณ์การเปลี่ยนแปลงการใช้ที่ดินในพื้นที่ได้ แต่แบบจำลอง CA-Social จะให้ผลลัพธ์ที่สอดคล้องกับแนวทางการดำเนินกิจกรรมที่เป็นจริงในพื้นที่ได้ดีกว่า

71 หน้า

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CHAPTER I
INTRODUCTION

1.1 Background Justification

The land use prediction could be supported both government and private sectors in the better decision making for land use planning and natural resources conservation approaches such as water balance, forest conservation, urban planning, risk assessment , environment policy etc.

The Markov-Cellular Automata model (CA-Markov) is accepted for being an appropriate technology and model in the global scale. The result of CA-Markov can be shown in both spatial and attribute data format. Thus, it can be more convenient for the further application in land use planning and management. The research related to land use prediction in Thailand using CA-Markov are including land use prediction in Nan Province (1) which there provided the accuracy of 82.12% within the substantial agreement (kappa index = 0.76). Land use prediction in Krabi Province (2) has been provided the accuracy of 74.83%, within the substantial agreement (kappa index = 0.62).

However, the application of CA-Markov is still limited, since the probabilities manipulated by Markov model is based upon the exactly or stability changes of the two dataset. Thus, the fluctuation situation in the specific area could be the factor that might be reduced the accuracy aspect. Besides, there are also many factors which enforced to the land use changes for instance economic, government policy, and social aspects etc. Thus, the social enforcement is selected for this study.

The Central Phetchaburi Watershed is located in the western region of Thailand. The common land use patterns are including paddy field, cassava, lime orchards, banana, water bodies, urban, and forest land. In the past decade, the dam has been constructed by Royal Irrigation Department (3) which affected to the land use

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pattern of the area. Thus, it is very interesting to testify the appropriate of prediction models including markov, cellular automata and social model in particular.

1.2 Objectives

1.2.1 To identify land use patterns and changes in 2003 and 2008 of central Petchaburi watershed.

1.2.2 To apply CA-Markov and CA-Social models for land use change prediction in 2013.

1.2.3 To compare the similarity of predicted land use based on CA-Markov and CA-Social models.

1.3 Conceptual Framework

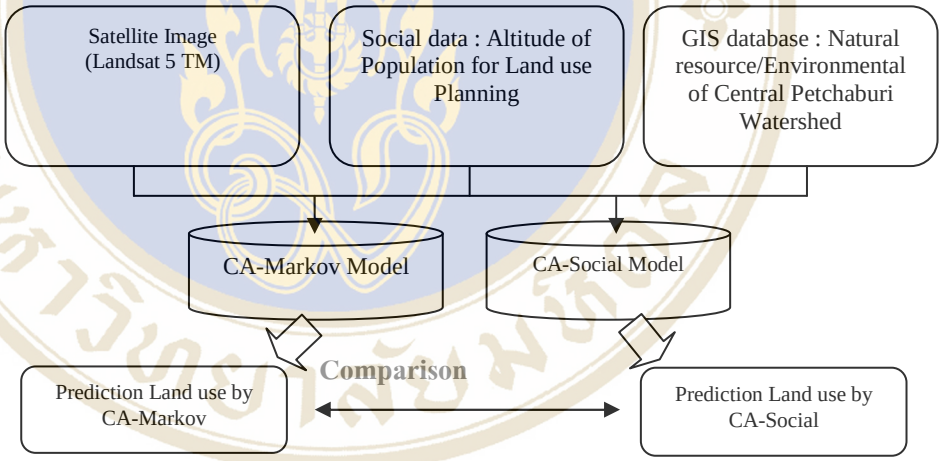

Figure 1.1 Conceptual Framework

1.4 Scope and Limitations of the Study

1.4.1 Study area

The study area is located in central Perchaburi watershed the western region of Thailand. The area is 1,132 square kilometers. It is administratively divided into 6 districts, including Pakthor, Ban Kha, Nong Ya Plong, Ban Lat, Kaengkrachan, and Tha Yang which consisted of 66 Villages.

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1.4.2 Scope of procedure

- Land use patterns has been classified using satellite imageries (LANDSAT-5 TM) which provided the resolution of 25x25 meters.

- The nomenclature of land use in 2003 and 2008 has been proposed to identify within 7 patterns included (1) Paddy Field, (2) Field Crop, (3) Orchard/Horticulture, (4) Disturbed Forest, (5) Forest Land, (6) Water bodies, (7) Urban/Build-up area.

1.5 Expected Results

Appropriate Prediction models which could be identify the better prediction of land use changes in central Petchaburi watershed.

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CHAPTER II
LITERATURE REVIEW

The content of this chapter is reviewing of secondary documents concerning: Study area , Land use and Land cover, Geo-Informatics, Landsat Satellite, Mathematical Model, Accuracy Assessment, , and Related researches.

2.1 Study Area

Central Petchaburi Watershed (3) is located on west region in Thailand. Its area is 1,132 square kilometers which majority of area in Petchaburi Province , the eastern border is Lower Petchaburi Watershed ,the western and southern borders is Upper Petchaburi Watershed , the northern borders is Ratchaburi Province

Central Petchaburi Watershed is administratively divided into 6 districts; Pakthor, Ban Kha, Nong Ya Plong, Ban Lat, Kaengkrachan, Tha Yang.

2.1.1 Topography

The west in Nong Ya Plong and Kaengkrachan districts is the plateau and low mountain in the east, be born are the watershed divide the water one flow down to Myanmar and again one flow to Petchaburi province.

Central Petchaburi Watershed cover majority area of Phetchburi province , and the some part of , Ratchaburi Province there is the origin from mountain tall side range the west in Ratchaburi border

2.1.2 Weather and Climate

Weather in Central Petchaburi Watershed has three seasons: the hot season starts from February to May, whereas the rainy season begins in May to October and the winter season begins in October to February. The temperature range between 17.5 degrees to 36.5 degrees Celsius or temperature average 28.05 degrees Celsius and annual rainfall per year is approximately 881.6 millimeters.

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2.1.3 River and Water bodies

Central Petchaburi Watershed has Hua-mae-pra-chan main river and long 186.25 Kilometers, which flows a mountain in Ratchaburi Province, Nong Ya Plong and end at the Mae-num-petchaburi river in Tayang.

2.1.4 Population

In 2008, Petchaburi Province has its population of 458,975 with 222,421 males and 236,554 females. There are 160,240 households.

2.1.5 Occupation

Most of people in Central Petchaburi Watershed have occupations concerning with agriculture such as Cassava , Banana , Lemon , Paddy field.

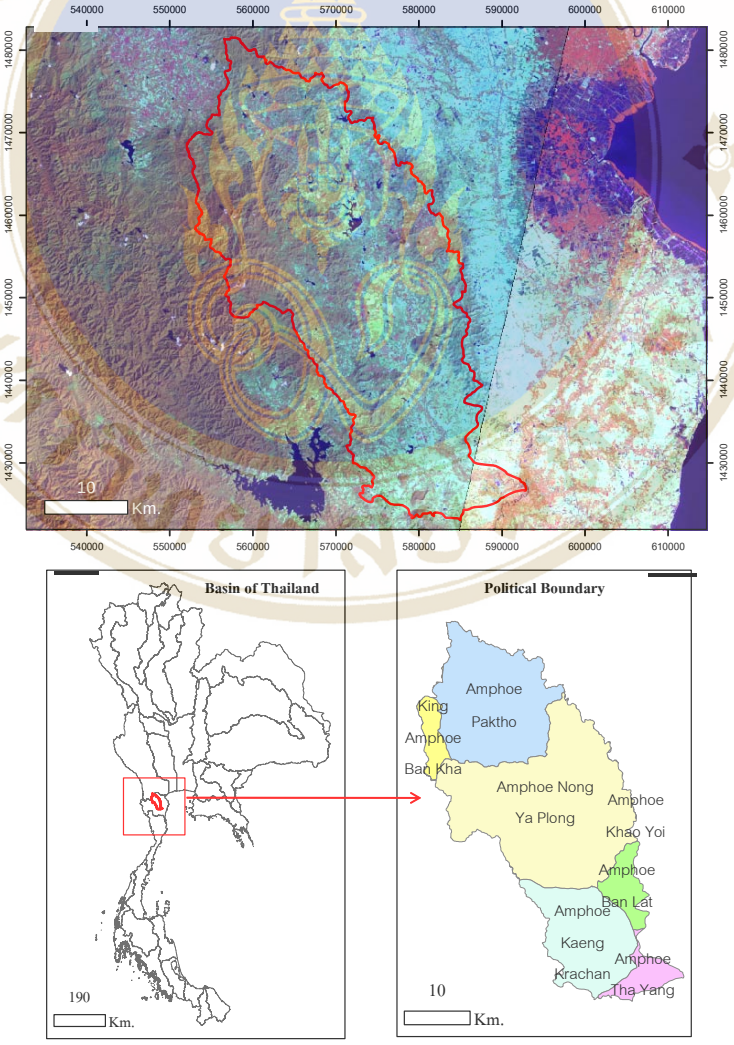

Figure 2.1 Central Petchaburi Watershed, Thailand Study area.

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2.2 Land use and land cover

Land cover is defined as the layer of soils and biomass, including natural vegetation, crops and human structures that cover the land surface. Land use refers to the purposes for which humans exploit the land cover (Fresco, 1994). Land cover change is the complete replacement of one cover type by another, while land-use changes also include the modification of land-cover types, e.g., intensification of agricultural use, without changing its overall classification (4).

2.2.1 The causes of land use change

It found out that the change of land use pattern was mainly caused by the growth of population, houses, agricultural, occupation and size of family respectively. The amount of population in labouring age hardly affects the change of form of land use.

It could be said that the mount of population mainly affected on the change of land use pattern, while the change could be affected by various factors as followings:

1. The increasing of population and the expansion of urban including with other activity, the need of land for agriculture is increased.

2. The expansion of agriculture land without appropriate control. Forest land is invaded, because of motivation in doing agriculture especially sugarcanes planting and corn planting.

3. The governmental development plan. The construction for development like the construction of roads and dams in rural area affects the change of form of land use.

4. The governmental policy and high-education of farmer cause the change of land use pattern to an area of cultivation resulted by governmental policy and private market. The total development of agriculture section is the convenience in transportation and transformation of products including with the forming of government offices for supporting those economic areas such as the areas of monioc planting, sugarcane planting and corn planting with factories sited in the areas.

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2.3 Geo-Informatics

The geo-informatics is included remote sensing (RS), geographic information system (GIS), and global positioning system (GPS). They are defined as multi-disciplinary science of geo-informatics to measure, record, process, analyze, represent, and visualize geo-spatial data (5). The geo-informatics are emphasized on 3D application, data acquisition for digital elevation models (DEM), data processing and analyses, and 3D-image output.

2.3.1 Remote Sensing

Remote Sensing is the science and art of acquiring information (spectral, spatial, and temporal) about material objects, area, or phenomenon, without coming into physical contact with the objects, or area, or phenomenon under investigation. Without direct contact, some means of transferring information through space must be utilized. In remote sensing, information transfer is accomplished by use of electromagnetic radiation (EMR). EMR is a form of energy that reveals its presence by the observable effects it produces when it strikes the matter. EMR is considered to span the spectrum of wavelengths from 10-10 mm to cosmic rays up to 1010 mm, the broadcast wavelengths, which extend from 0.30-15 mm (6).

2.3.1.1 Types

- In respect to the type of Energy Resources: Passive Remote Sensing: Makes use of sensors that detect the reflected or emitted electro-magnetic radiation from natural sources.

Active remote Sensing: Makes use of sensors that detect reflected responses from objects that are irradiated from artificially-generated energy sources, such as radar.

- In respect to Wavelength Regions: Remote Sensing is classified into three types in respect to the wavelength regions
  - Visible and Reflective Infrared Remote Sensing.
  - Thermal Infrared Remote Sensing.
  - Microwave Remote Sensing.

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2.3.1.2 Bands Used in Remote Sensing

Emission of EMR (Electo-Magnetic Radiation) from gases is due to atoms and molecules in the gas. Atoms consist of a positively charged nucleus surrounded by orbiting electrons, which have discrete energy states. Transition of electrons from one energy state to the other leads to emission of radiation at discrete wavelengths. The resulting spectrum is called line spectrum. Molecules possess rotational and vibrational energy states. Transition between which leads to emission of radiation in a band spectrum. The wavelengths, which are emitted by atoms/molecules, are also the ones, which are absorbed by them. Emission from solids and liquids occurs when they are heated and results in a continuous spectrum. This is called thermal emission and it is an important source of EMR from the viewpoint of remote sensing.(6)

The Electro-Magnetic Radiation (EMR), which is reflected or emitted from an object, is the usual source of Remote Sensing data. However, any medium, such as gravity or magnetic fields, can be used in remote sensing.

Remote Sensing Technology makes use of the wide range Electro-Magnetic Spectrum (EMS) from a very short wave "Gamma Ray" to a very long 'Radio Wave'.

Wavelength regions of electro-magnetic radiation have different names ranging from Gamma ray, X-ray, Ultraviolet (UV), visible light, Infrared (IR) to Radio Wave, in order from the shorter wavelengths.

The optical wavelength region, an important region for remote sensing applications, is further subdivided as follows:

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Table 2.1 Wavelength regions of electro-magnetic radiation

Name	Wavelength (mm)
Optical wavelength	0.30-15.0
Reflective	0.38-3.00
1. Portion Visible	0.38-0.72
2. Near IR	0.72-1.30
3. Middle IR	1.30-3.00
Far IR (Thermal, Emissive)	7.00-15.0

Source : GIS Development, 2005

Microwave region (1mm to 1m) is another portion of EM spectrum that is frequently used to gather valuable remote sensing information.

2.3.1.3 Resolution

In general resolution is defined as the ability of an entire remote-sensing system, including lens antennae, display, exposure, processing, and other factors, to render a sharply defined image. Resolution of a remote-sensing is of different types. (6)

1. Spectral Resolution: of a remote sensing instrument (sensor) is determined by the band-widths of the Electro-magnetic radiation of the channels used. High spectral resolution, thus, is achieved by narrow bandwidths width, collectively, are likely to provide a more accurate spectral signature for discrete objects than broad bandwidth.

2. Radiometric Resolution: is determined by the number of discrete levels into which signals may be divided.

3. Spatial Resolution: in terms of the geometric properties of the imaging system, is usually described as the instantaneous field of view (IFOV). The IFOV is defined as the maximum angle of view in which a sensor can effectively detect electro-magnetic energy.

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4. Temporal Resolution: is related to the repetitive coverage of the ground by the remote-sensing system. The temporal resolution of Landsat 4/5 is sixteen days.

Despite the undoubted potential application of RS technique to study feature on earth, there are still limitation and practical problems encounter in their uses. The limitations of using satellite data at least six points are follows: (6)

1) Spectral range. Sensor system mounted on elevated platform has multispectral. For example, Landsat satellite compose of MSS (4 spectral ranges) and TM (7 spectral ranges). In each spectral range is designed for each object or material studies. As a result, user should consider before choose specific spectral range in his research.

2) Data and image. Sensor has recorded feature on the earth in digital form. They are processed and manipulated many steps before produced thematic map.

3) Ground resolution. In each satellite (i.e. SPOT, LANDSAT, NOAA, JERS-1) has different ground resolution. User should be careful to choose satellite data which it is matched with size of material or area studies.

4) Land elevation. Most of satellite has not three dimensions data. They can not create contour line or elevation data. 3-D satellite data is difficult to record and has many problems to processes.

5) Cloud cover. Most serious constraint faced in the use of satellite data from passive remote sensing. The used of active remote sensing system, i.e. microwave sensor and airborne, is the only way to overcome cloud cover problem. However, microwave data can not totally replace passive remote sensing data for all studies such as ocean color.

6) Data acquisition. Ground receiving in Thailand has full capability to received satellite data from limited Earth observation programs such as Landsat from U.S.A., JERS-1 from Japan. It might increase more optional program in order to secure data continuity such as IRS of India.

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2.3.2 Geographic Information System (GIS)

There are several definitions concerning with geographic information system (GIS), almost are focus upon perspective view such as its development and disciplinary, like;

Geographic Information System (GIS) is a computer based information system used to digitally represent and analyse the geographic features present on the Earth' surface and the events (non-spatial attributes linked to the geography under study) that taking place on it. The meaning to represent digitally is to convert analog (smooth line) into a digital form. (7)

GIS is a computer–assisted system that can input, retrieve, analyze and display geographically referenced information useful for decision making. (8)

A GIS stores information about the world as a collection of thematic layers that can be linked together by geography. This simple but extremely powerful and versatile concept has proven invaluable for solving many real-world problems from tracking delivery vehicles, to recording details of planning applications, to modeling global atmospheric circulation.

Geographic information contains either an explicit geographic reference, such as a latitude and longitude or national grid coordinate, or an implicit reference such as an address, postal code, census tract name, forest stand identifier, or road name. An automated process called geocoding is used to create explicit geographic references (multiple locations) from implicit references (descriptions such as addresses). These geographic references allow you to locate features, such as a business or forest stand, and events, such as an earthquake, on the earth's surface for analysis.

Geographic information systems work with two fundamentally different types of geographic models--the "vector" model and the "raster" model. In the vector model, information about points, lines, and polygons is encoded and stored as a collection of x,y coordinates. The location of a point feature, such as a bore hole, can be described by a single x,y coordinate. Linear features, such as roads and rivers, can be stored as a collection of point coordinates. Polygonal features, such as sales territories and river catchments, can be stored as a closed loop of coordinates. The

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vector model is extremely useful for describing discrete features, but less useful for describing continuously varying features such as soil type or accessibility costs for hospitals. The raster model has evolved to model such continuous features. A raster image comprises a collection of grid cells rather like a scanned map or picture. Both the vector and raster models for storing geographic data have unique advantages and disadvantages. Modern GISs are able to handle both models.

2.3.3 Global Positioning System (GPS)

Global Positioning System or GPS is initiated under the Navigation satellites or NAVSTAR program, which consists of 24+ satellites. GPS uses the geometric principle of triangulation to determine location on earth surface. The distances are measured from satellites by means of radio signals with a very precise time scale. A minimum of three perfect distance measurements from satellites is theoretically required to determine an earth location in three dimensions. GPS is using for various field studies. It is being used to optimize logging operations, forest fire distribution areas, mapping habitats for a variety of animal species, and miniaturized for using in radio collars for tracking animal movements, limnology and oceanography, environmental quality, archeology and paleontology. (9,10)

The total GPS configuration is com-prised of three distinct segments:

2.3.3.1 The Control Segment consists of five monitoring stations (Colorado Springs, Ascesion Island, Diego Garcia, Hawaii, and Kwajalein Island). Three of the stations (Ascension, Diego Garcia, and Kwajalein) serve as uplink installations, capable of transmitting data to the satellites, including new ephemerides (satellite positions as a function of time), clock corrections, and other broadcast message data, while Colorado Springs serves as the master control station. The Control Segment is the sole responsibility of the DoD who undertakes construction, launching, maintenance, and virtually constant performance monitoring of all GPS satellites.

2.3.3.2 The Space Segment consists of the Constellation of NAVASTAR earth orbiting satellites. The current Defence Department plan calls for a full constellation of 24 Block II satellites (21 operational and 3 in-orbit spares). The satellites are arrayed in 6 orbital planes, inclined 55 degrees to the equator. They orbit

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at altitudes of about 12000, miles each, with orbital periods of 12 sidereal hours (i.e., determined by or from the stars), or approximately one half of the earth's periods, approximately 12 hours of 3-D position fixes. The next block of satellites is called Block IIR, and they will provide improved reliability and have a capacity of ranging between satellites, which will increase the orbital accuracy. Each satellite contains four precise atomic clocks (Rubidium and Cesium standards) and has a microprocessor on board for limited self-monitoring and data processing. The satellites are equipped with thrusters which can be used to maintain or modify their orbits.

2.3.3.3 The User Segment is a total user and supplier community, both civilian and military. The User Segment consists of all earth-based GPS receivers. Receivers vary greatly in size and complexity, though the basic design is rather simple. The typical receiver is composed of an antenna and preamplifier, radio signal microprocessor, control and display device, data recording unit, and power supply. The GPS receiver decodes the timing signals from the 'visible' satellites (four or more) and, having calculated their distances, computes its own latitude, longitude, elevation, and time. This is a continuous process and generally the position is updated on a second-by-second basis, output to the receiver display device and, if the receiver display device and, if the receiver provides data capture capabilities, stored by the receiver-logging unit.

There are several different methods for obtaining a position using GPS. The method used depends on the accuracy required by the user and the type of GPS receiver available. Broadly speaking, the techniques can be broken down into three basic classes:

- Autonomous Navigation using a single stand-alone receiver. Used by hikers, ships those are far out at sea and the military. Position Accuracy is about 20m.
- Differentially corrected positioning. More commonly known as DGPS, this gives an accuracy of between 0.5-5m. Used for inshore marine navigation, GIS data acquisition, precision farming etc.
-

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- Differential Phase position. Gives an accuracy of 0.5-20mm. Used for many surveying tasks, machine control etc.
-

2.4 Landsat-5 (TM)

The Landsat-5 was successfully launched on March 1, 1984. The TM (thematic mapper) scanner is an advanced that TM sensor records wide range of reflected/emitted electromagnetic energy in the visible, reflective-infrared, middle-infrared and thermal-infrared regions of the spectrum. TM has higher spatial, spectral and radiometric resolution than MSS

Landsat 5 has significantly exceeded its designed life expectancy, and has a maximum transmission bandwidth of 85Mbps. It was deployed at an altitude of 705.3 km, a lower orbit than Landsat 4. It takes some 16 days to scan the entire Earth. The satellite is an identical copy of Landsat 4, and was originally intended as a backup - it therefore carries the same instruments, including the Thematic Mapper (TM) Multi-Spectral Scanner (MSS) (11).

Table 2.2 Summary of TM sensor characteristics

Band	Resolution	Spectral definition	Some applications[a]
1	30 m	Blue, 0.45 - 0.52μm.	Penetration of clear water; bathymetry; mapping of coastal water; chlorophyll absorption; distinction between coniferous and deciduous vegetation
2	30 m	Green, 0.52 – 0.60μm.	Records green radiation reflected from healthy vegetation; assesses plant vigor; reflectance from turbid water
3	30 m	Red, 0.63 – 0.69μm.	Chlorophyll absorption important for plant-type discrimination
4	30 m	near infrared, 0.76 – 0.90μm.	Indicator of plant cell structure; biomass; plant vigor; complete absorption by water facilitates delineation of shorelines

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Table 2.2 Summary of TM sensor characteristics(continued)

Band	Resolution	Spectral definition	Some applications[a]
5	30 m	shortwave infrared, 1.55 – 1.75µm.	Indicative of vegetation moisture content; soil moisture mapping; differentiating snow from clouds; penetration of thin clouds
6	120 m	thermal-infrared, 10.40-12.50µm.	Vegetation stress analysis; soil moisture discrimination; thermal mapping; relative brightness temperature; soil moisture; plant heat stress
7	30 m	shortwave infrared, 2.08 – 2.35µm.	Discrimination of rock types; alteration zones for hydrothermal mapping; hydroxyl ion absorption

[a] Sample applications listed here; these are not the only applications.

Source: (11)

2.5 Statistic

2.5.1 Probability Theory

Probability (12) is a way of expressing knowledge or belief that an event will occur or has occurred, which compose

1. Sample Space 2. Sample Point

3. Event 4. Random Experiment

- Sample Space : In probability theory the sample space or universal sample space, often denoted S, Ω, or U (for "universe"), of an experiment or random trial is the set of all possible outcomes. For example, if the experiment is tossing a coin, the sample space is the set {head, tail}. For tossing a single six-sided die, the sample space is {1, 2, 3, 4, 5, 6}.

- Sample Point : is subset sample space refers to the set of all possible outcomes of an experiment that is random. If you toss a coin there are two possible

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outcomes: head (H) or tail (T). If you toss two coins, there are four outcomes: HH, HT, TH and TT, where the first letter refers to the outcome of the first tossing and the second to that of the second tossing. Each outcome is called a sample point.

- Event : is a subset of a sample space. If we want to list all sample points with the occurrence of at least one H, we have HH, HT and TH. Any events are called mutually exclusive if the occurrence of one event is independent of the occurrence of another event. For instance, if we got a head on one occasion, we could not simultaneously get a tail.

- Random Experiment : is an experiment, trial, or observation that can be repeated numerous times under the same conditions.The outcome of an individual random experiment must be independent and identically distributed. It must in no way be affected by any previous outcome and cannot be predicted with certainty.

$$\mathrm{P(E)} = \frac{n(E)}{n(S)}$$

When P(E) = probability

n(E) = number of event interest

n(S) = number of total random experiment

2.5.2 Sampling

Sampling is that part of statistical practice concerned with the selection of individual observations intended to yield some knowledge about a population of concern, especially for the purposes of statistical inference. Each **observation** measures one or more properties (weight, location, etc.) of an observable entity enumerated to distinguish objects or individuals. Survey weights often need to be applied to the data to adjust for the sample design. Results from probability theory and statistical theory are employed to guide practice. In business, sampling is widely used for gathering information about a population.

Non-Probability Sampling is any sampling method where some elements of the population have *no* chance of selection (these are sometimes referred to as 'out of coverage'/'undercovered'), or where the probability of selection can't be accurately determined. It involves the selection of elements based on assumptions

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regarding the population of interest, which forms the criteria for selection. Hence, because the selection of elements is nonrandom, nonprobability sampling does not allow the estimation of sampling errors. These conditions place limits on how much information a sample can provide about the population. Information about the relationship between sample and population is limited, making it difficult to extrapolate from the sample to the population.

1. Accidental Sampling is collect data by have no criterion.

2.Quota Sampling be groupwork specification follows to want by the proportion of assemble population group such as gender , education etc.

3. Purposive Sampling is the researcher uses the reason in the filtration population group for the suitability in the research.

2.5.3 Depth Interviews

Be the way in seeking data deep manner transfer by interviewing. Will the stimulation gave person interviewed show the though , belief , difficult attitude will can explain.

2.5.4 Questionnaire

A questionnaire is a research instrument consisting of a series of questions and other prompts for the purpose of gathering information from respondents. Although they are often designed for statistical analysis of the responses, this is not always the case. The questionnaire was invented by Sir Francis Galton. and type of Close ended question such as Check-list , Ranking question , Rating scale.

1. Check-list is each question has will answer choice since , 2 the choice goes up question some s might choose can answer just one choice but , question some might choose can answer 2 more than the choice

2.Ranking question be wants to give person answer add the number arranges the answer from importance too much froms a little by begin add since 1,2,3,4,5,6...N respectively.

3.Rating scale be wants to give person answer assess a question comes out to are scale level example the 3 scale level eg. high , moderate , less etc.

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2.5.5 Statistics analysis

Satistics analysis basically general base at should know eg. proportion analysis , average analysis which can apply to land use change.Descriptive statistics are used to describe the main features of a collection of data in quantitative terms.

Descriptive statistics are distinguished from inferential statistics or inductive statistics, in that descriptive statistics aim to quantitatively summarize a data set, rather than being used to support inferential statements about the population that the data are thought to represent. Even when a data analysis draws its main conclusions using inductive statistical analysis, descriptive statistics are generally presented along with more formal analyses, to give the audience an overall sense of the data being analyzed.

2.6 Mathematical Model

2.6.1 Markov Model

Markov-type model constitute some of historically most common method of predicting change among various categorical states. At their core is the mathematics of Markov chain, derived by the Russian Scientist Andrei A. Markov (1907). The first Markov model were not spatially explicit, but since the middle of last century the Markov model has been used to simulate change in map (13). Spatio-temporal Markov chain (STMC) models can be used to model changes over time among categories in a landscape, whereby each pixel on the landscape is classified as exactly as exactly one category, and each pixel has some probability of transitioning to some other category at every time step.

A finite first-order Markov process is a stochastic process {Xt, t ∈ T} with index set T = {0, 1, 2, …} and a finite state space $N = \{1, 2, \ldots, N\}$, which has the following Markov property:

$$P\{X_t=j|X_{t-1}=i,\ X_{t-2}=i_{t-2}, \ldots,X_0=i_0\}=P\{X_t=j|X_{t-1}=i\}$$

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for all t and all possible states j, i, i_k ($k = 0, 1, \ldots, t-2$). This means that the probability of the random variable X being in state j at time t depends only on the variable's state i at time $t-1$, and not on states at previous points in time.

If the transition probabilities $p_{ij}(t) = P\{X_t = j | X_{t-1} = i\}$ are independent of time t, then the Markov chain is said to be time stationary (time homogeneous). In this event:

$P_{ij}(t) = p_{ij}, \; t \Subset T$

A time-stationary Markov chain is completely determined by the Markov transition matrix P:

$$p = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1N} \\ p_{21} & p_{22} & \cdots & p_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ p_{N1} & p_{N2} & \cdots & p_{NN} \end{bmatrix}, \sum_{j=1}^{N} p_{ij} = 1$$

and the initial distribution $s(0) = (s_1(0), s_2(0), \ldots, s_N(0))$, $\sum_i s_i(0)=1$. As the time-stationary Markov chain advances in time, the distribution after the mth transition period is

$$s(m+1) = s(m)\boldsymbol{P}$$

When a sufficiently large number steps of transition occurred, $s(t)$ reaches the limiting distribution $s^* = \lim_{m\to\infty} s(0)P^m$, which is independent of the initial distribution.

If a Markov train is time stationary and the order is set, the transitional probabilities can be estimated through the maximum likelihood estimation. This estimation is obtained by maximizing the maximum likelihood function subject to the constraint that $\sum_j p_{ij} = 1$, and this yields

$$\hat{p}_{ij} = \frac{n_{ij}}{n_i} = \frac{n_{ij}}{\sum_{t=1}^{T} n_i(t-1)} = \frac{\sum_{t=1}^{T} n_{ij}(t)}{\sum_{t=1}^{T} \sum n_{ij}(t)}$$

where n_{ij} is the total number of observed cells from category i to j over all transition periods, n_i is the total number of cells transiting from category i over the all transition periods, $n_i(t-1)$ is the total number of cells transiting from category i during the tth transition period, $n_{ij}(t)$ is the number of cells transiting from category i

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to *j* in the *t*th transition period (14). This estimate is just the relative frequency of transitions observed over the entire time period.

2.6.2 Cellular Automata

Cellular Automata (16) are discrete dynamical systems and are often describe continuous dynamical systems. The meaning of “discrete” is that space, time and properties of the automata can have only a finite, countable number of states. The basic idea behind cellular automata is not to try to describe a complex system by using difficult equation, but simulating this system by interaction of cells following easy rules.

2.6.2.1 A brief history

The history of CA dates back to the forties with Stanislas Ulam. This mathematician was interested in the evolution of graphic construction generated by simple rules.

The based of his construction was a two dimensional space divides into “cell”, a sort of grid. Each of these cells could have two states: ON or OFF. Starting from a given pattern, the following generation was determines according to neighborhood rules.

Game of life was invited by mathematician John Conway in 1970 and publicized by Martin Gardner in his “Mathematical Games” column in Scientific American. It’s probably the first application that introduce the world what exactly CA are Like Ulam’s cellular spaces, the game o f life is based a grid constitutes of cells. Life has only two states, 1 and 0, standing for "living" and "dead", respectively. The transition rule is also simple:

1. One inactive cell surrounded by three active cells becomes active (“it’s born”)
2. One active cell surrounded by 2 or 3 active cells remains active
3. In any other case, the cell “dies” or remains inactive.

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2.6.2.2 Element of Cellular Automata

Cellular Automata are composed of five elements as described below:

- **Cell Space (Lattice):**

The cell space is composed of individual cell. Theoretically, these cells may be in any geometric shape. Yet, most CAs adopts regular grids to represent such a space, which make CA very similar to a raster GIS.

- **Cell states:**

The states of each cell may represent any spatial variable, e.g., the various types of land use.

- **Time steps:**

A CA will evolve at a sequence of discrete time steps. At each step, the cells will be updated simultaneously based on transition rules.

- **Transition rules:**

These rules are the heart of a CA that guides its dynamic evolution. A transition rule normally specifies the states of cell before and after updating based on its neighborhood conditions.

- **Neighborhood:**

The neighborhood of cell may be many type depend on the number of its adjacent cell. We may classify the neighborhood into 2 types which are: Von Neumann neighborhood and Moor neighborhood. Described them as;

- The Von Neumann neighborhood: the middle of cell is influenced by all neighbors in the wind direction

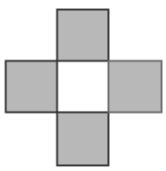

Figure 2.2 Von Neuman's neighborhood

Source : Vrije Universiteit, 2001

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- The Moor neighborhood: is an enlargement of the Von Neumann which the middle of cell is influenced by all neighbors even from diagonal direction

Figure2.3 Moor's neighborhood
Source : Vrije Universiteit, 2001

2.6.3 Series model

The Series Model (17) is used to build up from components to sub-assemblies and systems. It only applies to non replaceable populations (or first failures of populations of systems). The assumptions and formulas for the Series Model are identical to those for the Competing Risk Model, with the k failure modes within a component replaced by the n components within a system.

$$R_s = R_1(t) + R_2(t) + R_3(t) + R_4(t) + R_5(t)\ldots..R_n(t)$$

When R_s = Ratio of order
R_n = Possible different
t = Proportion series order

2.7 Accuracy Assessment

Land cover maps derived from remotely sensed data inevitably contain error of various types and degrees. It is therefore very important that the nature of these errors be determined, in order for both users and producers of the maps to be able to gauge their appropriateness for specific uses. In addition, identifying and correcting the sources of errors may increase the quality of map information. Classification accuracy assessment is necessary for comparing the performance of various classification

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techniques, algorithms, or interpreters (18). Classification accuracy assessment is now recognized as a critical component of any mapping project.

Accuracy assessments (18) determine the quality of the information derived from remotely sensed data. Most quantitative methods to assess classification accuracy involve an error matrix built from the two data sets: 1) the classified map derived from remotely sensed data and 2) existing sources of reference information such as aerial photos which allow a means of time and cost-efficient error checking. In order to assess classification accuracy, there must be perfect or near perfect registration between the reference information and classified maps. An error matrix is a square array of numbers set out in rows and columns which express the number of sample units assigned to a particular category relative to the actual category or as verified on the ground or typically large scale (at least 1:12,000) color aerial photography (19). The columns normally represent the reference data, while the rows indicate the classification generated from the remotely sensed data. An error matrix is a very effective way to represent accuracy because the accuracy of each category is clearly described, along with both errors of inclusion (commission errors) and errors of exclusion (omission errors), as well as summary statistics for the entire matrix. (20,21,22)

Error of omission is the percentage of pixels that should have been put into a given class but were not. Error of commission indicates pixels that were placed in a given class when they actually belong to another. These values are based on a sample of error checking pixels of known land cover that are compared to classifications on the map. Errors of commission and omission can also be expressed in terms of user's accuracy and producer's accuracy. User's accuracy represents the probability that a given pixel will appear on the ground as it is classed (the percentage correct for a given column divided by the total for that column), while producer's accuracy represents the percentage of a given class that is correctly identified on the map (the percentage correct for a given row divided by the total for that row). Calculated the Accuracy Assessment percentages as follow;

$$\text{Overall Accuracy} = \frac{\text{sum of major diagonal tallies}}{\text{total number of samples}} \text{x } 100$$

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2.7.1 Kappa Coefficient

The Kappa coefficient is a measure of overall agreement of a matrix. In contrast to the overall accuracy the ratio of the sum of diagonal values to total number of cell counts in the matrix the Kappa coefficient takes also non-diagonal elements into account (23).

Developed by Cohen (24) the Kappa coefficient measures the proportion of agreement after chance agreements have been removed from considerations. Kappa increases to one as chance agreement decreases and becomes negative as less than chance agreement occurs. A Kappa of zero occurs when the agreement between classified data and verification data equals chance agreement (25).

The Kappa coefficient was introduced to the remote sensing community in the early 1980s (26) and has become a widely used measure for classification accuracy. It was recommended as a standard by Rosen_eld and Fitzpatrick-Lins (27).

Due to a typographical error in Congalton et al., (26) there has been some confusion about the correct computation of the Kappa coefficient. Hudson and Ramm (28) have clarified this confusion. Most articles cite Bishop et al. (29) as a source of formulation:

$$\hat{K} = \frac{N \sum_{i=1}^{r} X_{ii} - \sum_{i=1}^{r} X_{i+} + X_{+i}}{N^2 - \sum_{i=1}^{r} X_{i+} X_{+i}}$$

When r = number of rows and columns in error matrix,

N = total number of observations,

Xii = observation in row i and column i,

Xi+ = marginal total of row i, and

X+i = marginal total of column i.

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Qualitative classification of kappa values as degree of agreement

< 0 Less than chance agreement

0.01–0.20 Slight agreement

0.21– 0.40 Fair agreement

0.41–0.60 Moderate agreement

0.61–0.80 Substantial agreement

0.81–0.99 Almost perfect agreement

2.8 Relate research

Metin Senbil, Akimasa Fujiwara and Junyi Zhang (30) studied, a cellular automata model for landuse evolution is proposed based on discrete choice estimation of transition probabilities as cellular automaton rules. The model is estimated on the panel data (four time points) of a hypothetical city land use development. The model estimated is used to predict the future landuse patterns of the city. The results show that mixed logit model fits well to the cellular automaton, thus offers more extensive research based on real data.

Brown G., Pijanowski C. and Duh D.(31) studied to modeling land-cover change as a function of land-use change. they argue that, in order to model the link between socio-economic change and changes in forest cover in a region that is experiencing residential and recreational development and agricultural abandonment, land-use and land-cover change need to be represented as separate processes. Forest-cover change is represented here using two transition probabilities that were calculated from Landsat imagery and that, taken together, describe a Markov transition matrix between forest and non-forest over a 10-year period. Using a three-date land-use data set, compiled and interpreted from digitized parcel boundaries, and scanned aerial photography for 136 sites (c. 2500ha) sampled from the Upper Midwest, USA, they test functional relationships between forest-cover transition probabilities, standardized to represent changes over a decade, and land-use conditions and changes within sample sites. Regression models indicated that about 60% of the variation in the average forest-cover transition probabilities (i.e. from forest to non-forest and vice

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versa) can be predicted using three variables: amount of agricultural land use in a site; amount of developed land use; and the amount of area increasing in development.

Cheng and Messer (32) studied urban growth between 1949 and 1999 at Wuhan, the largest mega city in central China, using CA. With the assistance of topographic maps of 1993 and SPOT Pan/Xs images of 2000, they found that land cover change in the period of 1993-2000 was dominated by the strong spatial agglomeration of a few large-scale projects, which was over 60 % of total changes. As a consequence, the understanding of local growth process of each project is highly crucial to that of whole study area. Zukou, car manufacturing center, the largest project, is used as a case study for testing the methodology proposed. The influential factors include distance to major roads, distance to minor roads, distance to center, master planning, and physical constraints from water body. The cell size in this research is 100. They founded that CA models generated the accuracy of 55 %.

Sura (33). studied about Remote Sensing for the Prediction on Coastal Land Use change of Krabi Province, Thailand. Landsat Thematic Mapper (TM) 1990 and 2003 were used to classify coastal land use pattern of Krabi province. Markov Chain Model combine with Cellular Automata was chosen for coastal land use change prediction. The probabilities (between 0 and 1) were calculated by using the digital analysis of satellite imageries for land use types. They were generated to 4 groups; P00 (1- P01), P01 (transits from 0 to 1), P10 (transits from 1 to 0), and P11 (1-P10). Then, the first transition probabilities were calculated. Thus, the trend of their changes was determined by assigning an expected duration, variances and confidential interval. Finally, the Cellular Automata was analyzed based upon neighborhood condition of 5 x 5 matrices. The result shows that, from 1990 to 2003, the area of Para rubber plantation, mangrove forest, and tropical rain forest are obviously decreased. Meanwhile, others area, oil palm plantation, and opened area are obviously increased. The land used change prediction for the year 2013, based on the data of 2003, shows that Para rubber plantation, tropical rain forest, and mangrove forest are still decreased, meanwhile others area, oil palm plantation, and opened area are increased.

Usawadee (2).studied about of Geo-informatics and models for land use change prediction in Krabi Province. The result from the study of changing land use

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from the year 1990 to 2000 as based for prediction land use in 2004 that analyzed by using CA-Markov model. The result shown that the land use pattern in 2004 were mainly classified as Para Rubber with the area of 2,12.36 square kilometers. Meanwhile the other were included oil palm plantation, moist evergreen forest, mangrove forest, agriculture land, miscellaneous land, aquaculture pond, urban and built-up area, and water body with the area about 1,060.19, 695.10, 394.24, 283.66, 97.54, 75.86, 65.27 and 22.8 square kilometers respectively. The accuracy of prediction land use of Krabi Province using CA-Markov has shown the overall accuracy of 74.83% and Kappa Index of 0.629. Thus, this process has been accepted.

Aingorn (1).studied about Application of Geo-informatics and models for land use change prediction in Nan Province. The result from the study of changing land use from the year 1990 to 2005 indicated that mixed deciduous forests had the most land reduction and field crops or upland crop increased the most areas as a result from decreasing forest areas as well as forecasting land use through of CA_Markov and Regression Models. Findings from predicting for the year 2010 suggested land use occurred mostly with mixed deciduous forests and field crops or upland crop. Testing accuracy of predicting in land use through the model CA_Markov in the year 2000 showed the accuracy of 82.12% and Kappa Index as equal as 0.78%. this process has been accepted.

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CHAPTER III
MATERIALS AND METHODS

This study was applied the Geographic Information System (GIS), Remote Sensing (RS), and Global Positioning System (GPS) to classify land use patterns and changes. CA-Markov and CA-Social Models were used to predict land use changes in Central Petchaburi Watershed, Thailand.

3.1 Materials

The hardware and software utilized in this study are as the following:

Personal computer

- GPS Receiver
- Digital Camera
- Printer
- Image Analysis software: Erdas Imagine 8.6
- GIS software: ArcViewGIS 3.3 and ArcGIS 9.2
- Microsoft Office 2007
- Operation System: WindowsXP Home

3.1.1 Data Sources

The main data sources are LANDSAT-5TM satellite imageries which are the main basis of this study. Table 3.1 shows the data attribute and accessing period.

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Table 3.1 Data sources for the study

Raster Image					
Data	Path/Row	Bands	Resolution	Date	Source
Landsat 5 TM	129/51, 130/51	3,4,5	25x25 m.	May 2003	GISTDA*
Landsat 5 TM	129/51, 130/51	3,4,5	25x25 m.	May 2008	GISTDA*
Vector Data					
Data	Type	Scale	Date	Source	
GIS database of Petchburi Province and Ratchaburi Province.	Point, Line, Polygon	1:50,000	2008	DEQP**	

Remark *GISTDA (Geo-Informatics and Space Technology Development Agency Public Organization)
**DEQP (Department of Environment Quality Promotion)

3.2 Methods

The process of this study is separated into 4 steps including; land use classification, land use change identification, prediction of land use change and comparison of the prediction models as shown in Figure 3.1.

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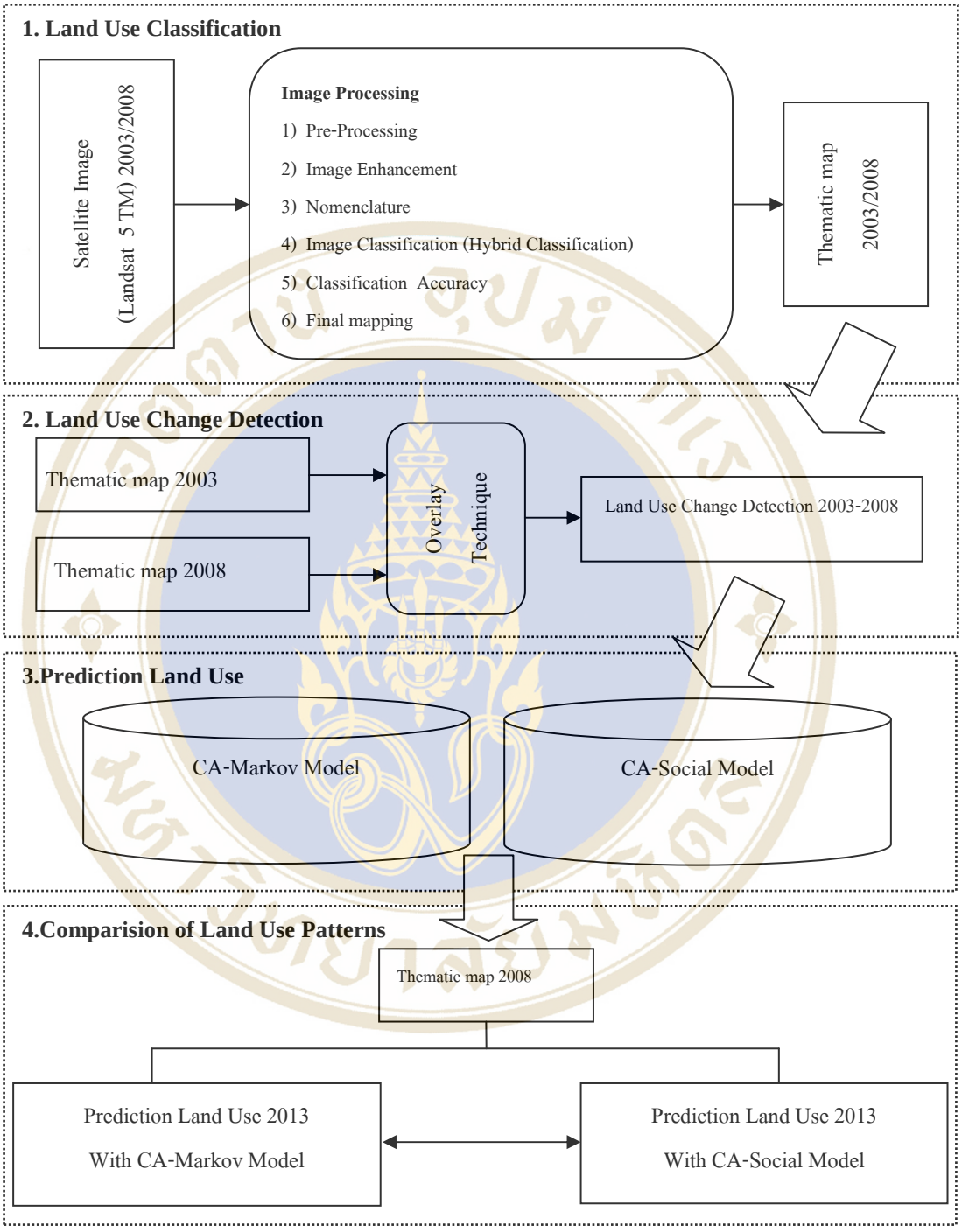

Figure 3.1 Study diagram

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3.2.1 Land use classification

The land use in the years 2003 and 2008 were classified using satellite imageries, LANDSAT- 5 TM. The land use was classified into 7 patterns. As shown in Table 3.2.

Tabel 3.2 Land use nomenclatures and categories

No	Symbol	Name	Definition
1	A1	Paddy Field	Abandoned, Transplanted, Broadcasted
2	A2	Field Crop	Mixed, Corn, Sugarcane, cassava, Pineapple, Tobacco, ect.
3	A4&A5	Orchard/Horticulture	Mixed, Orange, Lemon, Banan, Longan, Langsat
4	F	Forest land	Evergreen Forest,Mixed Deciduous Forest, Dipterocarp Forest
5	F100&F 200	Disturbed/Secondary Forest	Disturb Evergreen Forest,Disturb Mixed Deciduous Forest, Disturb Dipterocarp Forest
6	U	Urban/Built up land	Village, Air Port, Golf Course, Factory Park
7	W	Water bodies	Natural Water Body, Reservoir

The land use patterns in Central Petchaburi Watershed were classified using hybrid classification (both visual and computer assisted interpretation). The procedures are as follow.

3.2.1.1 Pre-Processing

LANDSAT-5 TM, used in this study, was prepared and verified by radiometric, atmospheric, and geometric corrections for strip or noise reducing and geometric position acquisition. In general, radiometric and atmospheric corrections were already processed by Geo-informatics and Space Technology Development Agency (GISTDA). In the geometric correction of the study, the co-register by image-to-image method was utilized. Map projection was Universal Transverse Mercator (UTM) zone 47, Everest spheroid and Word Geodetic System1984 datum (WGS1984). Acceptable root mean square error was not over 1.0 pixel (25meters in real distance). Then, the study area was subset from the mosaic images.

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3.2.1.2 Image Enhancement

Image enchantment was an addition process of image contrast for easier interpretation. The enchantment of this study was false color composite band 4-5-3 (R-G-B) and contrast stretching.

3.2.1.3 Nomenclature

Nomenclature was the determination of image classification frame. The nomenclature of this study was referenced from Land Cover Classification System of Land Development in 1999.

3.2.1.4 Image Classification

The satellite imageries were classified using Hybrid Interpretation method. It was integrated visual and computer assisted interpretation approaches. It was firstly classified using unsupervised classification together with ISODATA Clustering Algorithm technique. The result was generated cluster of differentiation that cover main land use pattern in study area. Then supervised classification was run by Maximum Likelihood to classify 7 land use patterns.

3.2.1.5 Classification Accuracy

Classification Accuracy was calculated by confusion matrix accuracy method. That was compared the classification result with ground truth. Number of check point was calculated by binomial probability theory (Equation 3-1) (34) The overall accuracy (Equation 3-2) was accepted at not least than 80%.

$$N = \frac{Z^2 (p)(q\sim)}{E^2}$$ Equation 3-1

When N = Least number of checkpoint

Z = the standard score required for the desired level of confidence (e.g., 1.96 for 95% confidence, 2.58 for 99%,etc.) in the assessment

p = Accuracy probability of pixel

q~ = 100- p

E = Acceptable error in percent

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$$\text{Overall accuracy} = \frac{\sum_{i=1}^{k} n_{ii}}{n} \qquad \text{Equation 3-2}$$

When n = number of checkpoint

3.2.1.6 Final mapping

The land use pattern from ground truth aspect was corrected, which call post classification step. The final land use map was then produced. Besides, the patch area less than 40,000 square meters was eliminated, based upon principle of mapping at the scale 1:50,000 (35).

3.3 Change detection of land use

3.3.1 The land use change in 2003 to 2008

was identified using an overlay technique. The output was captured into the GIS database as vector to overlay land map for all 2 years by using spatial analysis. Afterwards, calculation for land use area in each type and comparison in changing land use during the year 2003 to 2008 with the application of cross classification (34).

3.4 Land use prediction based on various models

3.4.1 Land use change prediction based on CA-Markov model

The Markov chain analysis was employed to define the probabilities aspect for the prediction based upon land use change between the year 2003 and 2008. It was derived into the transition matrix to manipulate the predicted land use patterns in 2013. Unfortunately, the output of Markov chain analysis could be identified only within the total number of predicted change. Thus, the cellular automata were then utilized to identify in term of the spatial data format. The pixel based analysis of cellular automata was employed with the 5 x 5 matrices. The nearest neighborhood theory was analyzed based on probabilities and transition values of Markov chain procedure. Then, the land use pattern in each pixel could be classified. Thus, the predicted land use change map could be produced.

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3.4.2 Land use prediction based on CA-Social model

The in-depth interview was employed for data gathering directly to the various stake holders concerned with the land use patterns occurred within the study area. They were included the representative from governmental and non-governmental organization, private sector and local people. The attitude and trend of land utilization in 2013 from those target groups were clarified. It was then transformed into probabilities of changes using series order analysis. The value number would be defined according to the weighting score for each land use pattern assigned by each stake holders. For instances, the weighting score of field crop, paddy field, and orchard/horticulture were 3, 2, and 1 then the probabilities would de identified as 0.50, 0.33, and 0.17 respectively. Those probabilities were proposed to transition matrices and analyzed using cellular automata procedure similar to CA-Markov, which now called CA-Social model.

The land use changes in 2008 and 2013 were also analyzed using overlay technique and cross classification or cross tabulation analysis.

3.5 Comparison of land use change based on CA-Markov and CA-Social models

The predicted land use in 2013 derived from CA-Markov and CA-Social models would be compared using overlay technique and cross classification matrices. The Kappa Index was employed to identify the degree of agreement of those two datasets (27), based on the Equation 3-3.

$$\hat{K} = \frac{N\sum_{i=1}^{r} X_{ii} - \sum_{i=1}^{r} X_{i+} + X_{+i}}{N^2 - \sum_{i=1}^{r} X_{i+} X_{+i}}$$

Equation 3-3

When r = number of rows and columns in error matrix,

N = total number of observations,

Xii = observation in row i and column i,

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Xi+ = marginal total of row i, and

X+i = marginal total of column i.

Whereas qualitative classification of kappa values as degree of agreement are as following.

< 0 Less than chance agreement

0.01–0.20 Slight agreement

0.21– 0.40 Fair agreement

0.41–0.60 Moderate agreement

0.61–0.80 Substantial agreement

0.81–0.99 Almost perfect agreement

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CHAPTER IV
RESULTS AND DISCUSSION

The results of this study can be divided into 4 parts as following :

4.1 Land Use Classification of Central Petchaburi Watershed in 2003 and 2008.

4.2 Land Use Change in Central Petchaburi Watershed.

4.3 Prediction of Land Use Change in Central Petchaburi Watershed.

4.4 Comparison of Predicted Land Use Manipulated by CA-Markov and CA-Social

4.1 Land Use Classification of Central Petchaburi Watershed in 2003 and 2008

The land use in 2003 can be classified into 7 classes including forest land, filed crops, disturbed/secondary forest, orchard/horticulture, urban/built up land, paddy field, and water bodies, with the area of 617.50 km^2 (54.57%) , 340.79 km^2 (30.12%), 70.75 km^2 (6.25%), 68.04 km^2 (6.01%), 17.94 km^2 (1.59%),11.35 km^2 (1.00%) 5.14 km^2 (0.45%), as shown in Table 4.1 and Figure 4.1-4.2.

Meanwhile, the land use in 2008 can be also classified including forest land, filed crops, disturbed/secondary forest, orchard/horticulture, urban/built up land, water bodies, and paddy field, with the area of 550.17 km^2 (48.62%), 402.52 km^2 (35.57%), 71.77 km^2 (6.34%), 68.81 km^2 (6.08%), 20.03 km^2 (1.77%),11.46 km^2 (1.01%), 6.75 km^2 (0.60%), as shown in Table 4.2 and Figure 4.3-4.4.

An accuracy of the classification was operated based upon ground truthing in 2008 of 306 sample points. The confusion error matrix was employed for the analysis. It was found that an overall accuracy was about 87.85%.

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Table 4.1 Land use in central Petchaburi watershed in 2003 and 2008

Land use	Year 2003		Year 2008	
	Km^2	%	Km^2	%
Paddy field	11.35	1.00	6.75	0.60
Field Crops	340.79	30.12	402.52	35.57
Orchards and Horticulture	68.04	6.01	68.81	6.08
Forest Land	617.50	54.57	550.17	48.62
Rehabilitate Forest	70.75	6.25	71.77	6.34
Urban and build-up Land	17.94	1.59	20.03	1.77
Water bodies	5.14	0.45	11.46	1.01
Total area (km^2)	1,131.51	100.00	1,131.51	100.00

Source: Analysis

Table 4.2 Confusion matrix of land use by hybrid classification and ground truth

		Land Use by Ground Truth								
		Paddy field	Field Crops	Orchards and Horticulture	Forest Land	Rehabilitate Forest	Urban and build-up Land	Water bodies	Row Total	User's Accuracy (%)
Land Use by Hybrid Classification	Paddy field	41	5	5	0	0	0	0	51	80.39
	Field Crops	5	77	4	0	3	0	0	89	86.52
	Orchards and Horticulture	9	0	15	0	0	0	0	24	62.50
	Forest Land	0	0	0	46	0	0	0	46	100.0
	Disturbed Forest	0	4	0	0	59	0	0	63	93.65
	Urban and build-up Land	0	3	0	0	0	7	0	10	70.00
	Water bodies	0	0	0	0	0	0	23	23	100.0
Column Total		55	89	24	46	62	7	23	306	
Producer's Accuracy (%)		74.55	86.52	62.50	100.0	95.16	100.0	100.0		

Source: Analysis

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Note: Overall accuracy $= \frac{\sum_{i=1}^{k} n_{ii}}{n}$

$= ((41+77+15+46+59+7+23) / 306)) \times 100 = 87.58\ \%$

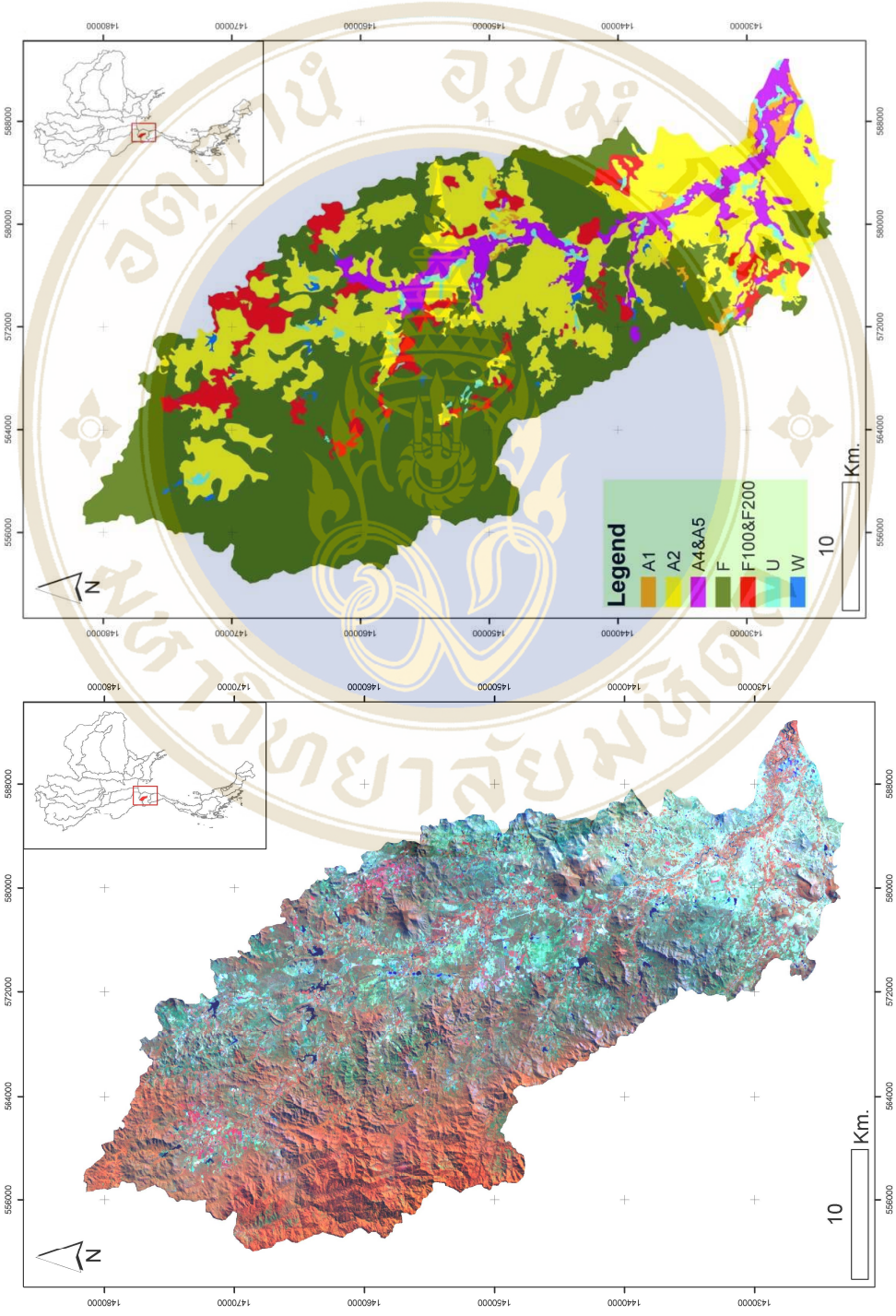

Figure 4.1 Landsat-5 TM image of Central Petchaburi Watershed, 2003

Figure 4.2 Land use in Central Petchaburi Watershed, 2003

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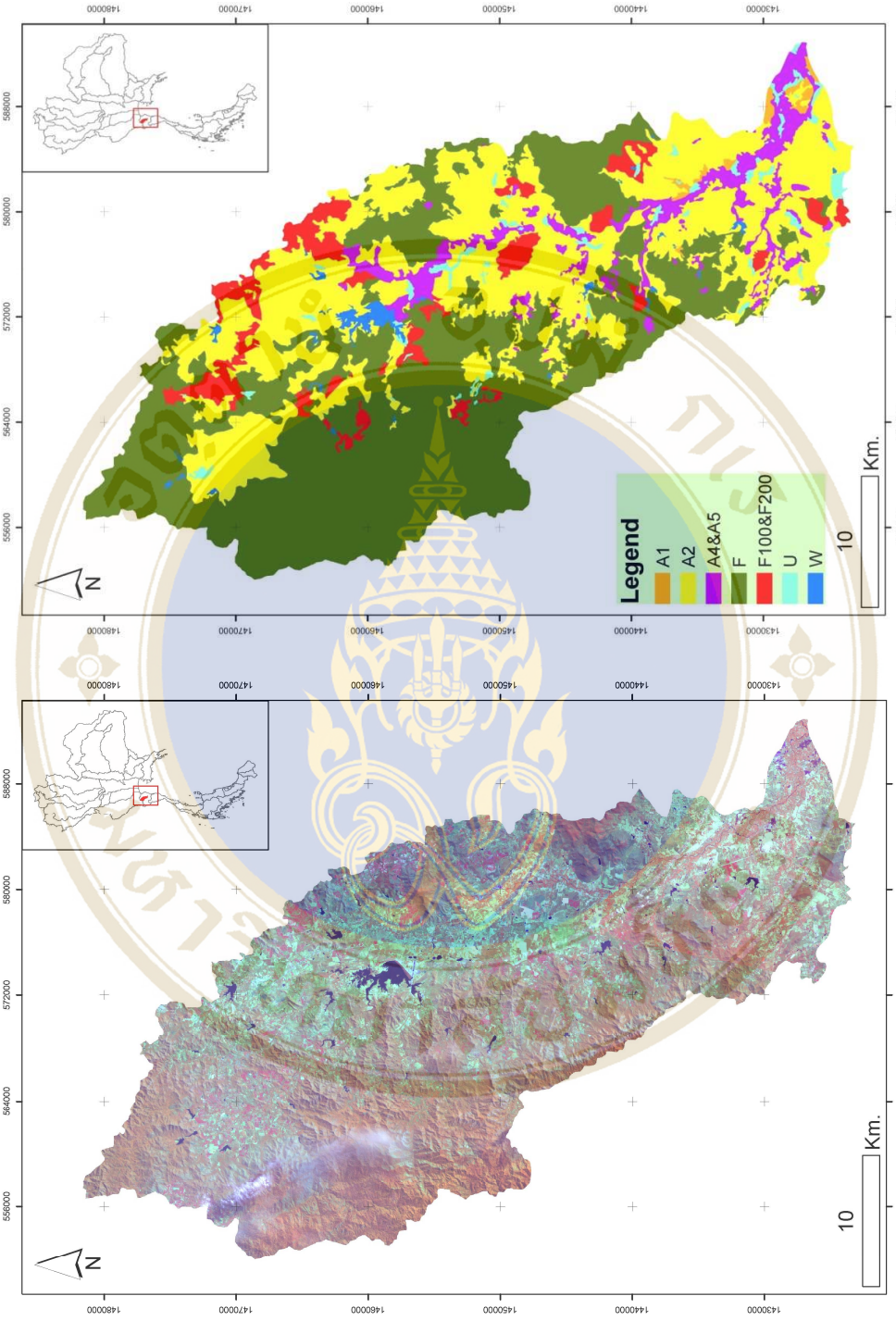

Figure 4.3 Landsat-5 TM image of Central Petchaburi Watershed, 2008

Figure 4.4 Land use in Central Petchaburi Watershed, 2008

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4.2 Land Use Change in Central Petchaburi Watershed

The land use change in central Petchaburi watershed between 2003 and 2008 can be clarified as following as shown in Table 4.3 , Table 4.4 , and Figure 4.5.

Paddy field was decreased about 4.60 km^2 or 40.52% of former area. It has been changed to field crops (4.06 km^2) and orchard/horticulture (1.98 km^2).

Field crops was increased about 62.01 km^2 or 18.21% of former area. It has been changed into the area of forest land, disturbed/secondary forest, orchard/horticulture, paddy field, and water bodies with the area of 46.04, 16.08, 13.20, 4.06, and 0.64 km^2 respectively.

Orchard/horticulture was increased about 0.77 km^2 or 1.13% of former area. It has been changed into the area of field crops, disturbed/secondary forest, paddy field, and forest land, with the area of 6.69, 5.15, 1.98, and 0.63 km^2 respectively.

Forest land was decreased about 67.80 km^2 or 10.97% of former area. It has been changed to the area of field crops, disturbed/secondary forest, orchard/horticulture, urban/built up land, and water bodies, with the area of 46.04, 21.43, 0.63, 0.38, and 0.22 km^2 respectively.

Disturbed/secondary forest was increased about 0.09 km^2 or 1.44% of former area. It has been changed into the area of forest land, field crops, and water bodies, with the area of 21.43, 1.66, and 0.13 km^2 respectively.

Urban/built up land was increased about 2.10 km^2 or 11.71% of former area. It has been changed into the area of field crops, forest land, and orchard/horticulture, with the area of 2.09, 0.38, and 0.19 km^2 respectively.

Water bodies was increased about 6.50 km^2 or 131% of former area, since the reservoir has been constructed. It has been changed into the area of field crops, forest land, and urban/built up land, with the area of 6.52, 0.2, and 0.59 km^2 respectively.

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Table 4.3 Changes in areas of different land use types in Central Petchaburi Watershed, 2003–2008

Land use	Area (Square kilometers)			
	Year 2003	Year 2008	Land use change	Percent of land use change
Paddy field	11.35	6.75	-4.60	40.52
Field Crops	340.51	402.52	62.01	18.21
Orchards and Horticulture	68.04	68.81	0.77	1.13
Forest Land	617.97	550.17	-67.81	10.97
Disturbed Forest	70.75	71.77	1.02	1.44
Urban and build-up Land	17.93	20.03	2.10	11.71
Water bodies	4.96	11.46	6.50	131.04
Total	1,131.51	1,131.51	144.81	

Source: Analysis

Remarks: Changing with positive value (+) is defined as increasing area and changing with negative value (-) is defined as decreasing area

Table 4.4 Land use change matrix of Central Petchaburi watershed, in 2003 – 2008

Year 2008 / Year 2003	A1	A2	A4&A5	F	F100&F200	U	W	Total area
A1	5.30	4.06	1.98	0.00	0.00	0.00	0.00	11.35
A2	1.09	322.46	6.69	0.00	1.66	2.09	6.52	340.51
A4&A45	0.36	13.20	54.29	0.00	0.00	0.19	0.00	68.04
F	0.00	46.04	0.63	549.27	21.43	0.38	0.22	617.97
F100&F200	0.00	16.08	5.15	0.90	48.55	0.07	0.00	70.75
U	0.00	0.03	0.01	0.00	0.00	17.30	0.59	17.93
W	0.00	0.64	0.06	0.00	0.13	0.00	4.14	4.96
Total area	6.75	402.52	68.81	550.17	71.77	20.03	11.46	1,131.51
Difference area	-4.60	+62.01	+0.77	-67.8	+1.02	+2.1	+6.5	

Source: Analysis Unit: km^2

Remark: A1 = Paddy Field A2 = Field Crop

A4&A5 = Orchards and Horticulture F = Forest Land F100&F200 = Disturbed Forest

U = Urban and build-up Land W = Water bodies

Symbol “+” = Increase areas Symbol “-” = Decrease areas

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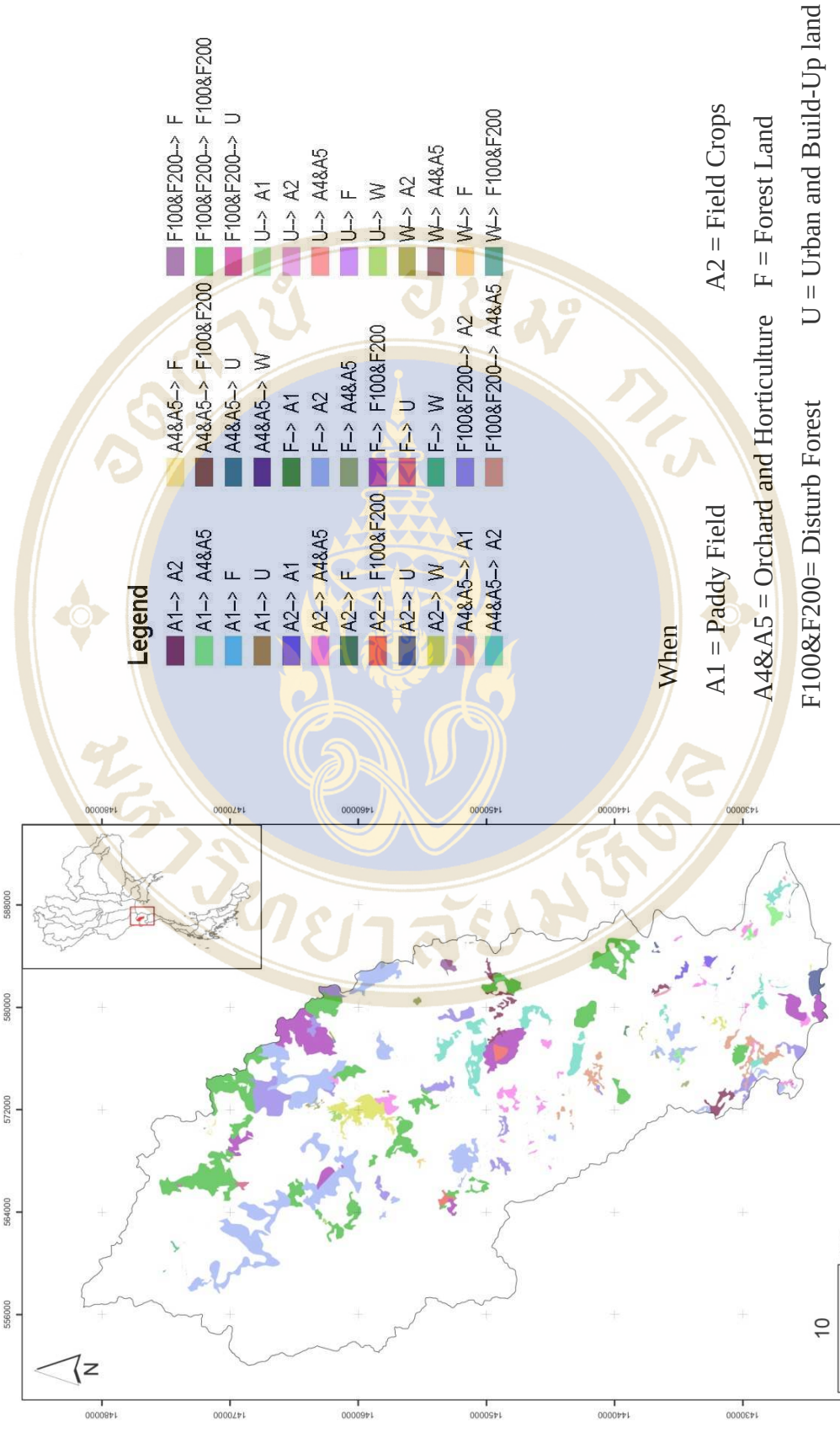

Figure 4.5 Land use changes of Central Petchaburi Watershed between 2003 and 2008

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4.3 Prediction of Land Use Change in Central Petchaburi Watershed

The prediction models using in this study are including CA-Markov and CA-Social, to define land use in 2013. The result for each model can be defined as following.

4.3.1 Prediction of land use in change 2013 using CA-Markov model

The land use change between 2003 and 2008 was manipulated to identify probability for being changed and transformed in 2013. The transition probabilities are shown in Table 4.5. Then, the cellular automaton was employed to classify land use pattern in each pixel using transition probabilities from Markov manipulation. The land use in 2013, which already transformed into vector format, is shown in Table 4.6 and Figure 4.6. The forest land has been covered with an area of 479.44 km^2 (42.39%). Meanwhile, field crops, orchard/horticulture, disturbed/secondary forest, urban/built up land, water bodies, and paddy field have been gradually covered with the area of 453.80 km^2 (40.12%), 75.58 km^2 (6.68%), 68.52 km^2 (6.06%), 26.00 km^2 (2.30%), 20.67 km^2 (1.83%), and 7.00 km^2 (0.62%) respectively.

Table 4.5 Transitional probabilities manipulated from Markov model based upon change of land use between 2003 to 2008

Year 2008 / Year 2003	A1	A2	A4&A5	F	F100&F200	U	W
A1	0.4202	0.3886	0.1905	0.0000	0.0000	0.0004	0.0000
A2	0.0088	0.8516	0.0541	0.0023	0.0134	0.0170	0.0528
A4&A5	0.0074	0.2705	0.7180	0.0001	0.0001	0.0040	0.0000
F	0.0000	0.1341	0.0018	0.7999	0.0624	0.0011	0.0006
F100&F200	0.0000	0.2770	0.0887	0.0155	0.6176	0.0012	0.0000
U	0.0004	0.0072	0.0023	0.0000	0.0000	0.8675	0.1210
W	0.0000	0.1750	0.0158	0.0490	0.0361	0.0000	0.7241

Source: Analysis

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Table 4.6 Predicted land Use in 2013 based on CA-Markov Model

Land use	Area in Year 2013 by CA-Markov model	
	Square kilometers	Percent
Paddy Field	7.00	0.62
Field Crops	453.80	40.12
Orchard and Horticulture	75.58	6.68
Forest land	479.44	42.39
Disturbed Forest	68.52	6.06
Urban and Build-up area	26.00	2.30
Water bodies	20.67	1.83
Total	1,131.02	100.00

Source: Analysis

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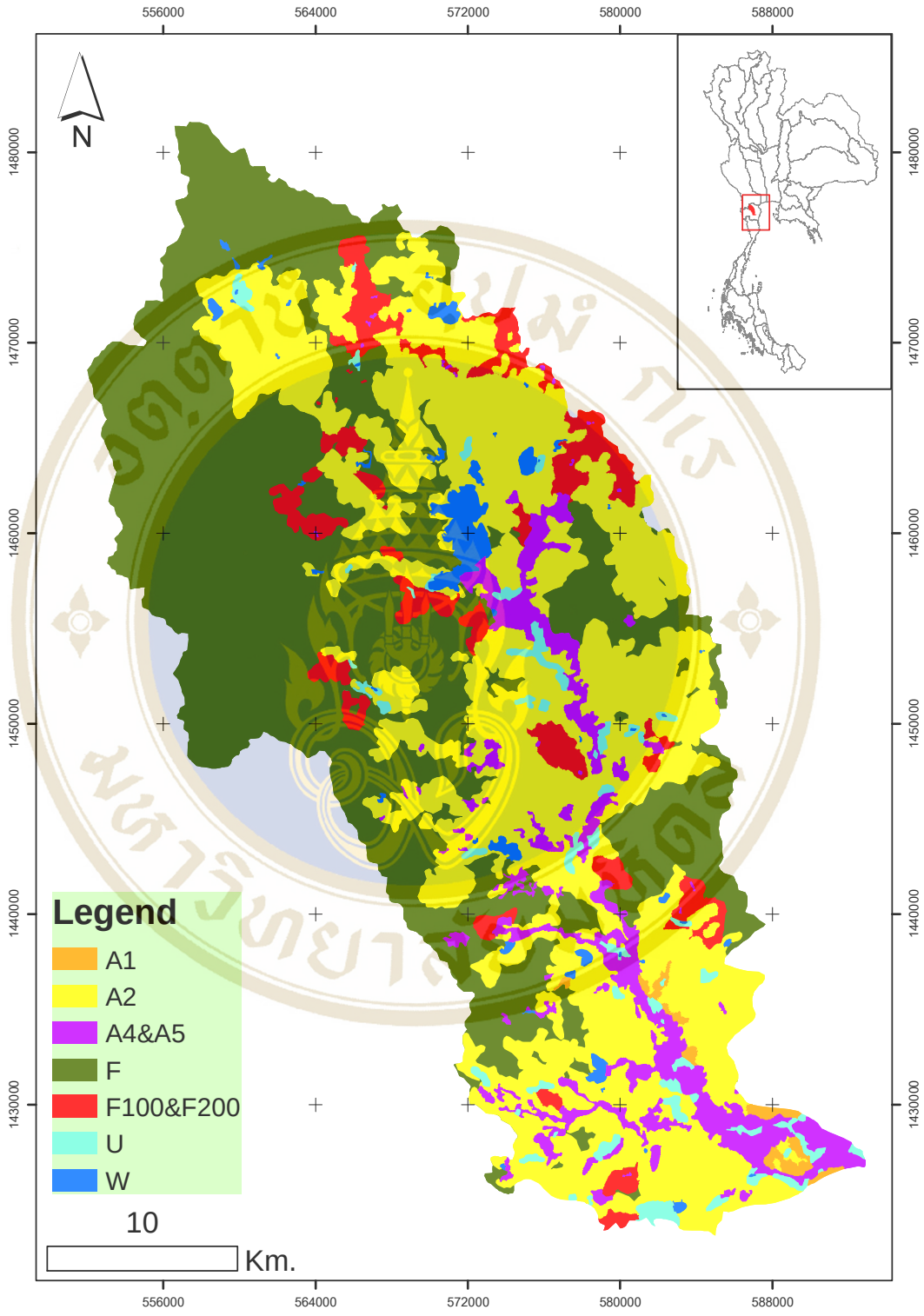

Figure 4.6 Predicted land use in 2013 based on CA-Markov analysis

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4.3.2 Prediction of land use change in 2013 using CA-Social model

The probabilities to predict land use change in 2013, was gathered from various stake holders in the study area as shown in Table 4.7. Then, it was employed cellular automata to classify land use pattern in each pixel. The land use in 2013, operated by this matter, which already transformed into vector format, is shown in Table 4.8 and Figure 4.7. It was found that predicted land use in 2013 gradually consisted of forest land, field crops, orchard/horticulture, urban/built up land, water bodies, and paddy field with area of 623.99 km^2 (55.17%), 400.07 km^2 (35.37%), 68.31km^2 (6.04%), 20.16 km^2 (1.82%), 11.75 km^2 (1.04%), and 6.27 km^2 (0.55%). The disturbed/secondary forest area was no more existed.

Table 4.7 Transitional probabilities of change based on the decision of various stake holders in the study area

Year 20013 / Year 2008	A1	A2	A4&A5	F	F100&F200	U	W
A1	0.6875	0.0972	0.0000	0.0000	0.0000	0.1597	0.0000
A2	0.0000	0.8000	0.1333	0.0000	0.0000	0.0533	0.0133
A4&A5	0.0000	0.1633	0.7517	0.0000	0.0000	0.0340	0.0510
F	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000
F100&F200	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000
U	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
W	0.000	0.000	0.000	0.000	0.000	0.000	1.000

Source: Analysis

Remark: A1 = Paddy Field A2 = Field Crops
A4&A5 = Orchard and Horticulture F = Forest land
F100&F200 = Disturbed Forest U = Urban and Build-up land
W = Water bodies

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Table 4.8 Predicted land Use in 2013 based on CA-Social Model

Land use	Area in Year 2013 by CA-Social model	
	Square kilometers	Percent
Paddy Field	6.27	0.55
Field Crops	400.07	35.37
Orchard and Horticulture	68.31	6.04
Forest land	623.99	55.17
Disturbed Forest	0.00	0.00
Urban and Build-up area	20.61	1.82
Water bodies	11.75	1.04
Total	1,131.02	100.00

Source: Analysis

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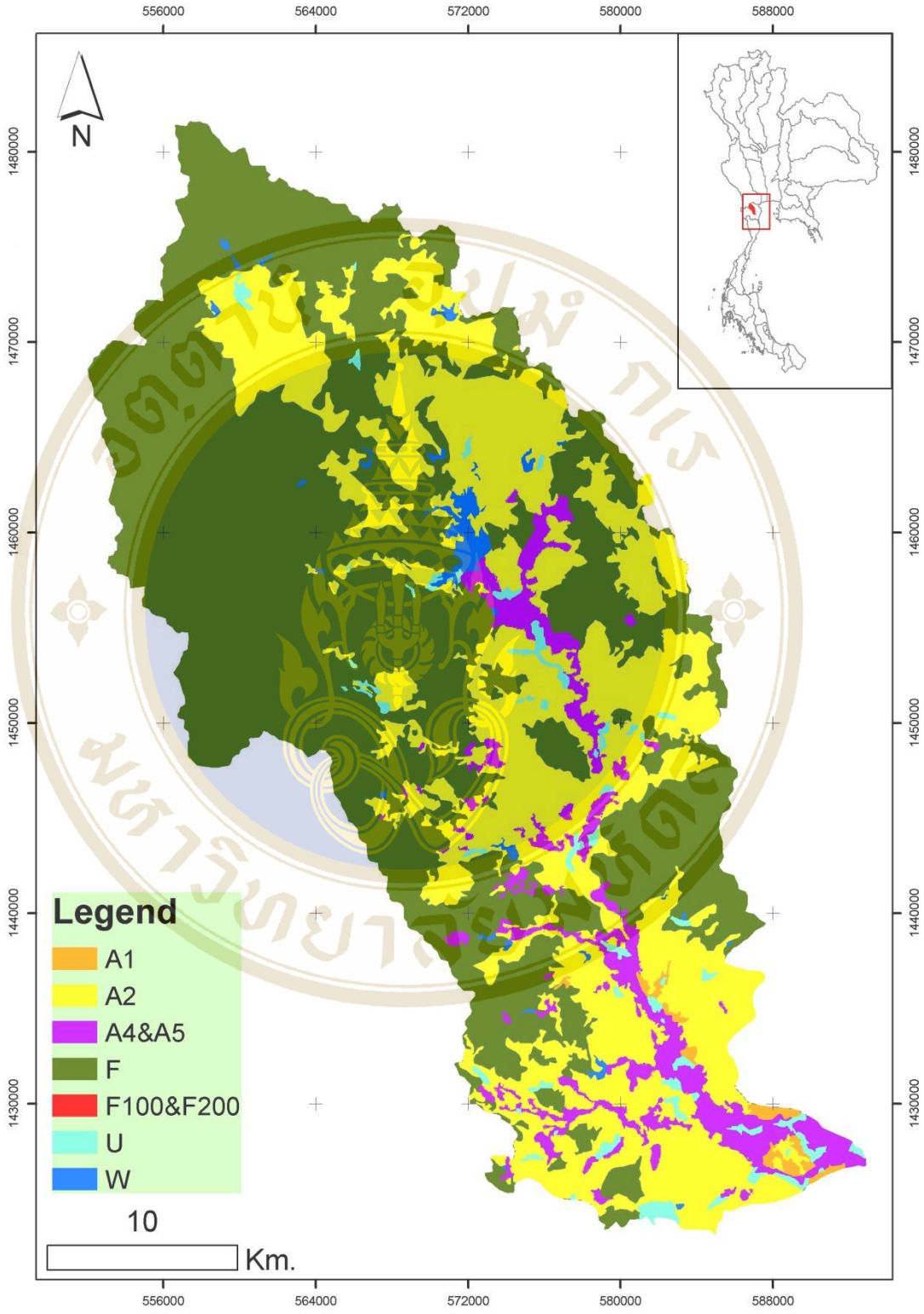

Figure 4.7 Predicted land use in 2013 based on CA-Social analysis

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4.4 Land Use Change between 2008 and 2013 based on CA-Markov Analysis

The land use change between 2008 and 2013 based on CA-Markov analysis has shown in Table 4.9 and Table 4.10.

The increased land use patterns were included water bodies, urban/built up land, field crops, orchard/horticulture, and paddy field with the area of 9.21 km^2 (80.37%), 5.97 km^2 (29.81%), 51.43 km^2 (12.78%), 6.79 km^2 (9.87%), and 0.27 km^2 (4.01%) respectively. Most of the water bodies area was increased with a high number since the dam had been constructed within the study period. It was gradually changed into field crops, urban/built up land, and forest land with the area of 8.98, 0.92, and 0.06 km^2 respectively. The urban/built up land was gradually changed into field crops, orchard/horticulture, forest land, paddy field, and disturbed/secondary forest with the area of 6.92, 0.25, 0.04, 0.03 and 0.02 km^2 respectively. The field crops were gradually changed into forest land, disturbed/secondary forest, orchard/horticulture, water bodies, and urban/built up land with the area of 57.92, 14.01, 0.36, 0.10 and 0.10 km^2 respectively. The orchard/horticulture was gradually changed into field crops, disturbed/secondary forest, paddy field, urban/built up land, forest land and water bodies with the area of 3.93, 2.33, 0.77, 0.21, 0.16 and 0.08 km^2 respectively. The paddy field was gradually changed into field crops and urban/built up land with the area of 1.04 and 0.03 km^2 respectively.

The forest land was decreased about 70.45 km^2 (12.81%), which changed to disturbed/secondary forest, orchard/horticulture, water bodies, and urban/built up land with the area of 57.92, 12.75, 0.16, 0.06, and 0.04 km^2 respectively. The disturbed/secondary forest was decreased about 3.21 km^2 (4.48%), which changed to field crops, orchard/horticulture, and urban/built up land with the area of 14.01, 2.33, and 0.02 km^2 respectively.

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Table 4.9 Land use change in central Petchaburi watershed between 2008 to 2013, based on CA-Markov analysis

Land use	Area (Square kilometers)			
	LU2008	LU2013 By CA-Markov	Land Use Change	Percent of Land Use Change
Paddy field	6.73	7.00	0.27	4.01
Field Crops	402.37	453.80	51.43	12.78
Orchards and Horticulture	68.79	75.58	6.79	9.87
Forest Land	549.90	479.44	-70.46	-12.81
Disturbed Forest	71.73	68.52	-3.21	-4.48
Urban and build-up Land	20.03	26.00	5.97	29.81
Water bodies	11.46	20.67	9.21	80.37
Total	1,131.02	1,131.02		

Source: Analysis

Remarks: Changing with positive value (+) is defined as increasing area and changing with negative value (-) is defined as decreasing area

Table 4.10 Matrix of land use change in central Petchaburi watershed, between 2008 – 2013 based on CA-Markov analysis

Year 2013 CA-Markov / Year 2008	A1	A2	A4&A5	F	F100&F200	U	W	Total area
A1	5.93	0.00	0.77	0.00	0.00	0.03	0.00	6.73
A2	1.04	381.49	3.93	0.00	0.02	6.92	8.98	402.37
A4&A45	0.00	0.36	68.09	0.09	0.00	0.25	0.01	68.79
F	0.00	57.92	0.16	478.96	12.75	0.04	0.06	549.90
F100&F200	0.00	14.01	2.33	0.00	55.36	0.02	0.00	71.73
U	0.03	0.01	0.21	0.07	0.06	18.73	0.92	20.03
W	0.00	0.01	0.08	0.32	0.33	0.00	10.71	11.46
Total area	7.00	453.80	75.58	479.44	68.52	26.00	20.67	1131.02
Difference area	0.27	51.43	6.79	-70.45	-3.21	5.97	9.21	

Source: Analysis Unit: km^2

Remark: A1 = Paddy Field A2 = Field Crop
A4&A5 = Orchards and Horticulture F = Forest Land F100&F200 = Disturbed Forest
U = Urban and build-up Land W = Water bodies
Symbol "+" = Increase areas Symbol "-" = Decrease areas

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4.5 Land Use Change between 2008 and 2013 based on CA-Social Analysis

The land use change between 2008 and 2013 based on CA-Social analysis has shown in Table 4.11 and Table 4.12.

The increased land use patterns were included forest land, urban/built up land, water bodies with the area of 74.09 km^2 (13.47%), 0.59 km^2 (2.93%), 0.29 km^2 (2.51%) respectively. Most of the forest land area was increased with a high number because decide probability as 1.00 of disturb forest to change into forest land within the study period. It was gradually changed into disturb forest, field crop, orchard/horticulture, water bodies, urban/built up land, and paddy field with the area of 71.46, 3.09, 0.43, 0.07, 0.05 and 0.05 km^2 respectively. The urban/built up land was gradually changed into field crops, orchard/horticulture, paddy field, forest land, disturbed/secondary forest and water bodies with the area of 0.62, 0.27, 0.13, 0.03, 0.02 and 0.01 km^2 respectively. The water bodies were gradually changed into field crop, forest land, orchard/horticulture, and urban/built up land with the area of 0.38, 0.07, 0.04 and 0.03 km^2 respectively.

The secondary/disturbed forest land was decreased about 71.73 km^2 (100%), which changed to forest land, field crop, urban/built up land and orchard/horticulture with the area of 71.46, 0.24, 0.02 and 0.01 km^2 respectively. The paddy field was decreased about 0.46 km^2 (6.58%), which changed to field crop, urban/built up land, orchard/horticulture and forest land with the area of 0.33, 0.13, 0.07 and 0.05 km^2 respectively. The orchard/horticulture was decreased about 0.48 km^2 (0.70%), which changed to field crop, forest land, urban/built up land, paddy field and water bodies with the area of 1.58, 0.43, 0.27, 0.4 and 0.4 km^2 respectively. The field crop was decreased about 2.30 km^2 (0.57%), which changed to forest land, paddy field, urban/built up land and water bodies with the area of 3.09, 1.4, 0.62 and 0.38 km^2 respectively.

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Table 4.11 Land use change in central Petchaburi watershed between 2008 to 2013, based on CA-Social analysis

Land use	Area (Square kilometers)			
	LU2008	LU2013 By CA-Social	Land Use Change	Percent of Land Use Change
Paddy field	6.73	6.27	-0.46	6.58
Field Crops	402.37	400.07	-2.30	0.57
Orchards and Horticulture	68.79	68.31	-0.48	0.70
Forest Land	549.90	623.99	74.09	13.47
Disturbed Forest	71.73	0.00	-71.73	100
Urban and build-up Land	20.03	20.61	0.59	2.93
Water bodies	11.46	11.75	0.29	2.51
Total	1,131.02	1,131.02		

Source: Analysis

Remarks: Changing with positive value (+) is defined as increasing area and changing with negative value (-) is defined as decreasing area

Table 4.12 Matrix of change in land use for Central Petchaburi Watershed , 2008 – 2013

Year 2013 / CA-Social / Year 2008	A1	A2	A4&A5	F	F100&F200	U	W	Total area
A1	6.15	0.33	0.07	0.05	0.00	0.13	0.00	6.73
A2	0.06	396.75	1.48	3.09	0.00	0.62	0.38	402.37
A4&A45	0.04	1.58	66.43	0.43	0.00	0.27	0.04	68.79
F	0.00	0.87	0.09	548.85	0.00	0.03	0.07	549.90
F100&F200	0.00	0.24	0.01	71.46	0.00	0.02	0.00	71.73
U	0.01	0.22	0.18	0.05	0.00	19.54	0.03	20.03
W	0.00	0.10	0.06	0.07	0.00	0.01	11.23	11.46
Total area	6.27	400.07	68.31	623.99	0.00	20.61	11.75	1131.02
Difference area	-0.46	-2.30	-0.48	74.09	-71.73	0.59	0.29	

Source: Analysis Unit: km^2

Remark: A1 = Paddy Field A2 = Field Crop

A4&A5 = Orchards and Horticulture F = Forest Land F100&F200 = Disturbed Forest

U = Urban and build-up Land W = Water bodies

Symbol “+” = Increase areas Symbol “-” = Decrease areas

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4.6 Comparison of Predicted Land Use Change Manipulated by CA-Markov and CA-Social analysis

The comparison of predicted land use change manipulated by CA-Markov and CA-Social analysis is shown in Table 4.13 and Table 4.14.

The different of land use was gradually occurred within water bodies, forest land, urban/built up land, field crops, paddy field, and orchard/horticulture with the area of 8.91 km^2 (43.11%), 144.55 km^2 (30.15%), 5.39 km^2 (20.73%), 53.73 km^2 (11.84%), 0.73 km^2 (10.43%), and 7.27 km^2 (9.62%) respectively.

The similarity of the outputs between CA-Markov and CA-Social was defined about 85 %. Meanwhile, the degree of agreement was defined as the substantial agreement (overall Kappa = 0.76). Thus, it was accepted that both models could be used for land use change prediction in central Petchaburi watershed.

Table 4.13 Comparative land use in 2013 between CA-Markov Model and CA-Social Model

Land use	Area (Square kilometers)			
	Year 2013 By CA-Markov Model	Year 2013 By CA-Social Model	Different areas	Percent of different areas
Paddy Field	7.00	6.27	0.73	10.43
Field Crops	453.80	400.07	53.73	11.84
Orchard and Horticulture	75.58	68.31	7.27	9.62
Forest land	479.44	623.99	144.55	30.15
Disturbed Forest	68.52	0.00	68.52	100.00
Urban and Build-up area	26.00	20.61	5.39	20.73
Water bodies	20.67	11.75	8.91	43.11
Total	1,131.02	1,131.02		

Source: Analysis

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Table 4.14 Difference matrix of predicted land use in 2013 between CA-Markov and CA-Social Model

		Land Use by CA-Markov model							
		Paddy field	**Field Crops**	**Orchards and Horticulture**	**Forest Land**	**Disturbed Forest**	**Urban and build-up Land**	**Water bodies**	**Row Total**
Land Use by CA-Social model	Paddy field	5.53	0.00	0.73	0.00	0.00	0.01	0.00	6.27
	Field Crops	1.29	379.22	4.41	0.00	0.02	6.53	8.60	400.07
	Orchards and Horticulture	0.00	0.71	67.33	0.07	0.00	0.19	0.01	68.31
	Forest Land	0.05	73.81	2.80	479.00	68.12	0.07	0.15	623.99
	Disturbed Forest	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Urban and build-up Land	0.13	0.04	0.24	0.06	0.05	19.20	0.90	20.61
	Water bodies	0.00	0.03	0.06	0.32	0.34	0.00	11.01	11.75
Column Total		7.00	453.80	75.58	479.44	68.52	26.00	20.67	1,131.02

Source: Analysis Unit: km^2

Overall similarity = 85.00% Overall Kappa = 0.76

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CHAPTER V
CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The Geo-Informatics together with CA-Markov and CA-Social models has been employed to identify and predict the land use change in central Petchaburi watershed, Thailand. The results can be concluded as follows:

5.1.1 The land use patterns in Central Petchaburi Watershed in 2003 and 2008

Land use in 2003 was classified into 7 categories including the forest land, water bodies, field crops, disturbed forest, orchards and horticulture, urban and build-up land, and paddy field with the area of 617.50 km^2 (54.57%), 5.14 km^2 (0.45%), 340.79 km^2 (30.12%), 70.75 km^2 (6.25%), 68.04 km^2 (6.01%), 17.94 km^2 (1.59%), and 11.35 km^2 (1.00%) respectively.

Land use in 2008 was classified into 7 categories including forest land, paddy field, field crops, disturbed forest, orchards and horticulture, urban and build-up land, and water bodies with the area of 550.17 km^2 (48.62%), 6.75 km^2 (0.60%), 402.52 km^2 (35.57%), 71.77 km^2 (6.34%), 68.81 km^2 (6.08%), 20.03 km^2 (1.77%), and 11.46 km^2 (1.01%) respectively.

The accuracy of land use in 2003 was identified using the former land use data of the Department of Land Development. Meanwhile, the accuracy of land use in 2008 was identified using confusion matrix analysis based on 306 point of ground checking. The overall accuracy was 87.58 % within the substantial agreement (Kappa = 0.64).

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5.2 Land use change between the years 2003 to 2008 in Central Petchaburi watershed

The absolute total areas of land use change in central Petchaburi watershed between 2003- 2008 was about 144.81 km^2. The water bodies were mostly increased about 6.50 km^2 (131%). Paddy field was decreased about 4.60 km^2 (40.52%). Field crop was increased about 62.01 km^2 (18.21%). Urban/Build-Up area was increased about 2.10 km^2 (11.71%). Forest land was decreased about 67.80 km^2 (10.97%). Disturbed forest was increased about 0.09 km^2 (1.44%). Orchards/Horticulture was increased about 0.77 km^2 (1.13%). The water bodies had been increased based upon irrigated dam construction in 2006 by Royal Irrigation Department.

5.3 Predicted of land use in 2013 based on various models

The land use prediction in 2013 using CA-Markov model indicated the forest land, field crops, orchard/horticulture, disturbed forest, urban/ build-up area, water bodies, and paddy field with the area of 479.44 km^2 (42.39%), 453.80 km^2 (40.12%), 75.58 km^2 (6.68%), 68.52 km^2 (6.06%), 26.00 km^2 (2.30%), 20.67 km^2 (1.83%), and 7.00 km^2 (0.62%) respectively

The land use prediction in 2013 using CA-Social model indicated the forest land, field crops, orchard/horticulture, urban/build-up area, water bodies, and paddy field with the area of 623.99 km^2 (55.17%) 400.07 km^2 (35.37%), 68.31 km^2 (6.04%), 20.16 km^2 (1.82%), 11.75 km^2 (1.04%)%), 6.27 km^2 (0.55%) respectively. The disturbed forest was not existed since the attitude of local people provided through the conservation aspect for this area.

5.4 Comparison of land use prediction based on CA-Markov and CA-Social models

5.4.1 Land use change between the years 2008 to 2013 in Central Petchaburi watershed

The predicted land use in 2013 by CA-Markov model has shown the increasing area of water bodies (80.37%), urban/build up area (29.81%), filed crop (12.78%), orchard/horticulture (9.87%), paddy field (4%) respectively. Meanwhile, the

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decreasing area has been included the forest land (12.78%) and disturbed forest (4.48%) respectively.

The predicting land use in 2013 by CA-Social model has shown the increasing area of forest land (13.47%), urban/build up area (2.93%), and water bodies (2.51%) respectively. Meanwhile, the decreasing area has been included the disturbed forest (100.00%), followed by paddy field (6.58%), orchard/horticulture (0.70%), and field crop (0.57%) respectively.

5.4.2 Comparison the suitability of the two models

The CA-Markov and CA-Social models has shown the similarity index of about 85% which classified as substantial agreement (Kappa = 0.76). Thus, those two models could be possibly accepted. However, the manipulation of land use pattern in 2013 using CA-Markov model has been based upon the statistically changes of the two dataset. The change has been proposed on the stability aspect. Hence, it could not be coped with any serious changes which might be occurred during the two periods. Meanwhile, the land use pattern in 2013 manipulated by CA-Social has been provided based upon the attitude of the stake holders that sometimes also fluctuated in many areas. Therefore, it could be explained for the disturbed forest which no more existed since most of the stake holders attitude proposing not to utilized in this particular area, which might be doubted for the real practical aspect.

5.5 Recommendations

1. The land use classification should be considered to provide more procedure and models including Digital Elevation Model; DEM, Normalized Vegetation Index; NDVI, Bare Soil Index; BI, Water Index; WI. In addition, the dataset of GIS database from various sources for example, the Royal Forest Department, Land Development Department and so fall should be provided for the better classification.

2. The better resolution of satellite imageries more than 25 meters would be appreciated. The product from various sources as Quick Bird, IKONOS, Sport and Theos should be considered to induce for the better classification and accuracy.

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3. The land use prediction should be integrated physical and human factor to cope with various phenomenon such as risk area of drought , flood , landslide , storm and government policy and watershed classification etc. for the better identification and accuracy.

4. The attitude test for social model should be operated with an observatory approach to cope with the real practical manner of each stake holders which could be made the manipulation based upon the real situation within the study area.

5. The future studies should be coped with the political aspect such as policy on an agricultural extension which could be stimulated the activities of the local people in the specific land use pattern. Besides, an economical aspect such as market prices should be also considered.

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APPENDIX

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APPENDIX A

Questionnaire Form

No…….

แบบสอบถาม

ตำแหน่งทางภูมิศาสตร์ x…… , y…… (UTM WGS1984 Zone47)

ที่ตั้ง……

ชื่อผู้ให้ข้อมูล……

การใช้ประเภทที่ดิน……..

การจัดอันดับประเภทการใช้ที่ดิน

ประเภทการใช้ที่ดิน	คะแนนอันดับ
-นาข้าว	
-พืชไร่	
-ไม้ผลและพืชสวน	
*-ป่าไม้	
*-ป่าเสื่อมโทรม/ป่าฟื้นฟู	
-ชุมชน/สิ่งปลูกสร้าง	
-แหล่งน้ำ	

Figure A.1 Questionnaire Form

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APPENDIX B

Probability by Markov and Social models

Table B.1 Transitional probabilities manipulated from Markov model based upon change of land use between 2003 to 2008.

Year 2008 / Year 2003	A1	A2	A4&A5	F	F100&F200	U	W
A1	0.4202	0.3886	0.1905	0.0000	0.0000	0.0004	0.0000
A2	0.0088	0.8516	0.0541	0.0023	0.0134	0.0170	0.0528
A4&A5	0.0074	0.2705	0.7180	0.0001	0.0001	0.0040	0.0000
F	0.0000	0.1341	0.0018	0.7999	0.0624	0.0011	0.0006
F100&F200	0.0000	0.2770	0.0887	0.0155	0.6176	0.0012	0.0000
U	0.0004	0.0072	0.0023	0.0000	0.0000	0.8675	0.1210
W	0.0000	0.1750	0.0158	0.0490	0.0361	0.0000	0.7241

Transitional probabilities manipulated from Markov model to show in figure B.1-B.7

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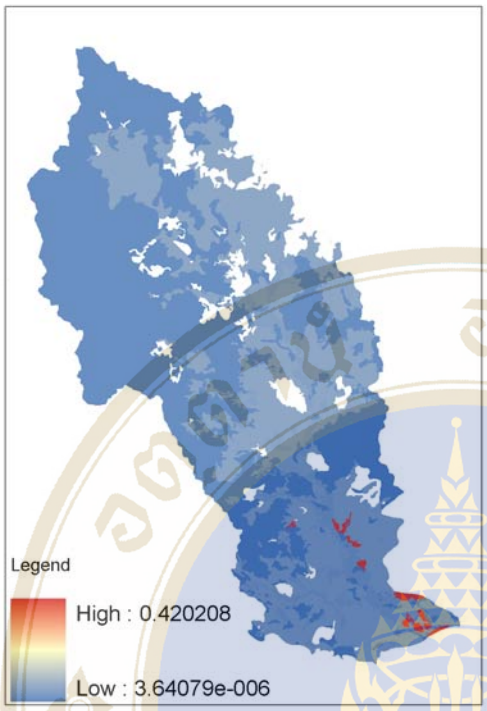

Figure B.1 Prob. of Paddy field

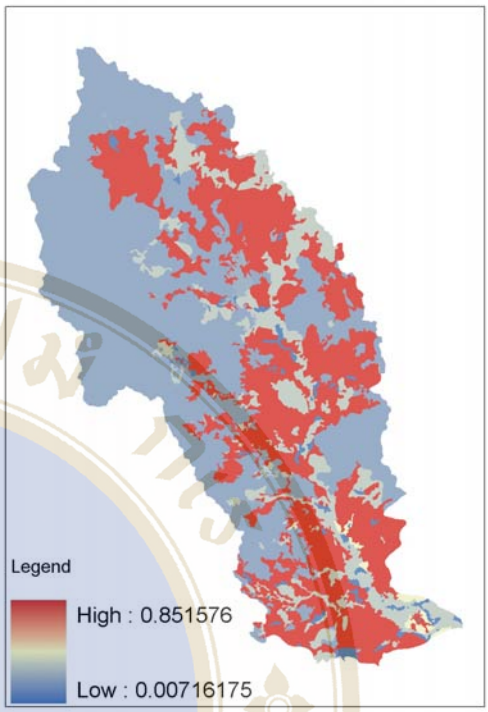

Figure B.2 Prob. of Field crop

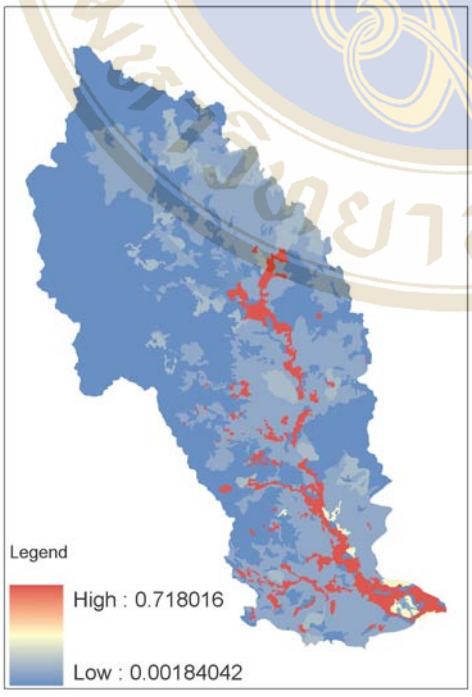

Figure B.3 Prob. of Orchard/Horticulture

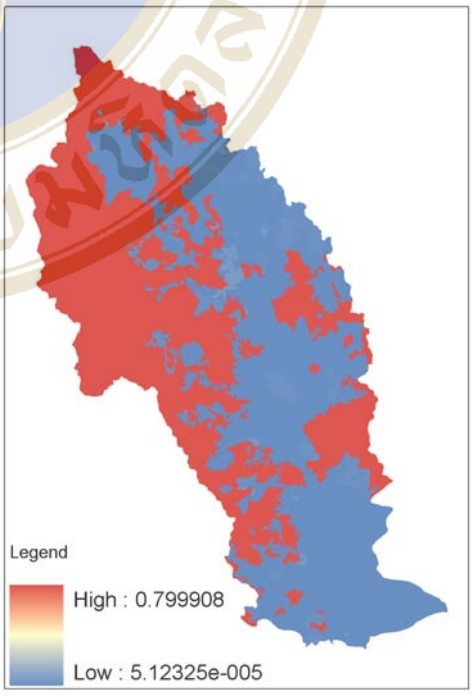

Figure B.4 Prob. of Forest land

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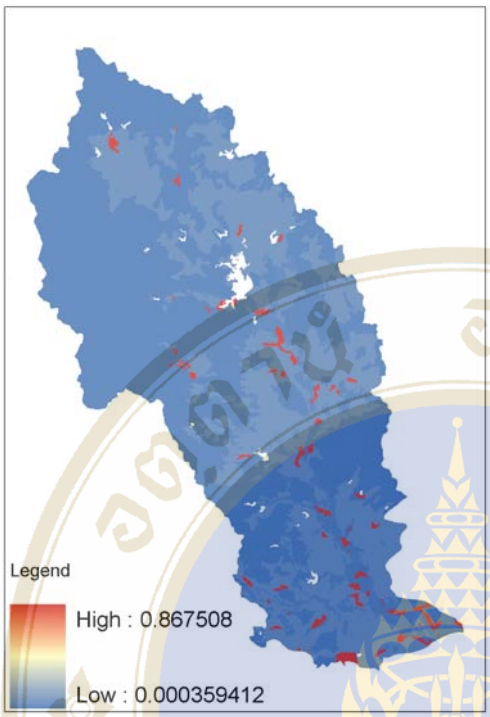

Figure B.5 Prob. of Urban/build-up land

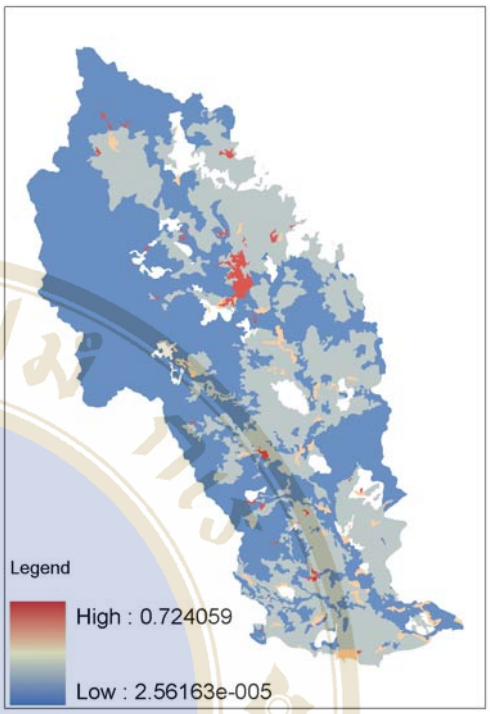

Figure B.6 Prob. of Water bodies

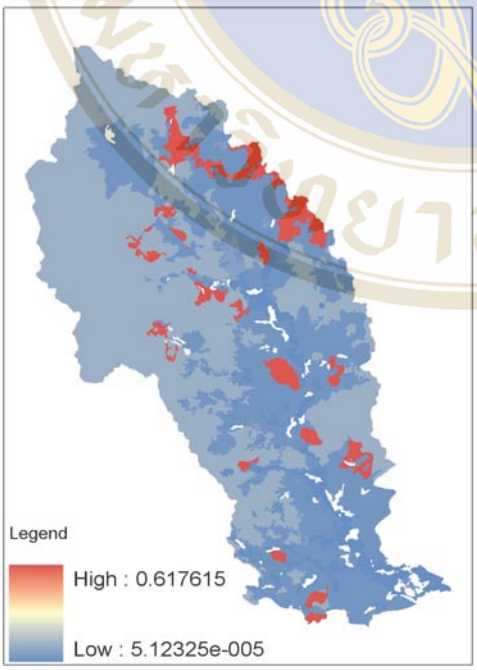

Figure B.7 Prob. of disturbed forest/second forest

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Table B.2 Transitional probabilities of change based on the decision of various stake holders in the study area

Year 20013 / Year 2008	A1	A2	A4&A5	F	F100&F200	U	W
A1	0.6875	0.0972	0.0000	0.0000	0.0000	0.1597	0.0000
A2	0.0000	0.8000	0.1333	0.0000	0.0000	0.0533	0.0133
A4&A5	0.0000	0.1633	0.7517	0.0000	0.0000	0.0340	0.0510
F	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000
F100&F200	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000
U	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000
W	0.000	0.000	0.000	0.000	0.000	0.000	1.000

Transitional probabilities manipulated from Social model to show in figure B.8-B.14

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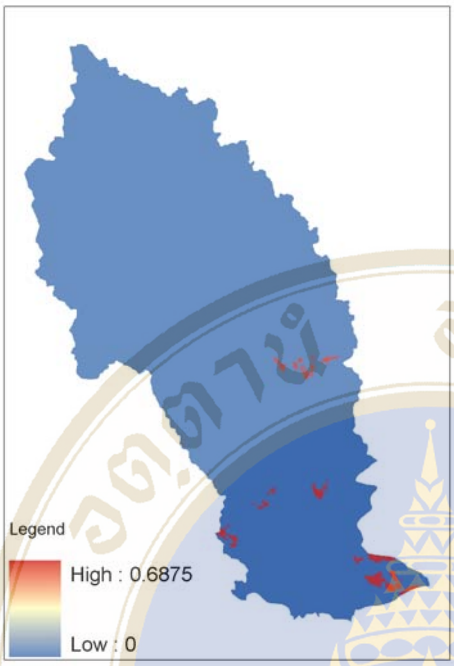

Figure B.8 Prob. of Paddy field

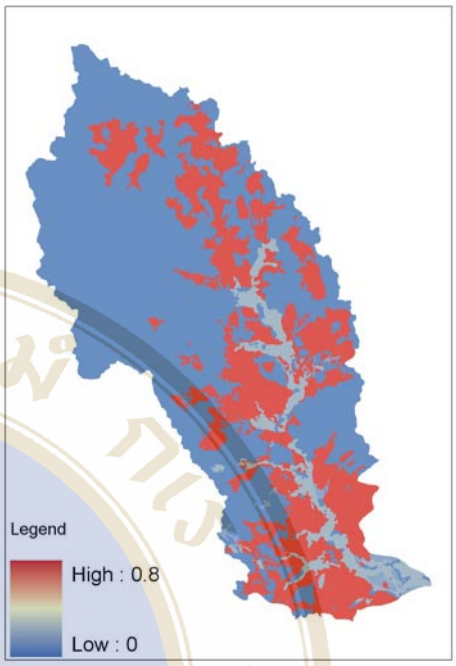

Figure B.9 Prob. of Field crop

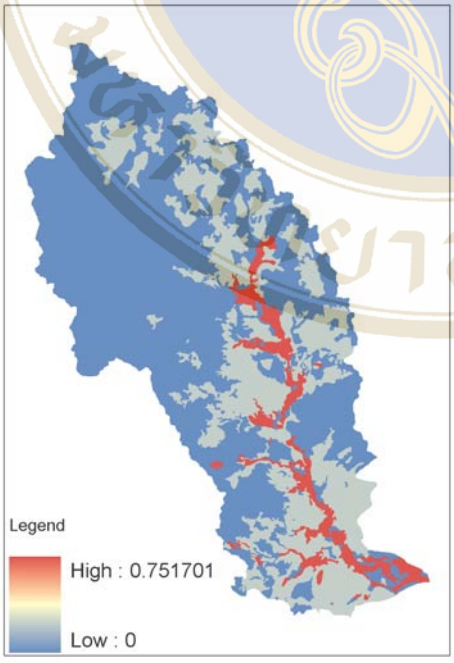

Figure B.10 Prob. of Orchard/Horticulture

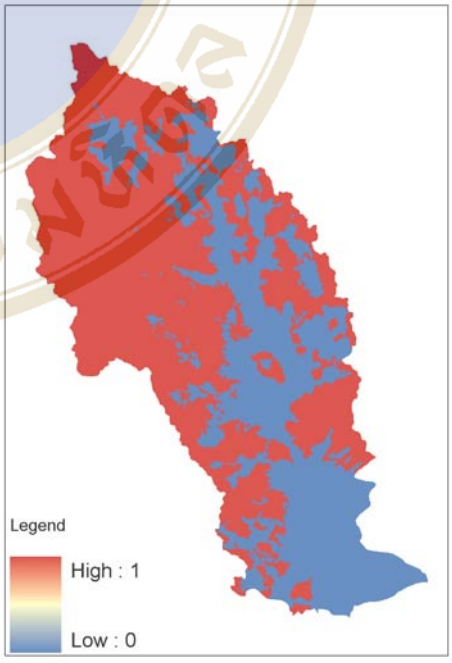

Figure B.11 Prob. of Forest land

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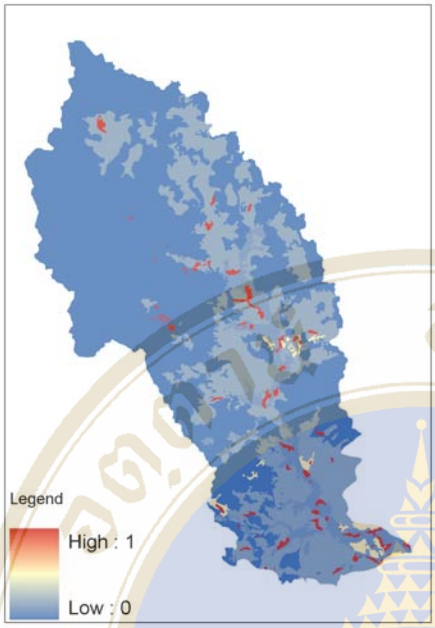

Figure B.12 Prob. of Urban/build-up land

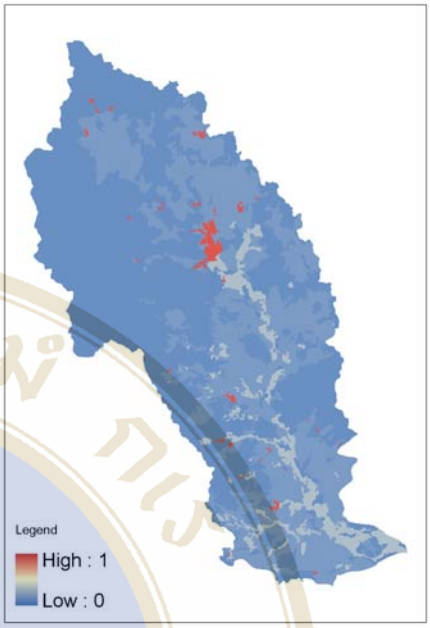

Figure B.13 Prob. of Water bodies

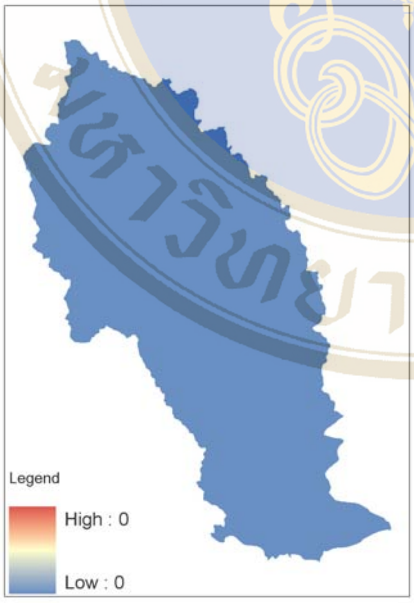

Figure B.14 Prob. of disturbed forest/second forest

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