ผลกระทบของการเปลี่ยนแปลงการใช้ประโยชน์ที่ดินต่อน้ำท่าบริเวณลุ่มน้ำยมระหว่างปี พ.ศ. 2531-2552 โดยใช้แบบจำลองอุทกวิทยา SWAT

นางสาวสุภัทรา กิติชูชัยฤทธิ์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต

สาขาวิชาโลกศาสตร์ ภาควิชาธรณีวิทยา

คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

ปีการศึกษา 2555

IMPACTS OF LAND USE CHANGES ON RIVER RUNOFF IN YOM BASIN DURING 1988-2009 USING SWAT HYDROLOGIC MODEL

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A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science Program in Earth Sciences
Department of Geology
Faculty of Science
Chulalongkorn University
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Thesis Title	IMPACTS OF LAND USE CHANGES ON RIVER RUNOFF IN YOM BASIN DURING 1988-2009 USING SWAT HYDROLOGIC MODEL
By	Ms. Supattra Kitichuchairit
Field of Study	Earth Sciences
Thesis Advisor	Assistant Professor Sombat Yumuang, Ph.D.
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สุภัทรา กิติชูชยฤทธิ์: ผลกระทบของการเปลี่ยนแปลงการใช้ประโยชน์ที่ดินต่อน้ำท่าบริเวณลุ่มน้ำยมระหว่าง ปี พ.ศ. 2531-2552 โดยใช้แบบจำลองอุทกวิทยา SWAT .(IMPACTS OF LAND USE CHANGES ON RIVER RUNOFF IN YOM BASIN DURING 1988-2009 USING SWAT HYDROLOGIC MODEL) อ.ที่ปรึกษาวิทยานิพนธ์หลัก : ผศ.ดร.สมบัติ อยู่เมือง, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: ผศ.ดร. ศรีเลิศ โชติพันธรัตน์, 198 หน้า.

พื้นที่ลุ่มน้ำยม เป็นพื้นที่ลุ่มน้ำที่มีขนาดใหญ่ลุ่มน้ำหนึ่ง ของประเทศไทย ลุ่มน้ำยมประสบปัญหาภัยแล้งอยู่บ่อยครั้ง เนื่องจากไม่มีแหล่งเก็บน้ำขนาดใหญ่ในบริเวณลุ่มน้ำ อีกทั้งมีการเปลี่ยนแปลงการใช้ประโยชน์ที่ดิน จากป่าไม้ที่อุดมสมบูรณ์ในอดีตเป็นพื้นที่เกษตรกรรมและชุมชนอยู่อาศัยมากขึ้น การเปลี่ยนแปลงการใช้ประโยชน์ที่ดินนี้ส่งผลกระทบต่อระบบทางอุทกวิทยาโดยการเปลี่ยนแปลงองค์ประกอบของระบบอุทกวิทยา เช่น การซึม การระเหย เป็นสาเหตุให้ส่งผลกระทบต่อปริมาณน้ำท่าโดยรวมในพื้นที่ลุ่มน้ำ

ในการวิจัยนี้ได้ศึกษาผลกระทบของการเปลี่ยนแปลงการใช้ประโยชน์ที่ดินต่อน้ำท่าในลุ่มน้ำยม ในช่วงเวลา 22 ปี โดยประยุกต์ใช้เทคโนโลยีโทรสัมผัสร่วมกับระบบสารสนเทศภูมิศาสตร์เพื่อวิเคราะห์การเปลี่ยนแปลงการใช้ประโยชน์ที่ดินในเชิงพื้นที่ และใช้แบบจำลองทางอุทกวิทยา SWAT ในการศึกษาปริมาณน้ำท่าจากการเปลี่ยนแปลงการใช้ประโยชน์ที่ดินดังกล่าว

ในการศึกษาวิเคราะห์การเปลี่ยนแปลงของพื้นที่ครั้งนี้ทำการศึกษาระหว่างปี พ.ศ.2531-2552 พบว่า พื้นที่ป่าไม้ที่เปลี่ยนเป็นพื้นที่เกษตรกรรมทั้งหมดประกอบด้วย นาข้าว พืชไร่ ไม้ยืนต้น เป็นพื้นที่1,359.09 ตร.กม. คิดเป็นร้อยละ 5.68 ของพื้นที่ลุ่มน้ำ พื้นที่ป่าเปลี่ยนเป็นพื้นที่แหล่งน้ำ 40.21 ตร.กม. คิดเป็นร้อยละ 0.17 นอกจากนี้พบว่าพื้นที่เมืองมีการขยายตัวเพิ่มขึ้น โดยเปลี่ยนจากพื้นที่ป่าและพื้นที่เกษตรกรรมในปี พ.ศ. 2531 ไปเป็นพื้นที่เมืองในปี พ.ศ. 2552 เป็นพื้นที่ 26 และ 309.97 ตร.กม. คิดเป็นร้อยละ 0.01 และ 1.29 ของพื้นที่ลุ่มน้ำทั้งหมดตามลำดับ สำหรับผลกระทบของการเปลี่ยนแปลงการใช้ที่ดินต่อน้ำท่าในลุ่มน้ำยม โดยใช้แบบจำลองอุทกวิทยา SWAT ตั้งแต่ปีพ.ศ. 2531-2552 พบว่าที่สถานี Y14 ปริมาณน้ำท่าเพิ่มขึ้นโดยเฉลี่ย1,835.95, 1,648.65 และ 1,620.70 ล้านลูกบาศก์เมตรต่อปี และที่สถานี Y20 พบว่าปริมาณน้ำท่าเพิ่มขึ้น 1,176.25, 1,090.27 และ 671.42 ล้านลูกบาศก์เมตรต่อปี เมื่อปริมาณป่าลดลง 1,979.67, 1,141.69 และ1,741.171 ตร.กม. และพื้นที่เมืองเพิ่มขึ้น 66.48, 125.6 และ104.22 ตร.กม. ในปีพ.ศ.2538, 2546 และ 2552 ตามลำดับ

ปริมาณน้ำท่าที่เพิ่มขึ้น โดยมีความสัมพันธ์กับปริมาณป่าที่ลดลงและพื้นที่เมืองที่เพิ่มขึ้น โดยเฉพาะอย่างยิ่งทางตอนบนของพื้นที่ลุ่มน้ำ ซึ่งอาจเป็นสาเหตุหนึ่งของการเกิดน้ำท่วมในทางตอนล่างของพื้นที่ลุ่มน้ำ ผลการศึกษานี้สามารถนำไปประยุกต์ใช้กับพื้นที่ลุ่มน้ำอื่น และประยุกต์ใช้กับการวางแผนการใช้ประโยชน์ที่ดิน รวมถึงวางแผนการใช้ทรัพยากรน้ำอย่างยั่งยืน

ภาควิชา ธรณีวิทยา	ลายมือชื่อนิสิต
สาขาวิชา โลกศาสตร์	ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก
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KEYWORDS : GIS AND REMOTE SENSING / LAND USE CHANGE / SWAT MODEL / YOM RIVER BASIN

SUPATTRA KITICHUCHAIRIT: IMPACTS OF LAND USE CHANGES ON RIVER RUNOFF IN YOM BASIN DURING 1988-2009 USING SWAT HYDROLOGIC MODEL. ADVISOR: ASST. PROF. SOMBAT YUMUANG, Ph.D., CO- ADVISOR: ASST. PROF. SRILERT CHOTPANTARAT Ph.D., 198 pp.

Yom river basin is one of largest basin in Thailand. The Yom does not have any large reservoirs to collect a large amount of water in rainy season. Therefore, the basin typically experienced floods in rainy season (May–October) and drought in the dry season (November - April). Land use change may affect surface and groundwater hydrology associated with hydrological factors such as interception, infiltration and evaporation, and thus causes changes in especially total runoff in the river.

The objective of this research project is to determine the hydrological impacts of land use changes in the Yom river over a 22-year period using an integration of remote sensing, geographic information system (GIS), and SWAT hydrological modeling to quantify contributions of such changes.

Through the interpretation of satellite images between 1981 and 2009, the forest changes to agriculture about 1359.088 km^2 (or 5.675%), the forest land changes to water body about 40.208 km^2 (0.168%), the forest land changes to urban and build-up land 26 km^2 (0.10 %) and the agriculture changes to urban and build-up land 309.965 (1.29%) km^2. For the contributions of land use changes on hydrological components, the average simulated yearly runoff at station Y14 were increased 1,835.95, 1,648.65 and 1,620.70 MCM/Year and station Y 20, the average simulated yearly runoff were increased 1,176.25, 1,090.27 and 671.42 MCM/Year, when the forest land was decrease 1,979.67, 1,141.69 and 1,741.171 km^2 , urban and build-up land was increase 66.48, 125.6 and 104.22 km^2 in year 1995, 2003 and 2009, respectively

Increased runoff occurred in the long term discharge, especially in the upper part of the basin, which may cause more floods in the lower part of the basin. The approach applied in this study could be applied to other watersheds, which have been highly changed and would essential for sustainable water resources management.

Department : Geology	Student's Signature
Field of Study : Earth Sciences	Advisor's Signature
Academic Year : 2012	Co- advisor's Signature

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CHAPTER I

INTRODUCTION

Because of the imbalance of nature, the effects in the watershed and natural resources, especially water, are likely to become more severe and more frequent at the moment. The volume and timing of river runoff in the watershed is not consistent with the demand for water in the basin, severe flooding in the rain season and prolonged drought during the dry season. In addition to meteorological changes, land use change is a major force altering the hydrologic processes over a range of temporal and spatial scales. Land use change can affect the runoff generation and concentration by altering hydrological factors such as interception, infiltration and evaporation, and thus causes changes in the frequency and intensity of flooding. A better understanding and assessment of land use change impacts on watershed hydrologic process is great importance for predicting flood potential and the mitigation of hazard, and has become a crucial issue for planning, management, and sustainable development of the watershed.

1.1 Rationale

At the present, it is common to observe an increasing vulnerability of global water resource to manmade and natural phenomena. Including many other factors climate change and population growth increase rapidly the vulnerability of the global water resource. The demand of technologies that help to develop a sustainable water system and the study of changes of hydrological process using various types of models have also been growing fast for past few decades. A number of researches and studies have been made to deal with global water related issues. However the problems still exist.

The Yom River is one of the outstanding streams of the area. It is typically flooded in August and September during each rainy season (May–October), the basin is very dry through the November-to-April dry season (Geo-Informatics and Space Technology Development Agency (GISTDA), 2005).

Apart from the pronounced monsoon climate mentioned above, geographical and hydrological features, deforestation, and particularly urbanization are claimed as major causes. With urban development, impervious surface areas (e.g. roads, sidewalks, driveways, parking areas, rooftops) decrease infiltration and increase the rate and volume of surface runoff (Fitzpatrick *et al*., 2005). Thus, urbanized areas would become a potentially greater cause of water inundation under conditions of high rainfall intensity. Without research to support these claims, however, conflicts and debate about how to make appropriate decisions to mitigate the flooding problem remains. Understanding the role and impacts of land use changes in hydrological cycle could play a significant role in alleviating the flooding problem.

The study of the impacts of land use changes on river runoff is a very complex because the factors that determine river flow vary both spatially and temporally. These problems can be addressed by using a Geographic Information System (GIS) that is efficient for spatial data analysis together with remote-sensing data, which can provide widely, regularly updated, and reliable data. Then, hydrological models can be used to help further understand and predict changes in river flow behavior.

The SWAT (Soil and Water Assessment Tool) model is a hydrological model that physically based distributed watershed models have higher accuracy in analyzing the impact of land management practices on water, sediment, and agricultural chemical yields in large complex watersheds. Adapting this kind of model can help to achieve more accurate and reliable prediction of streamflow and achieve good representations of the hydrologic processes occurring in the system. It is also one of the suitable watershed models for long-term impact analysis. Nowadays the model is widely used in many parts of United States and Europe and other parts of the world (Bingner 1996, Peterson and Hamlett 1998; Srinivasan et al. 1998; Arnold et al. 1998; Neitsch et al. 2001; Benaman et al. (2005).

1.2 Objectives

The purposes of this study are

- To study the pattern of land use changes in the Yom basin in 1988-2009.
- To study the impact of land use and land cover changes on river run off in the Yom river basin.

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1.3 Location of the study area

The Yom River basin is located in the north of Thailand, cover area about 23,948 Sq.km. The location of the watershed is between the southern latitude of 14 degrees 50 minute to 18 degrees 25 minute, and between longitude 99 degrees 16 minute to 100 degrees 40 minute. The Yom River watershed covers 11 provinces, which are Nan, Phayao, Kamphaeng Phet, Lampang, Phrae, Tak, Sukhothai, Phitsanulok, Phichit, Uttaradit and Nakhon Sawan (Figure 1-1). The Yom River flows in a north-to-south direction, is 735 km in length, and the elevation of the river ranges from 360 to 20 m above mean sea level at the watershed outlet at Chumsang District Nakhon Sawan Province (Department of Water Resources (DWR), 2011).

Geographically, the basin is divided into two characteristic parts, the upper and lower river basins. Most of the upper basin is mountainous, with 51% forest cover containing the only large teak forest remaining in the country (GISTDA, 2005), and 49% agriculture (in the river valleys) and urban areas. The lower basin is essentially the river's floodplain, and is well suited for cultivation. Therefore, the land use in the lower basin is mostly agriculture and urban with 26% forest (Srethasirote, 2007). The average annual precipitation in the study area is 1160 mm (ranges from 1000 to 1600 mm) and the average annual air temperature ranges from 25 to 28 °C (Royal Irrigation Department (RID), 2009). The climate is dominated by the tropical southwest monsoon, with over 90% of the annual precipitation occurring between May and October.

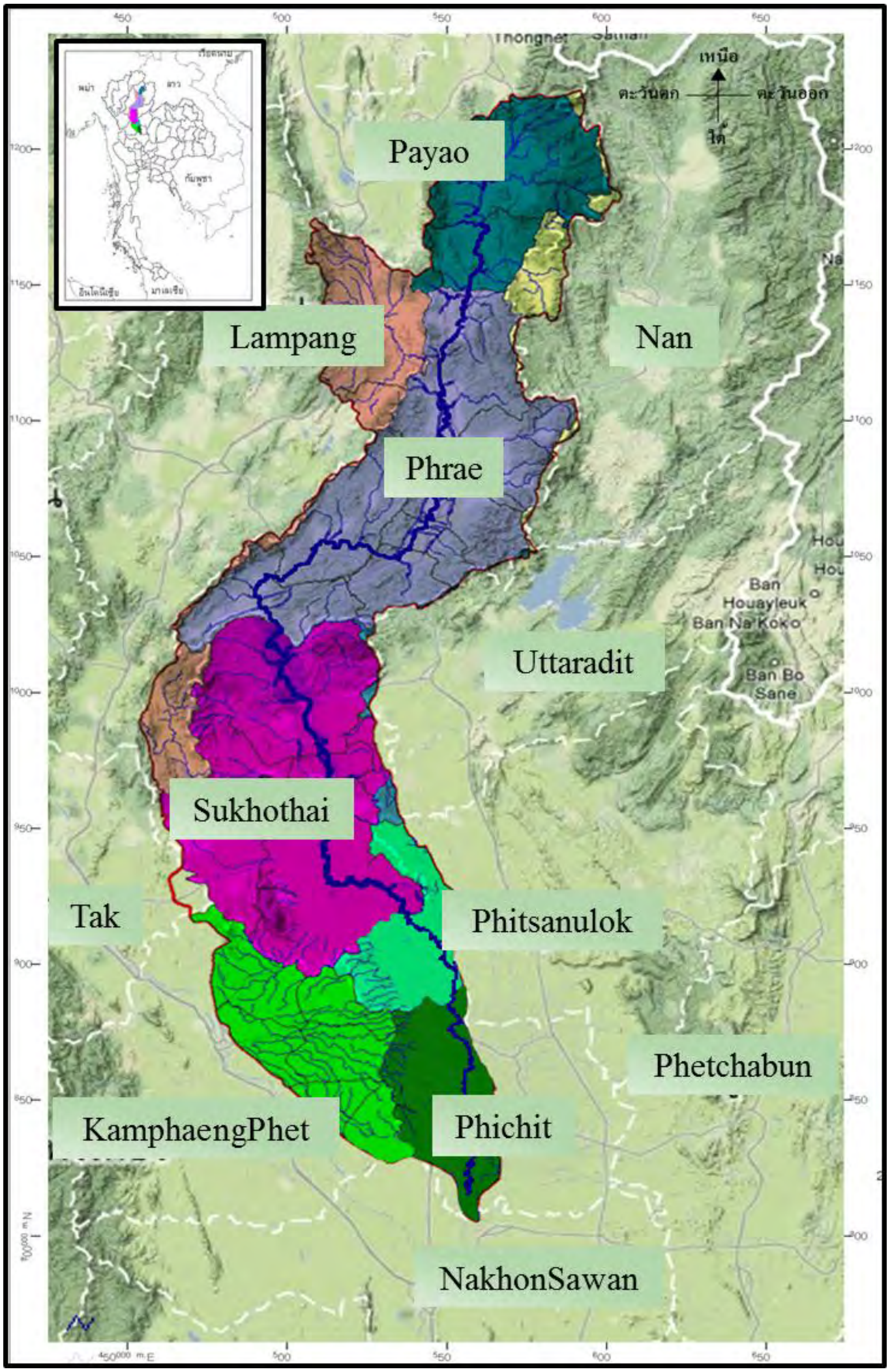

Figure 1-1 the location of the Yom river basin

Table 1-2 Sub-basin of Yom Basin (Department of Water Resources (DWR), 2011).

Id. Sub-Basin.	Sub-watershed name.	Catchment area. (Sq.km.).	Coverage area (district / province).
08.02	Upper Yom River	1,978	A. Chiangkam, A. Pong, A. Dokkamtai, A. Chiangmuan (Phayao), A, Songkawe (Nan) A. Song (Phrae)
08.03	Khuan River	858	A. Pong (Nan), A. Muang Nan Thawangpha (Nan)
08.04	Pee River	636	A. Chiangmuan (Phayao), A. Ban Luang (Nan)
08.05	Ngao River	1,644	A. Ngao, A. Mae Mah (Lampang)
08.06	Middle Yom River	2,884	A. Maung Phrae, A. Rongkaung, A. Nong Muang Kai
08.07	Kam mee River	444	A. Maung Phrae, A. Rongkaung, A. Song, A. Nongmuangkai, A. Denchai, A. Soongmen
08.08	Tha River	518	A. Long (Phrae)
08.09	Huay Mae Sin River	522	A. Wangchin (Phrae), A. Lublae (Uttaradit)
08.10	Mohk River	1,333	A. Turn (Lampang), A. Tungsaleum (Sukhothai)
08.11	Ram Phan River	895	A. Bantak (Tak), A. Tungsaleum, A. Bandanlanhoi, A. Muang, A. Srisuchanalai, A. Srisumrong, A. Sawankaloke (Sukhothai) A. Prankatai (Kampaengphet)
08.12	Lower Yom River	11,906	A. Long, A. Wangchin (Phrae), A. Bantak (Tak), A. Bandanlanhoi, A. Muang, A. Srisuchanalai, A. Srisumrong, A. Sawankaloke, A. Srinakorn, A. Kongkailad, A. keereemas, A. Pichai, A. Propiram, A. Bangrakam, A. Bangkratoom, A. Prankratai, A. Maung, A. Lankrabur, A. Saingam, A. Saithongwattana, A. Wachirabaramee, A. Samngam, A. P hopratubchang, A. Sapanhin, A. Photaleh, A. Choomseang

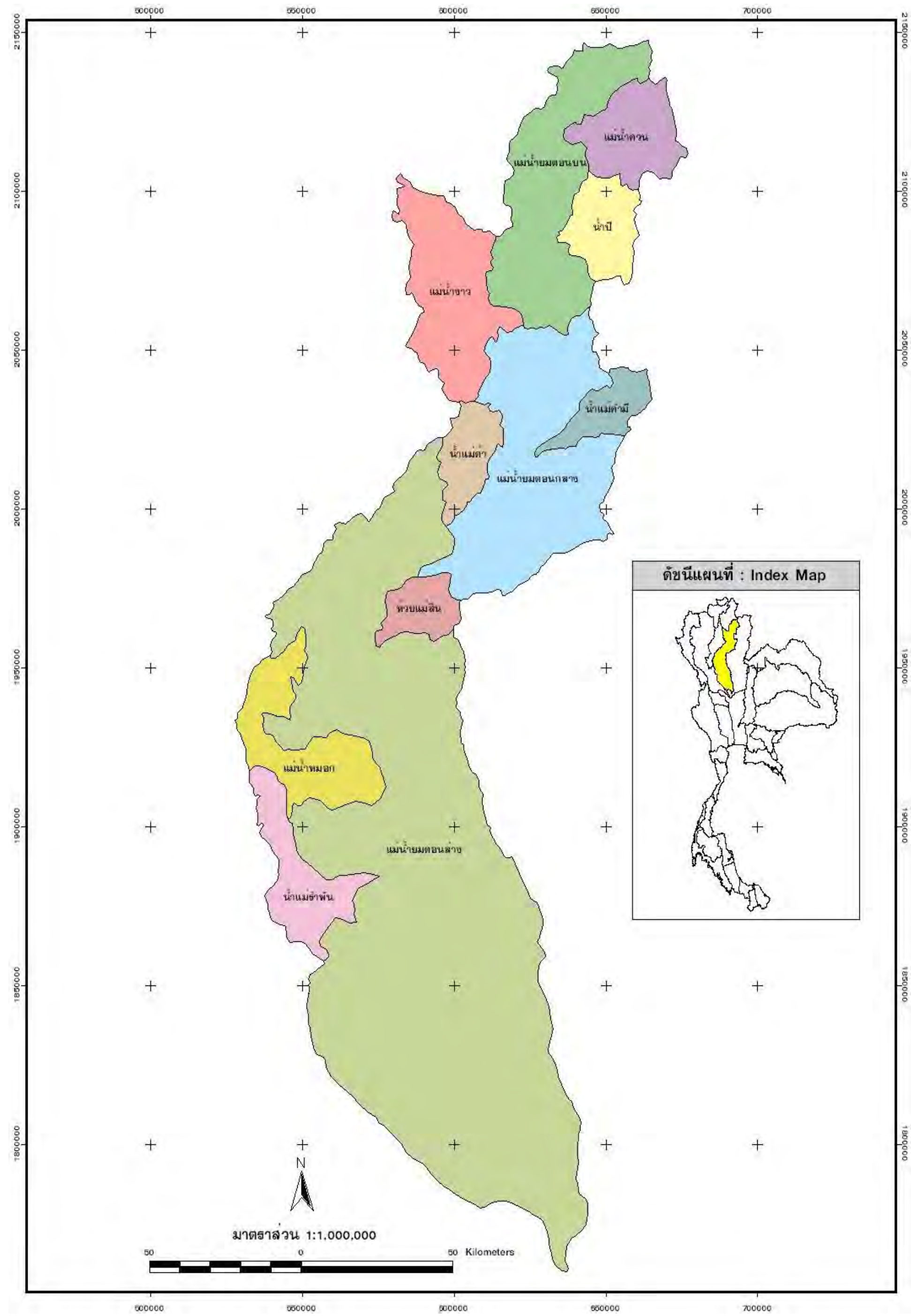

Figure 1-2 Sub-basin of Yom Basin (Department of Water Resources (DWR), 2011).

1.4 Expected outputs

The expected outputs of this thesis consist of:

- Land use and land use change maps during 1988-2007 in Yom River Basin.
- Relationships between hydrological impacts that caused land use changes in the Yom River Basin.

1.5 Research methodology

To accomplish the aims of this thesis, the research involves four sequential steps are designed. Each of which is described as follows:

1.5.1 Preparation

This step includes:

- Literature review of the related researches in the study area, western Thailand, and other countries.
- Acquisition and study of the previous basic data acquisition, i.e. satellite images of medium resolution (Landsat 5TM), topographic map, land use map, and soil map to understand the topography, land use, and agronomy of the study area as general background information.
- Intensive comprehension on the conceptual framework of land use changes, deforestations and CLUE-s model especially the criteria to evaluate land use changes occurrence.

1.5.2 Field investigation

The field investigation and direct observation were carried out as follows:

- Reconnaissance to understand and recognize the limitation in the study area for preparing the data and related plan that would be used in further steps of the field investigation.
- Intermediate field investigation to conduct ground-truth to inspect the correctness of the analyzed results from the remote sensing image analysis and interpretation.

1.5.3 Laboratorial studies

The laboratorial analysis is conducted as follows:

- Thematic (GIS and remote sensing) data preparation. These inventory data consist of topography (slope, elevation), land use and land cover. Software of geographic information system (GIS) and remote sensing (ArcGIS 9.3 and ERDAS IMAGINE 8.7) are applied in developing, manipulating, and analyzing the digital data.
- Interpretation of medium resolution satellite images (Landsat 5TM) that were acquired during 1988-2009. This sub-step was conducted to develop the new data (e.g. deforestation). These inventory data were also checked from ground-truth information from brief field traverses to inspect the accuracy in the intermediate field investigation.
- Impact of Land use changes analysis on river runoff in the Yom river basin is conducted using SWAT model. SWAT version 2009 is used thought ArcGIS 9.3 Interface. The influences of the land use changes were quantified by comparing the SWAT output of the 8 scenario. The precipitation data were used for each model run to determine if changes in river runoff were indeed due to changes in

land use. Differences in river runoff, and the associated changes in model parameters, were therefore associated with changes in land use.

1.5.4 Synthesis, discussion and conclusions

This step includes:

- Synthesizing, discussing and concluding land use changes detection and impact of land use changes on river runoff in the Yom river Basin During 1988-2009.

CHAPTER II

LITERATURE REVIEW

This chapter describes the applications of the remote sensing, geographic information system (GIS) and Global positioning system (GPS) in land use changes are briefly reviewed. Besides, the SWAT model description and the previous investigations from the related technical literatures are also presented.

2.1 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.

2.1.1 Remote sensing

Remote Sensing can be defined as the instrumentation, techniques and methods to observe the Earth's surface at a distance and to interpret the images or numerical values obtained in order to acquire meaningful information of particular objects on earth. Three definitions of remote sensing are given below:

Remote Sensing is defined as “instrument-based techniques employed in the acquisition and measurement of spatially organized (for the Earth, most commonly geographically distributed) data/information on some properties (spectral; spatial; physical) of an array of target points (pixels) within the sensed scene that correspond to features, objects, and materials, doing this by applying one or more recording devices not in physical, intimate contact with the item(s) under surveillance; techniques involve amassing knowledge pertinent to the sensed scene (target) by utilizing electromagnetic radiation, force fields, or acoustic energy sensed by recording cameras, radiometers and scanners, lasers, radio frequency receivers, radar systems, sonar, thermal devices, sound detectors, seismographs, magnetometers, gravimeters, scintillometers, and other instruments" (NASA, 2010)

Remote sensing is the science and art of obtaining information about an object, area, or phenomenon under investigation (Lillesand et. al., 2008).

Remote sensing is a tool or technique similar to mathematics. Using sensors to measure the amount of electromagnetic radiation (EMR) exiting an object or geographic area from a distance and then extracting valuable information from the data using mathematically and statistically based algorithms is a scientific activity". It functions in harmony with other spatial data-collection techniques or tools of the mapping sciences, including cartography and geographic information systems (GIS) (Clarke, 2001; Jensen et. al., 2007).

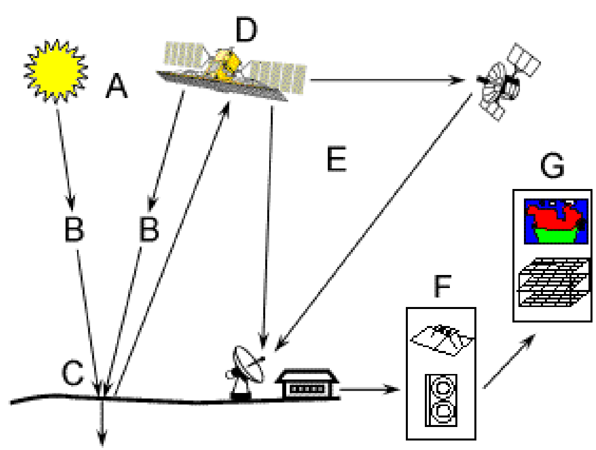

Figure 2-1 Process of Remote Sensing (Canada Centre for Remote Sensing, 2008).

Note: A) Energy source to illuminate the target; B) Interaction of the radiation with the earth's atmosphere; C) Radiation-target interactions; D) Data reception; E) Data transmision; F) Data processing; G) Data application

Basic concept of remote sensing focus on the facts that everything on the Earth above 0 Kelvin generates electromagnetic energy. An object reflects, absorbs sunlight or emits its own internal energy according to its atomic and molecular vibration.

Human eyes are restricted to see only visible reflected light (wavelength between 0.4-0.7 μm). Remote sensing uses sophisticated equipment to record invisible light such as infrared, thermal infrared and microwave radiation.

Remote sensing system may be classified into two systems, passive remote sensing and active remote sensing. (Jensen and Kiefer, 2007)

Passive remote sensing is sensors detect natural radiation that is emitted or reflected by the object or surrounding area being observed. Reflected sunlight is the most common source of radiation measured by passive sensors. Examples of passive remote sensors include film photography, infrared, charge-coupled devices, and radiometers.

Active remote sensing is emits energy in order to scan objects and areas whereupon a sensor then detects and measures the radiation that is reflected or backscattered from the target. RADAR is an example of active remote sensing where the time delay between emission and return is measured, establishing the location, height, speeds and direction of an object.

Generally, remote sensing works on the principle of the inverse problem. While the object or phenomenon of interest (the state) may not be directly measured, there exists some other variable that can be detected and measured (the observation), which may be related to the object of interest through the use of a data-derived computer model. The common analogy given to describe this is trying to determine the type of animal from its footprints. For example, while it is impossible to directly measure temperatures in the upper atmosphere, it is possible to measure the spectral emissions from a known chemical species (such as carbon dioxide) in that region. The frequency of the emission may then be related to the temperature in that region via various thermodynamic relations (Lillesand et. al., 2008).

The quality of remote sensing data consists of its spatial, spectral, radiometric and temporal resolutions as shown in Table 2-3 (Jensen and Kiefer, 2007).

- **Spatial resolution**

The size of a pixel that is recorded in a raster image – typically pixels may correspond to square areas ranging in size length from 1 to 1,000 meters (3.3 to 3,300 ft).

- **Spectral resolution**

The wavelength width of the different frequency bands recorded – usually, this is related to the number of frequency bands recorded by the platform. Current Landsat collection is that of eight bands (Table 2-2), including several in the infra-red spectrum, ranging from a spectral resolution of 0.07 to 2.1 μm. The Hyperion sensor on Earth Observing-1 resolves 220 bands from 0.4 to 2.5 μm, with a spectral resolution of 0.10 to 0.11 μm per band.

- **Radiometric resolution**

The number of different intensities of radiation the sensor is able to distinguish. Typically, this ranges from 8 to 14 bits, corresponding to 256 levels of the gray scale and up to 16,384 intensities or "shades" of color, in each band. It also depends on the instrument noise (Figure 2-11).

- **Temporal resolution**

The frequency of flyovers by the satellite or plane, and is only relevant in time-series studies or those requiring an averaged or mosaic image as in deforesting monitoring. This was first used by the intelligence community where repeated coverage revealed changes in infrastructure, the deployment of units or the modification/introduction of equipment. Cloud cover over a given area or object makes it necessary to repeat the collection of said location.

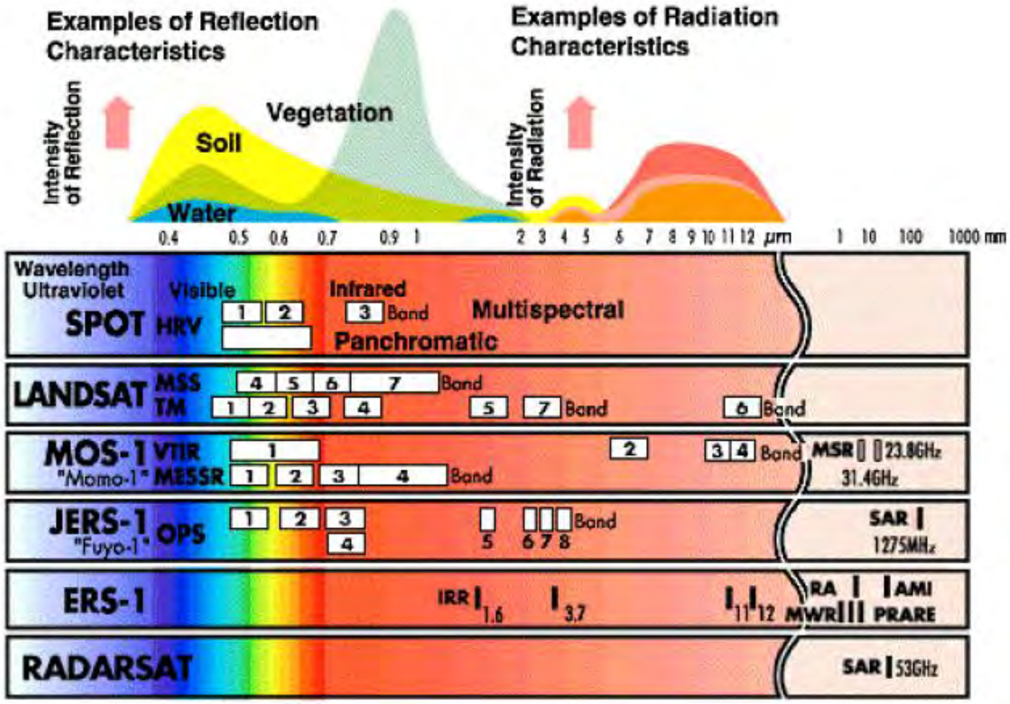

Figure 2-2 Radiometric resolution of Satellites characteristics.

Table 2-1 Spectral resolution of Landsat 7ETM+ and 5TM sensors (Geoscience Australia, 2009).

Band Number	Spectral Range (in Microns)	EM Region	Generalised Application Details
1	0.45 - 0.52	Visible Blue	Coastal water mapping, differentiation of vegetation from soils
2	0.52 - 0.60	Visible Green	Assessment of vegetation vigour
3	0.63 - 0.69	Visible Red	Chlorophyll absorption for vegetation differentiation
4	0.76 - 0.90	Near Infrared	Biomass surveys and delineation of water bodies
5	1.55 - 1.75	Middle Infrared	Vegetation and soil moisture measurements; differentiation between snow and cloud
6	10.40- 12.50	Thermal Infrared	Thermal mapping, soil moisture studies and plant heat stress measurement
7	2.08 - 2.35	Middle Infrared	Hydrothermal mapping
8	0.52 - 0.90 (panchromatic)	Green, Visible Red, Near Infrared	Large area mapping, urban change studies

Table 2-2 The quality of remote sensing data (Geoscience Australia, 2009).

Satellite	Sensors	Subsensors	Swath width	Bands	Spatial Resolution	Altitude	Orbit	Repeat
Landsat 5	Multispectral scanner, (MSS)		185 Km	1-5&7 +6	30 - 129 m	705 Km	Sun Synchronous	16 days or 233 orbits.
	Thermatic Mapper, TM							
Landsat 7	Enhance Thermatic Mapper Plus, (ETM+)		185 Km	1-5&7+6+8	15 - 60 m	705 Km	Sun Synchronous	16 days or 233 orbits.
Terra, EOS-AM1	Advanced Spaceborne Thermal Emission and Relfection Radiometer (ASTER)	Visible and Near Infrared(VNIR)	60 Km	1 to 3	15 Km	705 Km	Sun Synchronous	16 days
		Shortwave Infrared (SWIR)	60 Km	4 to 9	30 Km			
		Thermal Infrared (TIR)	60 Km	10 to 14	90 Km			
	Moderate Resolution Imaging Spectroradiometer (MODIS)		2330 Km	1 to 36	250 -1000 m			
Aqua, EOS-PM1	Moderate Resolution Imaging Spectroradiometer (MODIS)		2330 Km	1 to 36	250 -1000 m	705 Km	Sun Synchronous	16 days.
ALOS, Advanced Land Observing Satellite	Panchromatic Remote Sensing Instrument for Steromapping (PRISM)		35-70 Km		2.5 m	692 Km	Sun synchronous	46 days
	Advanced Visable and Near Infrared Radiometer type 2 (AVNIR-2)		70 Km	1 to 4	10 m			
	Phased Array type L-band Synthetic aperture radar (PALSAR)		30 - 70 Km	Radar	10 - 100 m			
NOAA	Advanced Very High Resolution Radiometer (AVHRR)		2399 Km	1 to 5		833 Km	Sun synchronous	9 days
Radarsat-1	Synthetic Aperture Radar (SAR)			Radar				24 days
Resourcesat-1	Linear Imaging and Self Scanning sensor (LISS-III)		141Km	2 to 4	23.5 m	817 Km		24 days
	Advanced Wide Field Sensor (AWiFS)		740km		56 m			5 days

2.1.2 Geographic information system

Geographic information system (GIS), a new technology, is becoming essential tools for analyzing and graphically transferring knowledge about the world. There are many definitions about geographic information system. For example, the United States Geological Survey-USGS (2007) defined as “a computer system capable of capturing, storing, analyzing, and displaying geographically referenced information; that is, data identified according to location. Practitioners also define a GIS as including the procedures, operating personnel, and spatial data that go into the system”. While Briggs (2010) noted that geographic information system can be defined as “a software systems with capability for input, storage, manipulation/analysis and output/display of geographic (spatial) information”. Skrdla (2005), however; defines the meaning of the geographic information system as “management of information with a geographic component primarily stored in vector form with associated attributes.”

GIS uses spatial-temporal (space-time) location as the key index variable for all other information. Just as a relational database containing text or numbers can relate many different tables using common key index variables, GIS can relate otherwise unrelated information by using location as the key index variable. The key is the location and/or extent in space-time.

Any variable that can be located spatially, and increasingly also temporally, can be referenced using a GIS. Locations or extents in Earth space-time may be recorded as dates/times of occurrence, and x, y, and z coordinates representing, longitude, latitude, and elevation, respectively. These GIS coordinates may represent other quantified systems of temporal-spatial reference (for example, film frame number, stream gage station, highway mile marker, surveyor benchmark, building address, street intersection, entrance gate, water depth sounding, POS or CAD drawing origin/units). Units applied to recorded temporal-spatial data can vary widely (even when using exactly the same data, see map projections), but all Earth-based spatial-temporal location and extent references should, ideally, be relatable to one another and ultimately to a "real" physical location or extent in space-time (Bettinger and Wing, 2004).

Related by accurate spatial information, an incredible variety of real-world and projected past or future data can be analyzed, interpreted and represented to facilitate education and decision making. This key characteristic of GIS has begun to open new avenues of scientific inquiry into behaviors and patterns of previously considered unrelated real-world information.

Traditionally, there are two broad methods used to store data in a GIS for both kinds of abstractions mapping references: Spatial data and Attribute data (Clarke, 2001). Sutton et al. (2009) explains that spatial data is usually represented on maps as one of two type of spatial primitive: raster data and vector data

Raster data are stored as a grid of values, or pixel or fixed size cells having digital values, covering a certain area, provided by satellite images, scanned maps and digital terrain modeling. Raster data display information that is continuous across an area.

Vector data is stored as a series of x,y coordinate pairs inside the computer's memory. Vector data is used to represent points features represent spatial data existing at a single location, lines represent linear features and polygon features represent enclosed homogeneous areas or regions. A polygon is a series of line segments connected to form an enclosed area.

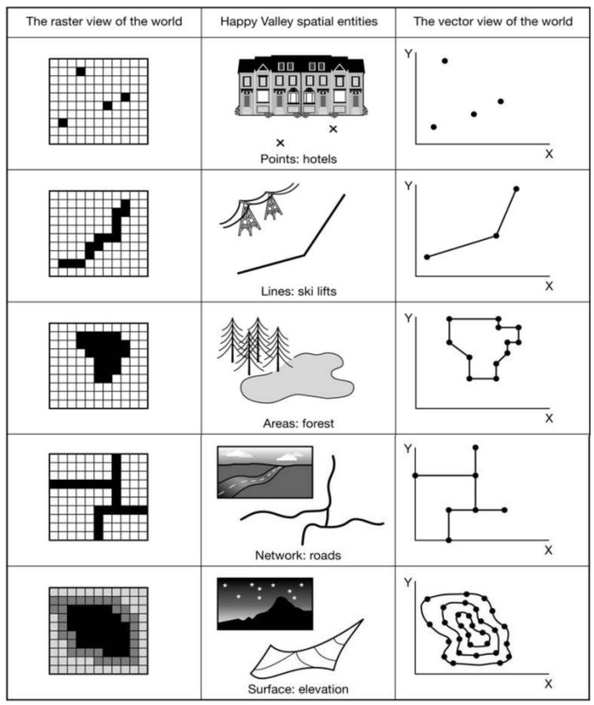

Figure 2-3 Spatial Data in GIS Database (Indiana University, 2005).

Attribute data is an object's description which may be graphical, such as a symbol, point, line or polygon, or it could be test describing specific nature of an object, i.e. number of inhabitants, production volume, and population density. The attribute data is stored in a relational database, with the spatial data kept in a standard hierarchical database (Clarke, 2001).

2.1.3 Global positioning system

Global positioning system (GPS) has permitted convenient, inexpensive, and accurate measurement of absolute location. GPS has greatly enhances the usefulness of remote sensing data. These instruments now are inexpensive, easy to use, and can be employed in almost any area on the earth's surface.

A Global positioning system receiver consists of a portable receiving unit sensitive to signals transmitted by a network of earth-orbiting satellites. These satellites are positioned in orbits such that each point on the earth's surface will be in view of at least four, and perhaps as many as twelve, satellites at any given time. A system of 24 satellites is positioned at an altitude of about 13,500 miles, to circle the earth at intervals of 12 hours, spaced to provide complete coverage of the earth's surface (Earth Science Australia, 2010).

These satellites continuously broadcast signals at two carrier frequencies within the L-band region of the microwave spectrum. Although at ground level these signals are very weak, they are designed so that they can be detected even under adverse condition (e.g. severe weather or interference from other signals). The frequency of each of these carrier signals is modulated in a manner that both identify the satellite that broadcasts the signal and gives the exact time that the signal was broadcast. A receiver therefore can calculate the time delay for the signal to travel from a specific satellite, and then accurately estimate the distance from the receiver to specific satellite (Bettinger and Wing, 2004).

One reason that it is possible to employ such a weak signal is that the time and identification information each satellite transmits is very simple, and the receiver can listen for long periods to acquire it accurately. Because a receiver is always within range of multiple satellites, it is possible to combine positional information from three or more satellites to accurately estimate geographic positional on the earth's surface. A network of ground stations periodically recomputed and uploads new positional data to the GPS satellites (Earth Science Australia, 2010).

2.1.4 Use of Geo-Informatics in land use changes assessment

The geo-informatics is powerful tools to derive accurate and timely information on the spatial distribution of land use changes over medium to large. A past and present study conducted by organizations and institutions around the world, mostly, has concentrated on the application of land use changes.

Remote Sensing Technology involves the use of a sensor that is not in physical contact with its subject of interest. This electromagnetic reflectance is recorded by the sensors in terms of their wavelength of energy, as described by the electromagnetic spectrum (Lillesand et al., 2008). The electromagnetic wave lengths are then converted to a digital format and transmitted back to a computer for processing and interpolation. Satellites such as the Landsat Thematic Mapper (TM) series can capture wide swaths of the Earth's surface (185 km, or 115 mile) and, thus, have the potential to record vast amounts of information over a short time period (Geoscience Australia, 2009). The advantages provided by the much finer spatial resolution of the second generation satellites (e.g. Landsat TM, SPOT) are now well recognized. In favorable circumstances, thematic maps can be prepared at a scale of 1:50000 and revised at a scale of 1:25000 or possibly larger (Howard, 1991). In addition, the finer resolution data of these second generation satellites provides a record of the surface texture of forests, which in classification of the images can be combined with their spectral characteristics. Further, the spectral inclusion of the mid-infrared in Landsat TM sensing is helping to improve the classification of land use and land cover (Adams and Gillespie, 2006).

GIS provides a flexible environment for collecting, storing, displaying and analyzing digital data necessary for change detection. Remote sensing imagery is the most important data resources of GIS. Satellite imagery is used for recognition of synoptic data of earth's surface. Landsat Multispectral Scanner (MSS), Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) data have been broadly employed in studies towards the determination of land use changes, the starting year of Landsat program, mainly in forest and agricultural areas. The rich archive and spectral resolution of satellite images are the most important reasons for their use. And GPS has permitted convenient, inexpensive, and accurate measurement of absolute location. And GPS has greatly enhances the usefulness of remote sensing data. These instruments now are inexpensive, easy to use, and can be employed in almost any area on the earth's surface. The frequency of each of these carrier signals is modulated in a manner that both identify the satellite that broadcasts the signal and gives the exact time that the signal was broadcast. A receiver therefore can calculate the time delay for the signal to travel from a specific satellite, and then accurately estimate the distance from the receiver to specific satellite. The results of this analysis from the geo-informatics technology in the study area. This information is essential for a feasible and sustainable land use plan (Wang et al., 2010).

2.2 SWAT Model description

2.2.1 Overview of hydrological model

Hydrological models are tools that describe the physical processes controlling the transformation of precipitation to stream flows. There are different hydrological models designed and applied to simulate the rainfall runoff relationship under different temporal and spatial dimensions. The focus of these models is to establish a relationship between various hydrological components such as precipitation, evapotranspiration, surface runoff, ground water flow and soil water movement (infiltration). Many of these hydrological models describe the canopy interception, evaporation, transpiration, snowmelt, interflow, overland flow, channel flow, unsaturated subsurface flow and saturated subsurface flow. These models range from simple unit hydrograph based models to more complex models that are based on the dynamic flow equations.

Simulation programs implementing watershed hydrology and river water quality models are important tools for watershed management for both applied and operational research purposes. A hydrological model represents the water cycle of a drainage basin and studies the response of this basin to climatic and physical conditions (Renaud, 2004). Three different categories of hydrological models can be distinguished: physically process based, empirical and statistically based. Physically process based models are described by mathematically formulated fundamental physical laws, where each basin is represented by a concept; a reservoir for instance. They are useful for inferring the distribution, magnitude, and past, present 14 and future behavior of a process with limited observations (Hermance, 2003). These equations can relate the changes of water properties into the reach to those across the surface.

HEC-HMS (Fleming and Neary, 2004) is a classical conceptual semi-distributed rainfall-runoff model. It uses the soil moisture accounting (SMA) algorithm for runoff generation, the Clark Unit Hydrograph for the transformation of direct runoff, two linear reservoirs to consider interflow and base flow transformation and the kinematic wave for river routing. Snow melt is calculated externally using the degree day method. Potential evapotranspiration is estimated using the Priestley-Taylor method.

The model WaSiM-ETH (Schulla, 1997) is a more complex process-based fully distributed hydrological model for the simulation of hydrological fluxes on a rectangular grid. Besides the digital elevation model input data grids for soil properties and land use are required. Soil water balance and runoff generation is modelled using a modified variable saturated area approach (top-model). The kinematic wave is used in combination with a single linear storage for discharge routing. Evapotranspiration is calculated after Penman-Monteith and snow melt using a temperature index- approach.

In addition to categorizing both soil erosion and hydrological models with respect to the way they are being synthesized, another distinction is the difference between distributed and global models. In distributed models, the watershed is one single entity and in global models, many units represent the variability of hydrological parameters on the surface. Spatial variability is handled by dividing a drainage basin into smaller geographical units, such as sub basins, land cover classes, elevation zones or a combination of them. The so called hydrological response units (HRUs) represent areas where the modeling has been simplified and where the hydrological response is supposed to be homogeneous.

In recent years, distributed watershed models are increasingly used to study alternative management strategies in the areas of water resources allocation, flood control, impact of land use change and climate change, and finally environmental pollution control. Many of these models share a common base in their attempt to incorporate the heterogeneity of the watershed and spatial distribution of topography, vegetation, land use, soil characteristics, rainfall and evaporation.

2.2.2 SWAT Model

SWAT (Soil and Water Assessment Tool) is spatially distributed physically based model. The physically based distributed watershed models have higher accuracy in analyzing the impact of land management practices on water, sediment, and agricultural chemical yields in large complex watersheds. Adapting this kind of model can help to achieve more accurate and reliable prediction of stream flow and achieve good representations of the hydrologic processes occurring in the system. It is also one of the suitable watershed models for long-term impact analysis.

The major model components of SWAT are weather, hydrology, soil temperature, plant growth, nutrients, pesticides, and land management. One of the many advantages of SWAT is that it can be used to model watersheds with less monitoring data. It can also be used to assess predictive scenarios using alternative input data such as climate, land-use practices, and land cover on water movement, nutrient cycling, water quality, and other outputs.

For simulation SWAT needs basic input digital data of topography, land use/cover, soil properties and the weather and land management of a study area. They are used as an input for analysis of hydrological simulation of evapotranspiration, runoff and ground water recharge. To enable to deal with type of soils and soil properties without difficulty, SWAT divides the soil profile into multiple layers.

SWAT is designated to predict the impact of management on water sediment, nutrient and pesticide yields in ungauged watersheds (Arnold et al., 1994). It is physically based model and uses readily available inputs. It is an efficient tool for handling large amount of information in databases and computing. It can be used to predict and assess long term impacts on the hydrology of a watershed. It helps for simulating a high level of spatial detail by partitioning larger watersheds into smaller sub watersheds.

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SWAT simulates the hydrologic cycle based on the water balance equation:

$$SW_t = SW + \sum_{i=1}^{t}(R_i - Q_i - ET_i - P_i - QR_i)$$

Where:

SWt is the final soil water content (mm)

SW is the initial soil water content on day *i* (mm *H2O*)

t is the time (days)

Ri is the amount of precipitation on day *i* (mm *H2O*)

Qi is the amount of surface runoff on day *i* (mm)

ETi is the amount of evapotranspiration on day *i* (mm *H2O*)

Pi is the amount of water entering the vadose zone from the soil profile on day *i* (mm *H2O*)

and *QRi* is the amount of return flow on day *i* (mm *H2O*)

The SWAT model is widely used in the United States and in some European countries to solve water management problems. It has been used for a variety of applications, including water balance calculation, sediment transport and stream-aquifer interaction Guen, (2005). SWAT was integrated in GIS with ArcGIS 9.3. The different types of data required by the model were added, allowing the model to run. The calibration permitted the prediction of the behavior of the basin depending on different conditions. Sophocleous et al (2000). SWAT was combined with MODFLOW (Modular Three Dimensional Finite Difference Ground Water Flow Model). The results showed that SWAT distorted the shape of the watershed by using a mean distance of overland flow to the stream during transport processes. However, the study demonstrated that SWAT:

- Was capable of operating on a watershed scale with several sub-basins
- Allowed topographical, land use and management differences
- Was capable of simulating several management practices
- Could simulate long periods of time
- Could be calibrated through field testing

A study by Flay (2000) had the aim of understanding nitrate and phosphate dynamics in agricultural basins. It analyzed the ability of SWAT to model the effect of changes of land use patterns and practices. This study concluded on the main assets and drawbacks of SWAT. Major shortcomings:

- Extensive data input requirements
- Difficulties of selecting appropriate parameters for calculation
- Subjectivity of selecting coefficients
- Limitations in simulating short-term events

Despite the complexity of the model, major benefits include: SWAT is applicable to decision-making in land management and is able to model the impacts on water quality and quantity such as cropping patterns, fertilizer applications, pesticide applications and timing and amount of irrigation.

An important issue to consider in the prediction of hydrology, sediment yield and water quality is uncertainties in the predictions. The main sources of uncertainties are:

(I) Simplifications in the conceptual model. For example, the simplifications in a hydrologic model, or the assumptions in the equations for estimating surface erosion and sediment yield, or the assumptions in calculating flow velocity in a river,

(II) Processes occurring in the watershed but not included in the model. For example, wind erosion, soil losses caused by landslides,

(III) Processes that are included in the model, but their occurrences in the watershed are unknown to the modeler or unaccountable; for example, reservoirs, water diversions, irrigation, or farm management affecting water quality,

(IV) Processes that are not known to the modeler and not included in the model. These include dumping of waste material and chemicals in the rivers, or processes that may last for a number of years and drastically changes the hydrology or water quality such as constructions of roads, bridges, tunnels and dams, and

(V) Errors in the input variables such as rainfall and temperature.

Among the above mentioned models, the physically based distributed model SWAT is a well-established model for analyzing the impact of land management practices on water, sediment, and agricultural chemical yields in large complex watersheds. It is one of the watershed models for long term impact analysis. It is widely applied in many parts of United States and many other countries.

2.3 Previous investigations on land use changes assessment

The previous investigations on land use changes assessment have been studied in many parts of the world. Some important literatures have been briefly reviewed below in chronological order to be the background information.

Scott N. Miller et al. (2002) Modeled and estimated of the trends and direction of hydrologic watershed response due to land cover change are predicated on the chosen hydrologic model is sensitive to changes in the landscape, the input data are adequate and accurate and that observed changes are not artificial and River in Sonora, Mexico, and southeast Arizona. the model is responding to changes in cover correctly in the San Pedro River in Sonora, Mexico, and southeast Arizona. Simulation results for the San Pedro indicate that increasing urban and agricultural areas and the simultaneous invasion of woody plants and decline of grasslands resulted in increased annual and event runoff volumes, flashier flood response, and decreased water quality due to sediment loading. These results demonstrate the usefulness of integrating remote sensing and distributed hydrologic models through the use of GIS for assessing watershed condition and the relative impacts of land cover transitions on hydrologic response.

PIKOUNIS M. (2003) Investigates the hydrological effects of specific land use changes in a catchment of the river Pinios in Thessaly ,through the application of the Soil and Water Assessment Tool (SWAT) on a monthly time step. The model is used to simulate the main components of the hydrologic cycle, in order to study the effects of land use changes. All three scenarios resulted in an increase in discharge during wet months and a decrease during dry periods. The deforestation scenario was the one that resulted in the greatest modification of total monthly runoff.

Olan V.(2005) Distributed parameter model SWAT (Soil and Water Assessment Tool) was tested on monthly basis for estimating surface runoff from the Upper Nan River Basin, to determine the impacts of land use changes. The network of streams in the basin was delineated from the DEM data. Land uses data for the year 1977, 1994 and 2001 which shown significant land use changes in the watershed are utilized to classify the basin hydrologic response units (HRUs) for each case study. The comparison of each runoff series shows the impact of land use changes. Besides, three scenarios postulating changes in land uses, reforestation, agricultural and the urban expansions, are modeled and then used to assess the consequences on surface runoff. The results demonstrated that impacts on runoff can be clearly detected, and hence verify the applicability of using SWAT model in the planning and management of water resource of the river basin.

P. Thanapakpawin (2006) Conflicts between upland shifting cultivation, upland commercial crops, and lowland irrigated agriculture cause water resource tension in the Mae Chaem watershed in Chiang Mai, Thailand. They assess hydrologic regimes of the Mae Chaem River with land use changes. Three plausible future forest-to-crop expansion scenarios and a scenario of crop-to-forest reversal were developed based on the land cover transition from 1989 to 2000, with emphasis on influences of elevation bands and irrigation diversion. Basin hydrologic responses were simulated using the Distributed Hydrology Soil Vegetation Model (DHSVM).

Yu-Pin Lin (2006) developed an approach for simulating and assessing land use changes and their effects on land use patterns and hydrological processes at the watershed level is essential in land use and water resource planning and management. The study provided a novel approach that combines a land use change model, landscape metrics and a watershed hydrological model with an analysis of impacts of future land use scenarios on land use pattern and hydrology. The proposed models were applied to assess the impacts of different land use scenarios that include various spatial and non-spatial policies in the Wu-Tu watershed in northern Taiwan. Analysis results revealed that future land use patterns differed between spatial policies. The variability and magnitude of future hydrological components were significantly and cumulatively influenced by land use changes during the simulation period, particularly runoff and groundwater discharge.

B. Schmalz and N. Fohrer (2009) investigate how specific landscape features influence the SWAT model behavior. To access differences occur between landscapes features in comparison to mountainous or low mountain range catchments in the mesoscale catchments St¨or, Treene and Kielstau are located in Northern Germany. The results showed groundwater and soil parameters were found to be most sensitive in the studied lowland catchments and they turned out to be the most influential factors on simulated water discharge. The most sensitive parameter was the threshold water level in shallow aquifer for baseflow (GWQMN). In contrast, many studies of mountainous or low mountain range catchments show that the most sensitive parameters were the surface runoff parameters.

Zhi Li et al. (2009) assessed the impacts of land use change and climate variability on surface hydrology (runoff, soil water and evapotranspiration) in an agricultural catchment on the Loess Plateau of China during 1981-2000. Results indicated that SWAT proved to be a powerful tool to simulate the effect of environmental change on surface hydrology. The integrated effects of the land use change and climate variability decreased runoff, soil water contents and evapotranspiration. Both land use change and climate variability decreased runoff.

Pakorn Petchprayoon (2009) explore the impacts of LULC change, particularly urbanization, in the Yom River's discharge behavior and contribute to discussions regarding the nature of this impact in relation to floods in the Yom watershed in central–northern Thailand over a 15-year period using an integration of remote sensing, Geographic Information System, statistical methods, and hydrological modeling. The results demonstrated the impacts of changes in LULC on peak river discharge, hence flooding behaviour, of a major river in central–northern Thailand.

CHAPTER III

METHODOLOGY AND DATA PREPARATION

The sources of input data and the steps in image processing used remote sensing are comprehensively explained hereafter. These are the most cumbersome and time consuming steps of GIS and remote sensing techniques in this research. The prepared and processed thematic data that were used in this thesis will be mainly explained in this chapter. Meanwhile, phases of land use mapping analysis in GIS-based land use change detection techniques are also reviewed. Whereas, the detailed statistic analysis of the land use database and the parameter maps will be explained in the following chapter.

3.1 Phases of land use changes mapping analysis in Remote Sensing and GIS-based detection techniques

The following phases can be distinguished in the process of land use change analysis using GIS (Van Westen, 1993 and 1994 cited in Yumuang, 2005). They are listed in logical order or sequence though sometimes they may be overlapping (Figure 3-1) as follow:

- Preliminary phase:

  Phase 1: Defining of objective of study and the methods of analysis which will be applied.

- Data collection phases:

  Phase 2: Collection of existing data (collection of existing maps and reports with relevant data)

  Phase 3: Image interpretation (interpretation of images and creation of new input maps)

  Phase 4: Data base design (design of the database and definition of the way in which the data will be collected and stored)

Phase 5: Fieldwork (to verify the image interpretation)

Phase 6: Laboratory analysis

- GIS work:

  Phase 7: Data entry (digitizing of maps and attribute data)

  Phase 8: Data validation (validation of the entered data)

  Phase 9: Data manipulation (manipulation and transformation of the raw data in a form which can be used in the analysis)

  Phase 10: Data analysis and modeling (analysis of data for preparation of land use change maps)

  Phase 11: Presentation of output maps (final production of land use change maps and adjoining report)

An ideal Remote Sensing and GIS for land use analysis combines conventional GIS procedures with image processing capabilities and a relational data base. Map overlaying, modeling, and integration with satellite images are required, thus a raster system is preferred. The program should be able to perform spatial analysis on multiple-input maps and connected attribute data tables for map overlay, reclassification, and various other spatial functions.

3.2 Thematic data preparation from Remote Sensing and GIS techniques

Remote sensing data can be readily merged with other sources of geo-coded information as a GIS. This allows the overlapping of several layers of information with the remotely sensed data, and the application of a virtually unlimited number of forms of data analysis.

The input data used for land use changes detection in this thesis consists of several spatial data categories from the available resources (as shown in Table 3-1), being digitized from available maps and prepared from image interpretation, and from field investigation data. These input data will be further used to analyze the dynamic behavior of land use by the statistical analysis in the Chapter 4.

The brief techniques and thematic maps of the input data produced in this thesis, namely, elevation (slope and hill shade), hydrology, soil properties, land use, and meteorology are consequently presented as below.

Table 3-1 input data themes that were pre-processed and invented in this thesis.

Main themes	*Year*	*Sub-themes*	*Typs*	*Data preparation methodology*
Soil Group	2001	Soil texture	Shape file	Derived from 1:50,000 scale digital map of Land Development Department (LDD)
Hydrology	2004	Sub-basin	Shapefile	Derived from digital map of Water Resources Department
		Steam	Shape file	Derived from digital map of Water Resources Department
		Hydro Station	Attribute DATA	Royal Irrigation Department
DEM		Digital Elevation Model (DEM)	Grid	Derived from elevation data with GIS
Meteorology	1980 to 2009	Precipitation	Table .DAT	Interpolated from existing rainfall information of the observation stations of Thai Meteorological Department (TMD) Royal Irrigation Department
		Temperature Max-Min	Table	Interpolated from existing rainfall information of the observation stations of Thai Meteorological Department (TMD)
		relative humidity	Table	Interpolated from existing rainfall information of the observation stations of Thai Meteorological Department (TMD)
		Solar Radiation	Table	Interpolated from existing rainfall information of the observation stations of Thai Meteorological Department (TMD)
		Wind Speed	Table	Interpolated from existing rainfall information of the observation stations of Thai Meteorological Department (TMD)
		Meteorology Station	Attribute DATA	Interpolated from existing rainfall information of the observation stations of Thai Meteorological Department (TMD)
Land use	1988, 1995, 2003,2009	Land use	Shapefile	Derived from interpretation of remote sensing imageries and field investigation

3.3 Elevation

Instead of using a discrete elevation map such as contour points, it is more advantageous to work with a continuous map. Regarding this advantage, the contour data was converted into a color-coded continuous map (Digital Elevation Model-DEM). DEM is used to create a slope, aspect and landform topographic shape. In order to increase visual interception of DEM, it had been chosen to convert into a color-coded DEM (Figure 3-1).

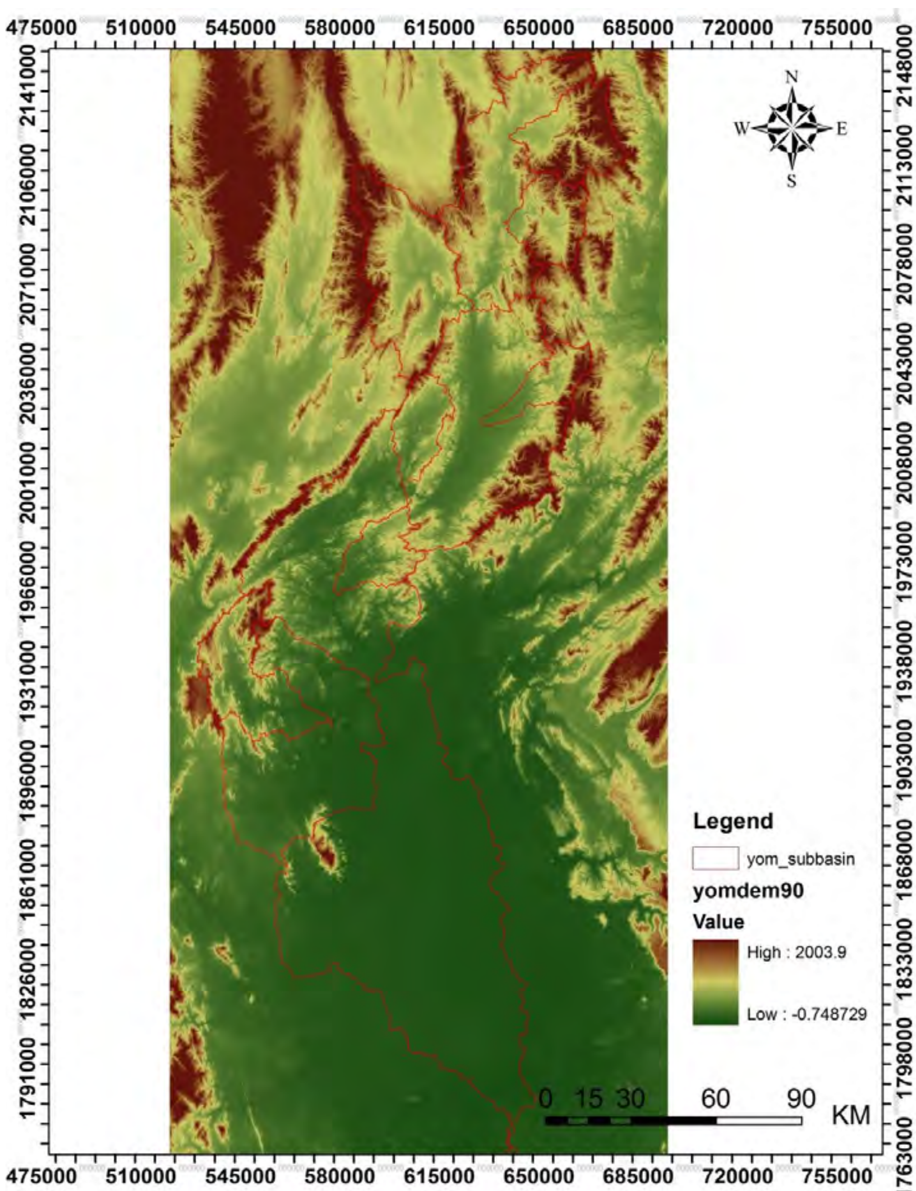


Figure 3-1 Color-coded DEM of the study area.

3.4 Hydrology

Analysis of water quantity use data from 23 measurement stations located in the Yom River basin from the Royal Irrigation Department (RID) Thailand. This study was conducted in two hydrology station ; Y.20 located in Song District, Phrea Province in the upper part of the basin, Y.14 in Si Satchanalai District, Sukhothai Province in the central–lower part of the basin.

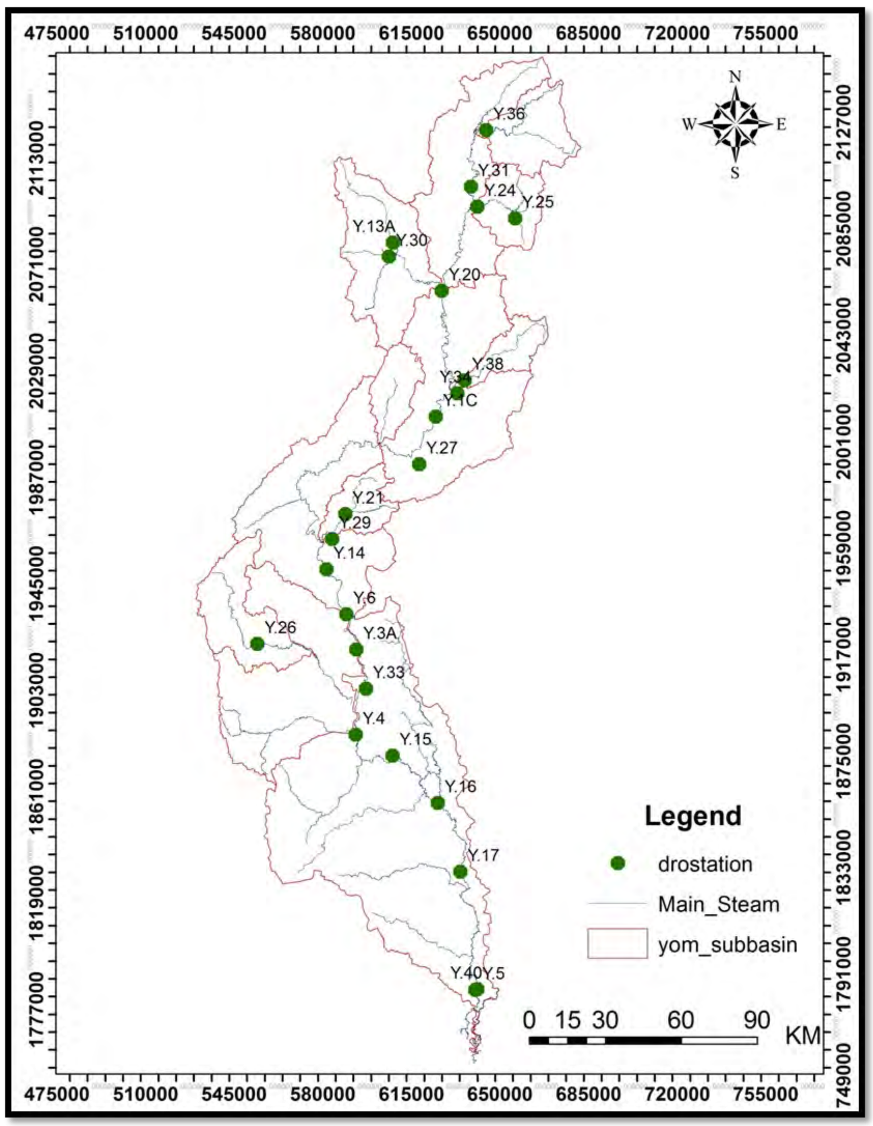


Figure 3-2 Hydrological measurement stations of the Royal Irrigation Department (RID) Thailand located in the Yom river basin.

3.5 Soil properties

The soil properties, was collected in a form of soil group 63 unit map of the study area prepared by compiling data from the available reports, publications, and analogue map of Land Development Department. The compiled analogue maps were transformed into digital image, via digitizing and edit using ArcMap GIS version 9.3 software. (as shown in Figure 3-6)

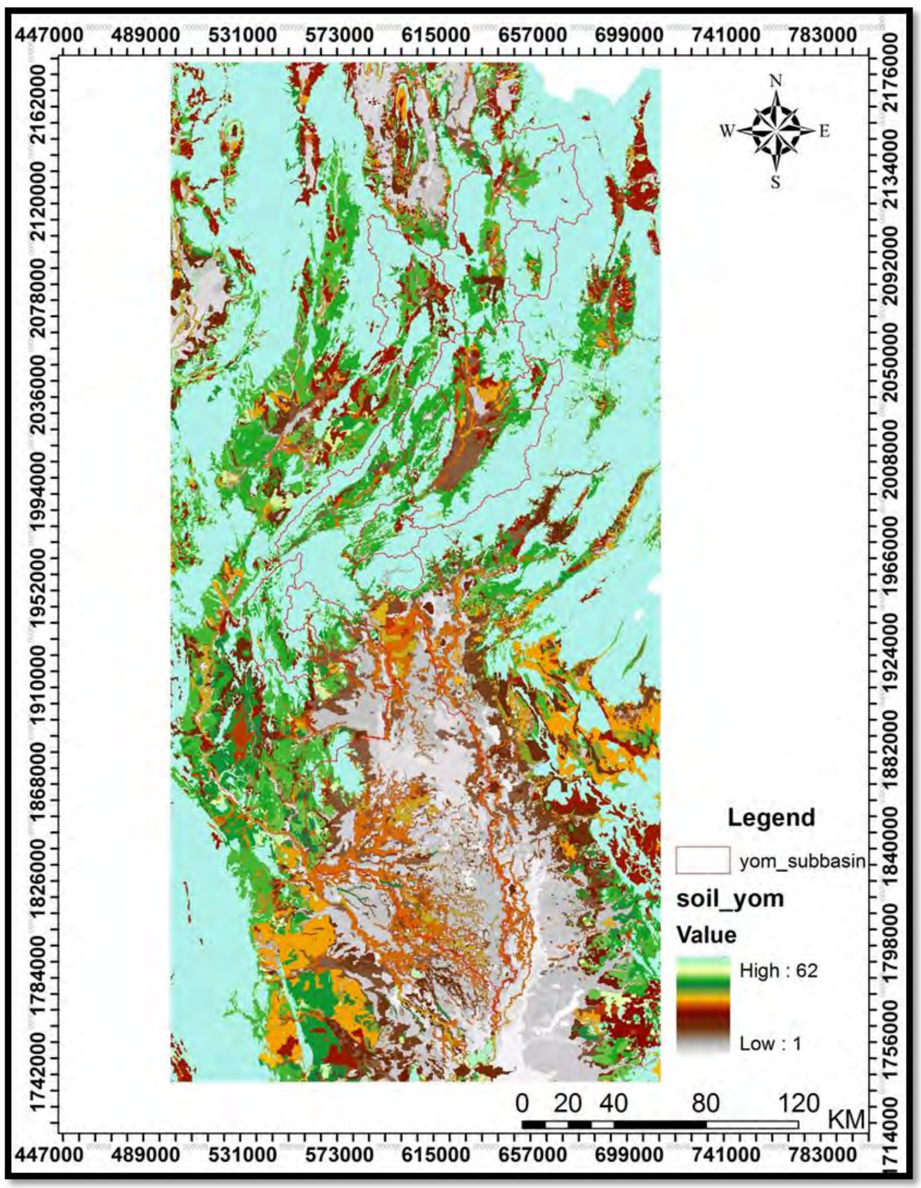


Figure 3-3 Color-coded DEM of the study area.

3.6 Geology

The Lower Yom River Basin is underlain by Pre-Cambrian Sedimentary and metamorphic rock (PE), Cambrian Sedimentary and metamorphic rock (E), Triassic Igneous rock (Trgr), Permian Ratburi Group (Pr), the younger unconsolidated sediments of Terrace deposits (Qt) and the sediments of Quaternary age also form in the alluvial fan as alluvial fan deposits (Qaf)

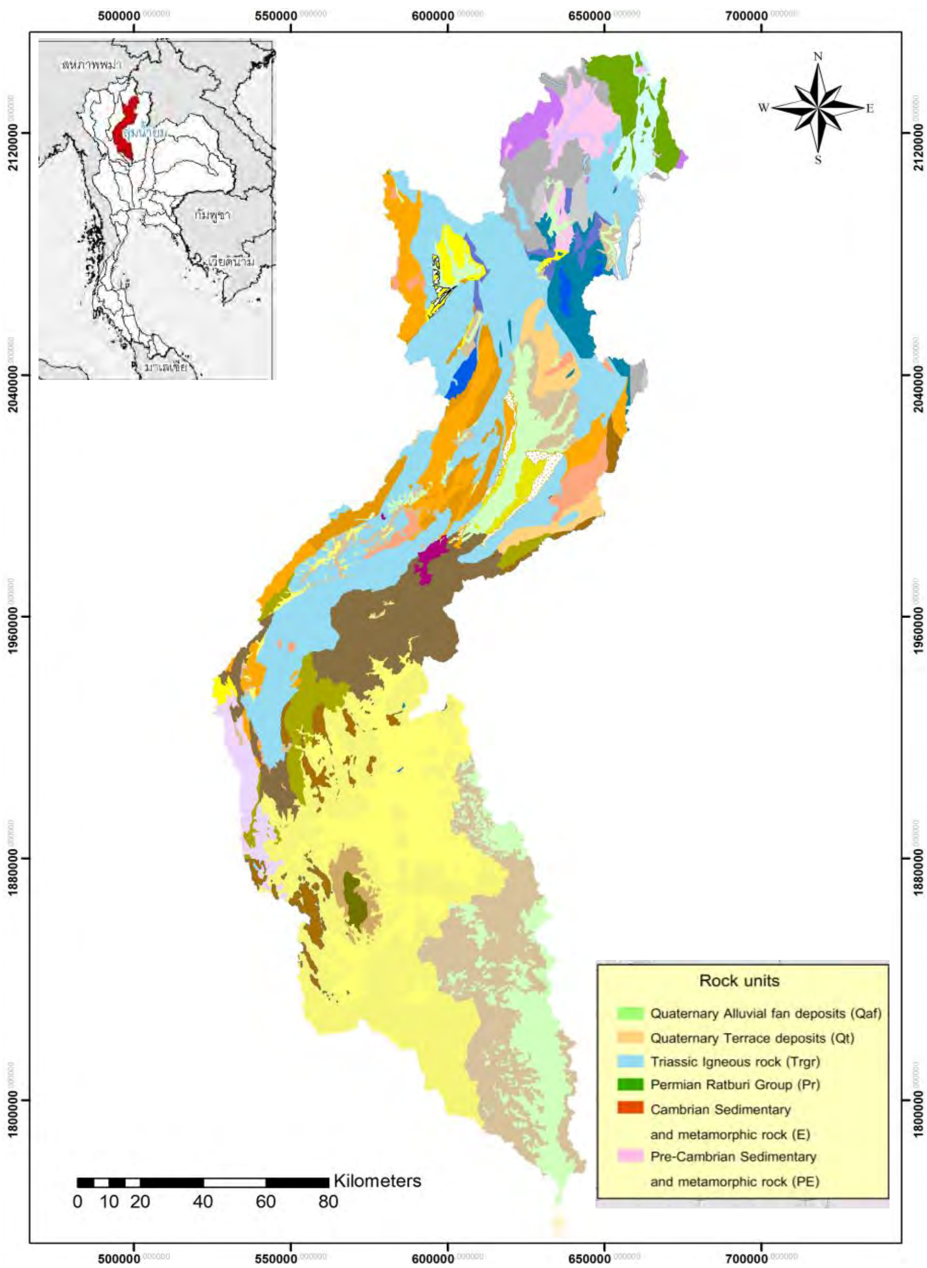


Figure 3-4 Geology map of the Yom river basin.

3.7 Meteorology

In this study, rainfall data were received from observation stations of Thai Meteorology Department during 1st January 1988 to 31st December 2009. Analysis of rainfall used data from 34 rain measurement stations located in the Yom river basin and nearby. Stations were located in Kamphaeng Phet , Lampang Province, Nakhon Sawan, Nan , Phichit, Phitsanulok, Phrae, Sukhothai, Tak, Uttaradit and Payoa.

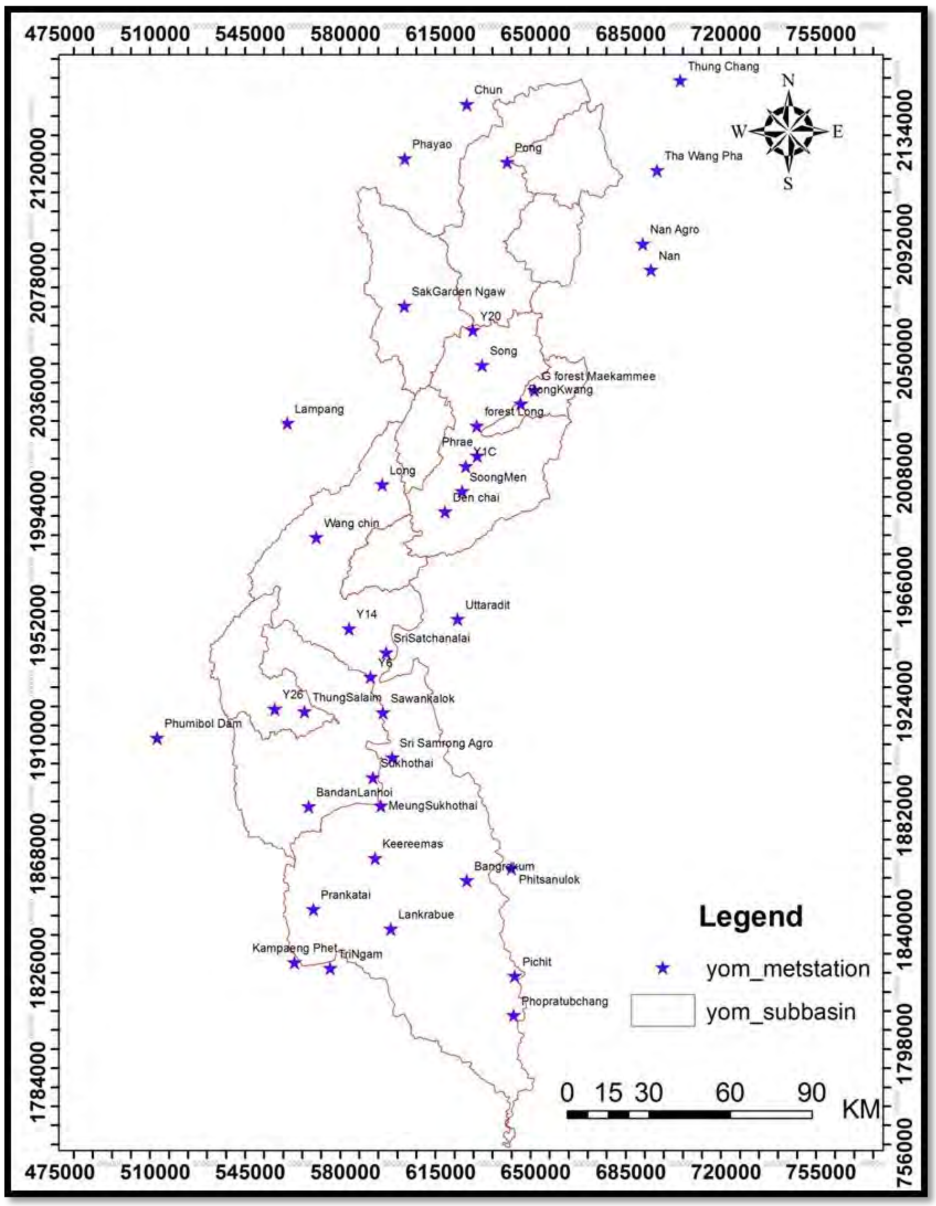


Figure 3-5 Meteorology Station of the Thailand Meteorology Department (TMD) located in the Yom river basin.

3.8 Land use

The land use classification system presented in this study includes only the more generalized first and second levels. The system satisfies the three major attributes of the classification process as outlined by Land Development Department (LDD) (2003) in conjunction with U.S. Geological Survey (USGS) (2007):

- It gives names to categories by simply using accepted terminology
- It enables information to be transmitted; and
- It allows inductive generalizations to be made.

The classification system is capable of further refinement on the basis of more extended and varied use. At the more generalized levels it should meet the principal objective of providing a land use and land cover classification system for use in land use planning and management activities. Attainment of the more fundamental and long-range objective of providing a standardized system of land use and land cover classification for national and regional studies will depend on the improvement that should result from widespread use of the system.

A systematic study of image interpretation usually involves several basic characteristics of features shown on an image. The elements of image interpretation are tone, color, size, shape, texture, pattern, site, height and association (Table 3-2). These are routinely used when interpreting a satellite images as shown in Figure 3-8 (Jensen and Kiefer, 2007). This study used satellite images Landsat 5TM in the years 1988, 1995, 2003 and 2009 representing the land use and then they were classified as 6 land use categories as shown in Table 3-3.

Table 3-2 Elements of Image Interpretation (Jensen and Kiefer, 2007).

No.	Interpretation elements	General characteristics
1	tone/ color	Relative brightness of black and white image and hue for colored pictures
2	size	Relative dimension of different objects
3	shape	Form also height of an object (in 3D)
4	texture	Relates to the frequency of tonal change and is expressed as coarse, fine, smooth or rough, even or uneven, etc
5	pattern	Spatial arrangement of objects and implies characteristic repetition of certain forms or relationship. It can be described as concentric, radial, check board, etc
6	site	Occurrence of an object to a particular easily identifiable feature
7	height	z-elevation, slop, aspect, volume
8	association	Close relationship/links of different or combination of objects.

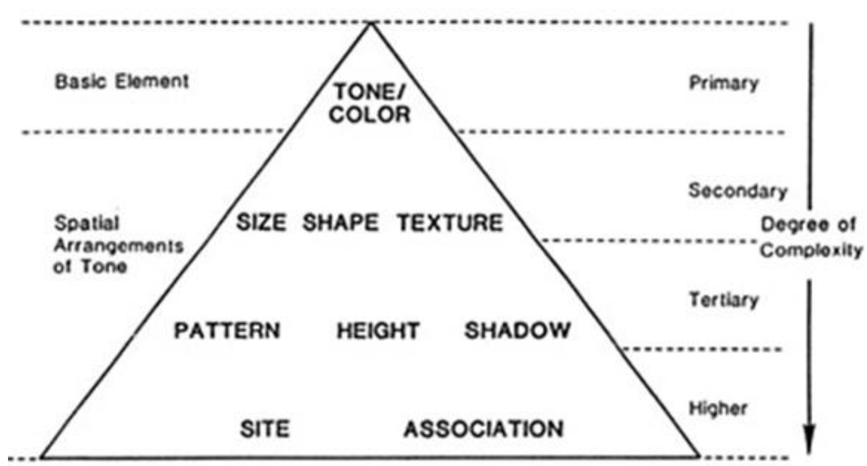


Figure 3-6 Primary ordering of image elements fundamental to the analysis process.

Table 3-3 Land use and land cover classification system (Land Development Department, LDD) used in remote sensing data interpretation in the Yom River Basin,

LU_CODE	
Level I	**Level II**
A Agricultural land	A01 Paddy field
	A02 Field crops
	A03 Perennial crops
F Forest land	F00 Forest land
W Water Bodies	W00 Water bodies
U Urban and built-up land	U00 Urban and built-up land

3.8.1 Data Sources

Remote sensing data used in this study comprises of Landsat 5TM satellite images in the year 1988, 1995, 2003 and 2007. These data will be used for land use change analysis and input for trend extrapolation to calculate land use requirements future year that will be further presented in Chapter 4. Table 3-4 showed the remote sensing data attribute and accessing periods that were used in this study.

Table 3-4 The remote sensing data attributes and accessing periods that were used in this study.

Image type	Path/Row	Acquisition date	Format	Source
Landsat 5TM Satellite Image resolution 25 m.	Path 130 Row 47 Band 5:4:3 (R:G:B) Path 130 Row 48 Band 5:4:3 (R:G:B) Path 130 Row 49 Band 5:4:3 (R:G:B)	2531-04-06	Image File	Geo-Informatics and Space Technology Development (GISTDA)
		2538-04-26		
		2546-11-10		
		2552-12-12		

3.8.2 Data Processing

Satellite imagery was analyzed using the program ERDAS Imagine version 8.7 to obtain the results for land use classification and grid interpolation. This study used ArcMap GIS version 9.3 for analyzing previous secondary data and classifying results. Digital data analysis techniques employed in this study involved the following two steps. The first step, image classification is the process of making quantitative decision from image data, grouping pixels of the image into classes to represent different physical object. The second step, the procedures of the classification consisted of unsupervised classification and supervised classification.

Unsupervised classification was performed using algorithm called the Iterative Self-Organizing Data Analysis Technique or ISODATA (Tou and Gonzalez, 1974 cited in Lillesand et. al., 2008). Performed an unsupervised classification with 30 clusters

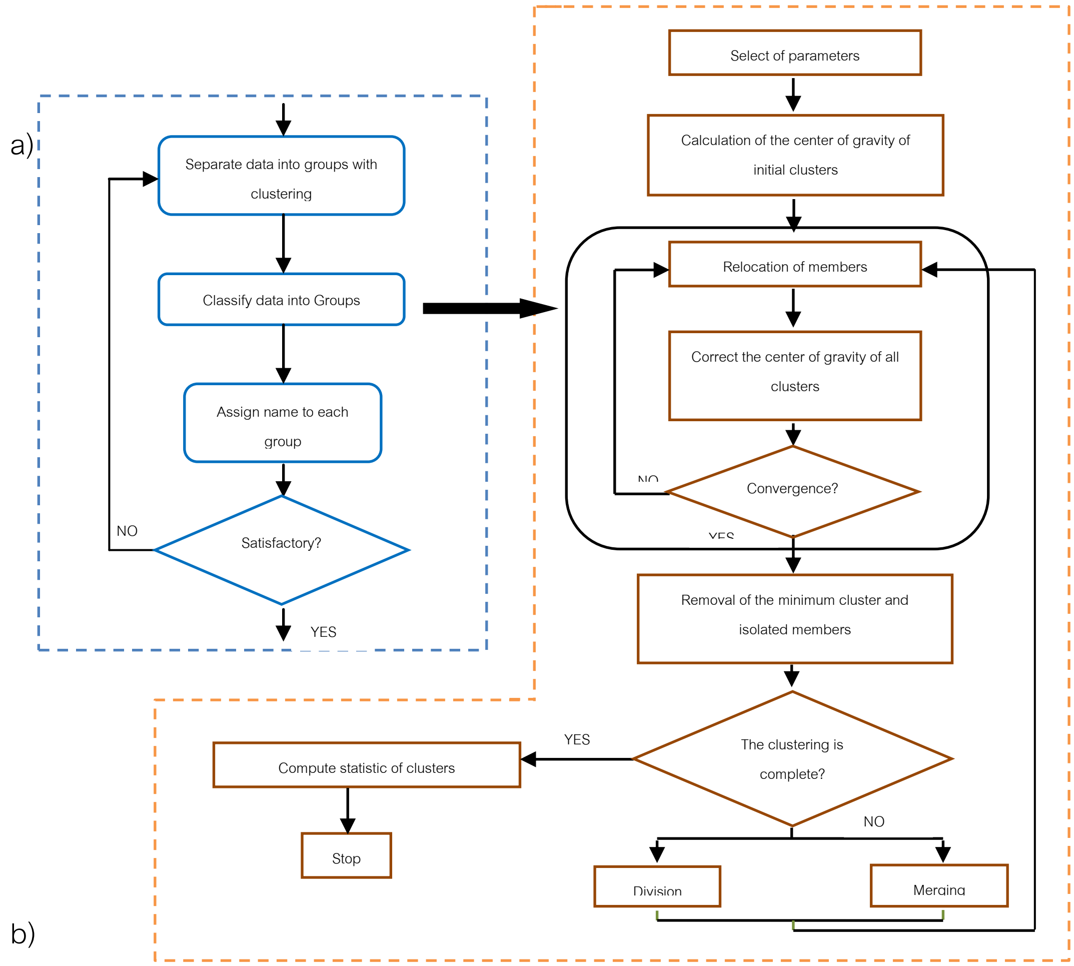


Figure 3-7 a) unsupervised classification.

b) Iterative Self-Organizing Data Analysis Technique (ISODATA).

Source: Adapted from F.F. Sabins (2007) cited in Lillesand et. al. (2008)

In unsupervised classification any individual pixel was compared to each discrete cluster to see which one it was closest to. A map of all pixels in the image, classified as to which cluster each pixel was most likely to belong, was produced (in black and white or more commonly in colors assigned to each cluster) as shown in Figure 3-6. This must be interpreted by the user as to what the color patterns may mean in terms of classes that were actually presented in the real world scene; this required some knowledge of the scene's feature/class/material content from general experience or personal familiarity with the area imaged (Lillesand et. al., 2008).

The supervised classification performed by the method of Maximum likelihood was to delineate a given pixel to the class that generated from the spectral signature analysis. For avoiding bias, each training area was not least than 30 pixels distributed around study area. In this study, land use was classified into 7 categories. The random samplings were rechecked by field observation convincing the correct classification as shown in Figure3-7.

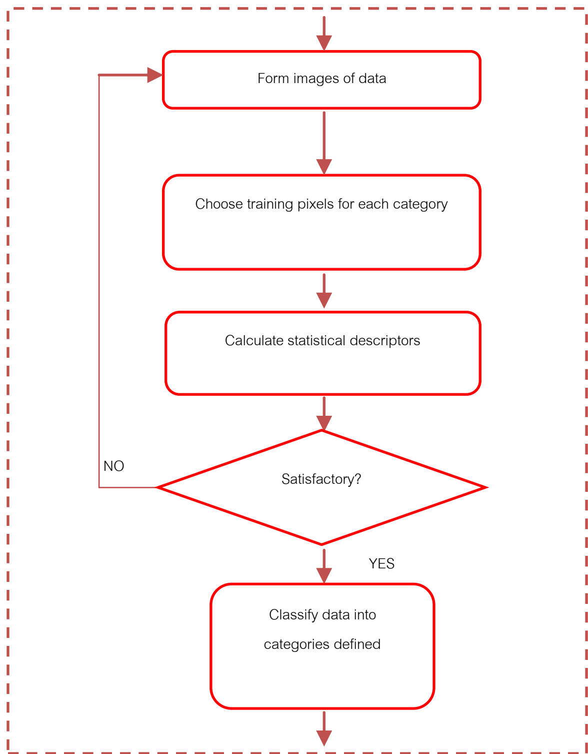


Figure 3-8 Supervised classification.

Source: Adapted from F.F. Sabins (2007) cited in Lillesand et. al. (2008)

Maximum likelihood classification (MLC) technique was employed to perform the classification of an unknown pixel. This technique had been found to be the most accurate procedure in quantitatively evaluate both the variance and correlation of the category spectral reflectance patterns. In this study land use was classified into seven categories based on vegetation characteristics and field investigation.

3.8.3 Accuracy assessment

A complete accuracy test of a classification map would be a verification of the class of every pixel. Obviously this is impossible and indeed defeats the purpose of the image classification. Therefore, representative test areas must be used instead to estimate the map accuracy with as little error as possible. Classified image accuracy consists of two accuracy types. Firstly, overall accuracy which represents the accuracy of the entire product and secondly, user's accuracy (or map accuracy) which a map user is interested in the reliability of the map in how well the map represents what be really on the ground.

Overall accuracy is the accuracy of total number of correctly classified pixels, defined as:

$$\text{Overall accuracy} = \sum_{i=1}^{k} x_{ij} / N \quad \text{(Equation 3-1)}$$

where

x_{ij} = a value of the contingency matrix for an element in column i row j

k = the number of classes

N = the total number of sampling cells

i = class i^{th} as classified by classified image

j = class j^{th} as classified by ground truth

The Kappa coefficient ($\hat{k}$ or KHAT) is a measure of the difference between the actual agreement between reference data and an automated classifier and the chance agreement between the reference data and a random classifier (Lillesand et. al, 2008). Conceptually, $\hat{k}$ can be defined as

$$\hat{k} = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+} \cdot x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+} \cdot x_{+i})} \quad \text{(Equation 3-2)}$$

where

r	=	number of rows in the error matrix
x_{ii}	=	number of observations in row i and column i (on the major diagonal)
x_{i+}	=	total of observations in row i (shown as marginal total to right of the matrix)
x_{+i}	=	total of observations in row i (shown as marginal total at bottom of the matrix)
N	=	total number of observations included in matrix

Qualitative classification of overall accuracy value and Kappa coefficient value as degree of agreement (USGS, 1971 and 2007)

< 0	Less than chance agreement
0.01-0.40	Poor agreement
0.41-0.60	Moderate agreement
0.61-0.80	Substantial agreement
0.81-1.00	Almost perfect agreement

3.9 Runoff Simulation

3.9.1 Modeling the effects of land use changes on river runoff

The differences between river runoff response before and after land use changes were examined under similar precipitation conditions by using SWAT hydrological model. SWAT (Soil and Water Assessment Tool) is a semi-distributed model capable to simulate runoff, nutrients and other agricultural chemicals as well as sediment yield in large complex watersheds with varying soils, land use, and management conditions. Evapotranspiration is calculated here after Penman-Monteith, snow melt with the degree day method, infiltration based on the SCS curve number method, runoff transformation using a surface runoff lag method and flood routing is calculated with the variable storage method. Here, SWAT version 2009 is used.

To capture the potential effects of land use changes on runoff, the model was run for 22-years study period (1988-2009). Annual runoff of 1988-1989 and land use map of 1988 were used for model calibration and annual runoff of 2008 -2009 and land use map of 2009 were used for model validation. The precipitation data were used for each model run to determine if changes in river runoff were indeed due to changes in land use. Differences in river runoff, and the associated changes in model parameters, were therefore associated with changes in land use. The influences of the land use changes were quantified by comparing the SWAT output of the 8 scenario as follows:

- Scenario 1 : 1988 land use and 1988-1989 climate (calibration)
- Scenario 2 : 1995 land use and 1995-1996 climate (calibration)
- Scenario 3 : 2003 land use and 2002-2003 climate (validation)
- Scenario 4 : 2009 land use and 2008-2009 climate (validation)

- Scenario 5 : 1988 land use and 2008-2009 climate
- Scenario 6 : 1995 land use and 2008-2009 climate
- Scenario 7 : 2003 land use and 1988-1989 climate
- Scenario 8 : 2009 land use and 1988-1989 climate

3.9.2 Sensitivity analysis

In order to make calibration processes, it was crucial to find out the sensitive parameters using sensitivity analysis. Sensitivity analysis is important for a model to reduce the number of model parameters for calibration and to examine the more sensitive parameters, which in turns determines the main causes of river runoff from different practices and physical conditions.

Results of sensitivity analysis showed that sensitive parameters for the watershed were curve number (CN2), soil evaporation compensation factor (ESCO), Base flow alpha factor (ALPHA_BF/Days), Threshold water depth in the shallow aquifer for flow (GWQMN/mm), Available water capacity (SOL_AWC /mm water/mm soil), Threshold depth of water in shallow aquifer for "REVAP" to occur (REVAPMN/mm) and Groundwater "REVAP" coefficient (GW_REVAP/mm). These parameters were used for calibration.

CN2 determines the partitioning of precipitation between surface runoff and infiltration as a function of soil hydrologic group, land use, and antecedent moisture condition (Mishra and Singh 2003). ESCO adjust the depth distribution for evaporation from soil to account for the effect of capillary action, crusting, and cracking (Neitsch et al. 2002). GWQMN are correlated to base flow and that could be the reason for their higher ranking in the sensitivity analysis. ALPHA_BF is a direct index of groundwater flow response to changes in recharge. REVAPMN are Decreased to lowest suggested value by calibration tips in order to reduce base flow. The maximum amount of water that will be removed from the aquifer via revap is correlated by the REVAP coefficient (GW_REVAP) and the potential evapotranspiration (Neitsch et al., 2005).

3.9.3 Model calibration and validation

Model calibration is often important in hydrologic modeling studies, since uncertainty in model predictions can be increased if models are not properly calibrated. Calibration is tuning of model parameters based on checking results against observations to ensure the same response over time. This involves comparing the model results, entered with the use of historic meteorological data, to recorded stream flows. In this process, model sensitive parameters varied until recorded flow patterns are accurately simulated. Model calibration can be done manually or by a combination of manual and automatic. For this study manual calibration was applied. The calibration was carried out using the output of the sensitivity analysis of the model and by changing the sensitive parameter at a time while keeping of the rest of the parameters constant. Initial values were already assigned by the model itself and parameters which are then optimized manually. Calibration was performed until the predicted and observed results were visibly close. The parameter changes during calibration process was showed in Table 3-6.

Table 3-5 List of all general parameter changes during calibration process.

Parameter	code	Units	Original	Change
Initial SCS curve number for moisture condition II	CN2	-	-	*0.5-0.6
Soil evaporation compensation factor	ESCO	-	0.95	0.05
Available water capacity of the soil layer	SOL_AWC	mm/mm	-	*1.4-1.8
Base flow alpha factor	ALPHA_BF	days	0.048	0.08
Threshold depth of water in shallow aquifer for return flow to occur	GWQ_MN	mm	0	20
Threshold depth of water in shallow aquifer for "REVAP" to occur	REVAPMN	mm	1	0
Groundwater "REVAP" coefficient	GW_REVAP		0.02	0.03

Calibration and validation of SWAT model is typically performed with data collected at the hydrological stations of the Yom River. This study was conducted in two hydrology station; Y.20 located in Song District, Phrea Province in the upper part of the basin, Y.14 in Si Satchanalai District, Sukhothai Province in the central–lower part of the basin. SWAT was executed for a total simulation period of 22 years, which includes 1988-1996 as a calibration period and 2002-2009 as a validation period. The simulated flow was calibrated manually using the separated observed surface flow gauged at the outlet of the sub watershed. It was calibrated temporally by making delicate adjustments to ensure best fitting of the simulated flow curves with the gauged flow curves. Manipulation of the parameter values were carried out within the allowable ranges recommended by SWAT developers.

The methods of quantitative assessment for the goodness of model fit are the Coefficient of determination (R^2, R-square) of monthly discharges. The Coefficient of determination is also reported for quantifying the volume errors, and bias is the percent error in total stream discharge.

$$R^2 = SSR/SST \qquad \text{(Equation 3-2)}$$

where SSR is the sum-of-squares of the residuals,

and SST is the total sum-of-squares is the sum of the squares of the distances from a horizontal line through the mean of all Y values.

The goodness-of-fit statistics was used in describing the model's performance relative to the observed data. The goodness of fit that was quantified by the coefficient of determination (R^2) between the observations and the final best simulations. Coefficient of determination (R^2) coefficient values close to zero it indicates that the model performance was unacceptable or poor and the model performance as satisfactory if the correlation coefficient was greater than 0.5.

The regression coefficient (R^2) was 0.85 and 0.84, respectively for the calibrated results, these show that the model performance was good and in the acceptable limit. The purpose of the validation was to observe visually how much the simulated pattern seems to be the measured one. The remaining reserved data from 2008-2009 was used for model validation. The process continues till simulation of validation-period stream flows confirm that the model performs satisfactorily.

After the model is validated, the application of statistical on Figure 15 shows that the regression coefficient (R^2) resulted 0.69 and 0.77, respectively . These results indicated that the model performance is very good and highly acceptable.

CHAPTER IV

ANALYSIS AND RESULTS

This chapter mainly presents the results of overall analysis, including analysis of land use changes, result of relationship between land use changes and river runoff in the Yom River Basin. The first part of this chapter explained the result of dynamic spatial patterns of land use changes. The second part is relationship between land use changes and river runoff in the Yom River Basin. All of the results in this chapter will be further discussed and finally concluded in Chapter 5.

4.1 Land use classification in the year 1988, 1995, 2003 and 2007 in The Yom River Basin

According to the land use classification processes by Landsat 5TM satellite images, there were 6 land use categories were identified, namely, paddy field, field crops, perennial, forest, urban and built-up land, and water bodies. The trends of land use changes of the area during 1988-2009 were presented in Table 3-8 and Figure 3-11. The areal distributions and locations of land use categories were presented in the Figure 3-12 to 3-17.

Table 4-1 Land use classification in the Yom River Basin by Landsat 5TM satellite images in the year 1988, 1995, 2003 and 2009.

LAND USE	1988 (Sq.km)	1988 (%)	1995 (Sq.km)	1995 (%)	2003 (Sq.km)	2003 (%)	2009 (Sq.km)	2009 (%)
Paddy Field	6237.16	26.04	6904.51	28.83	6118.47	25.55	6334.18	26.45
Field Crop	2791.91	11.66	2999.03	12.52	3914.12	16.34	3458.88	14.44
perennial	892.17	3.73	603.70	2.52	611.94	2.56	1166.55	4.87
Forest	13133.61	54.84	12562.77	52.46	12308.98	51.40	11710.94	48.90
Urban	701.88	2.93	768.36	3.21	893.96	3.73	998.18	4.17
Water	191.42	0.80	109.78	0.46	100.68	0.42	279.43	1.17
Total	23948.15	100.000	23948.15	100.00	23948.15	100.00	23948.15	100.00

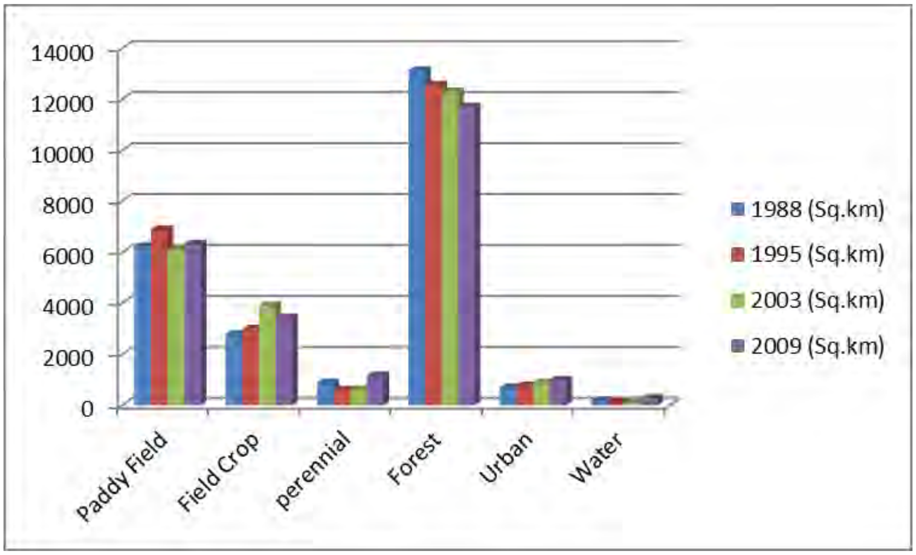


Figure 4-1 Graphs showing the areal distributions of land use categories in the Yom River Basin during 1988-2009.

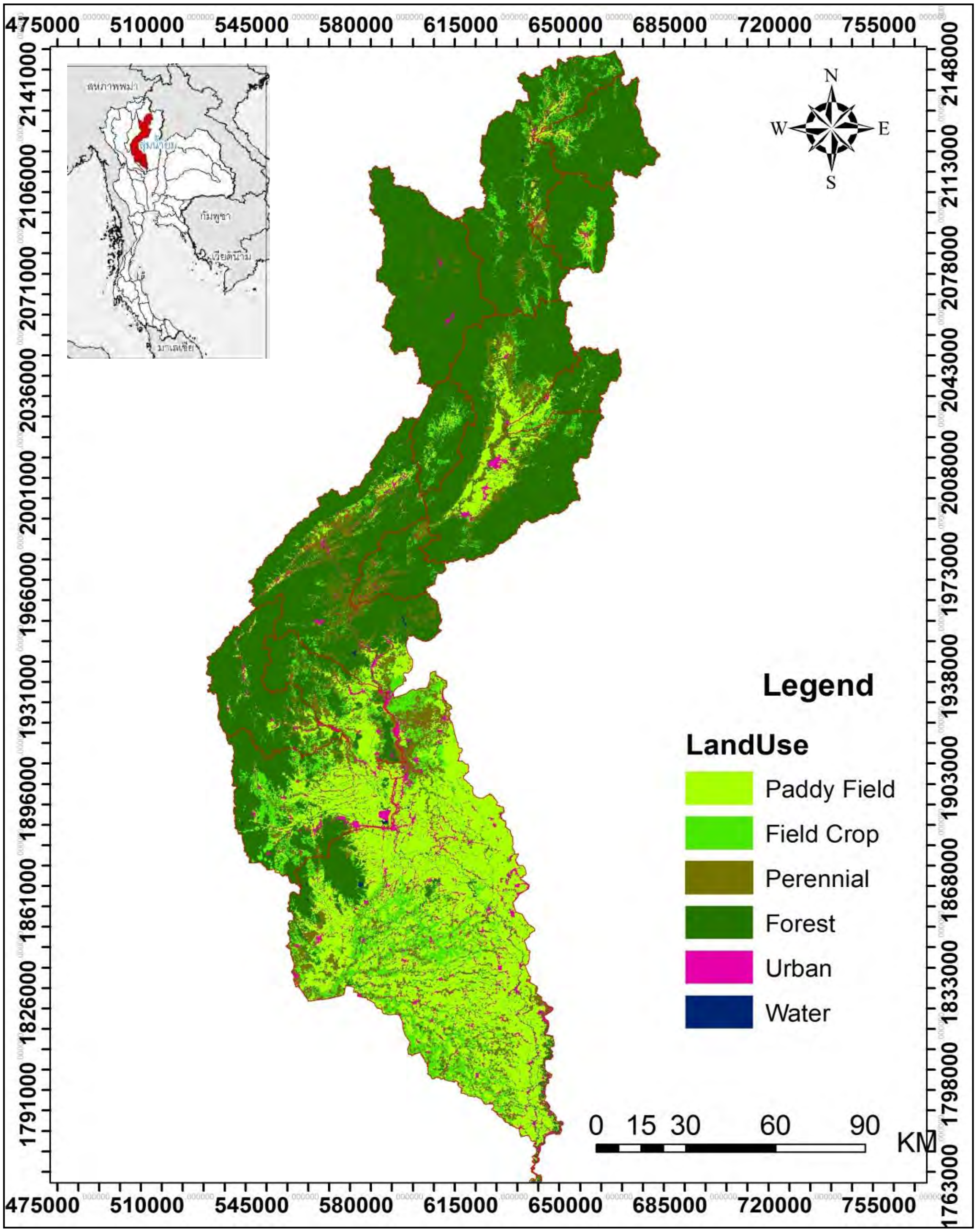


Figure 4-2 Land use Classification of land use categories in Yom River Basin in 1988.

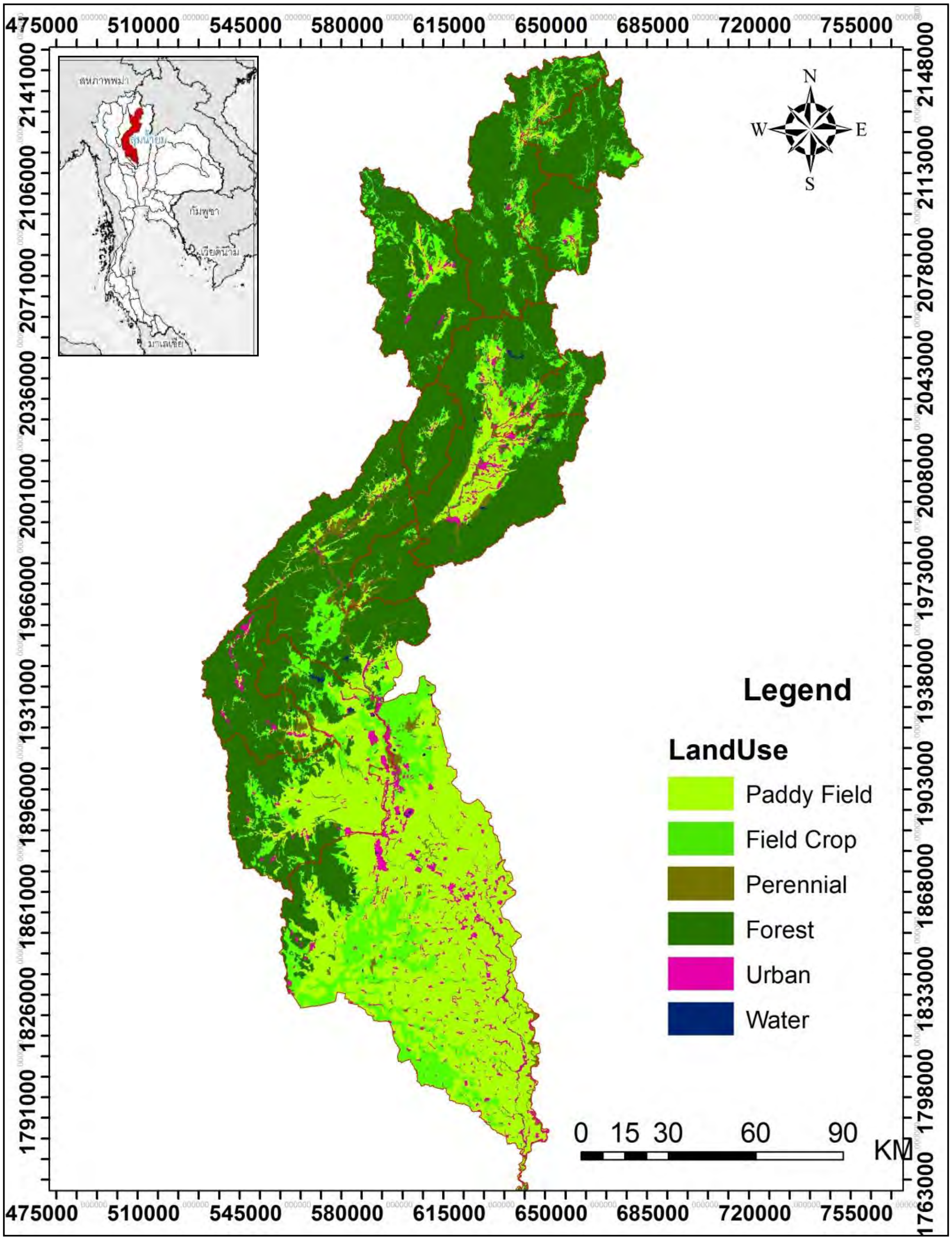


Figure 4-3 Land use Classification of land use categories in Yom River Basin in 1995.

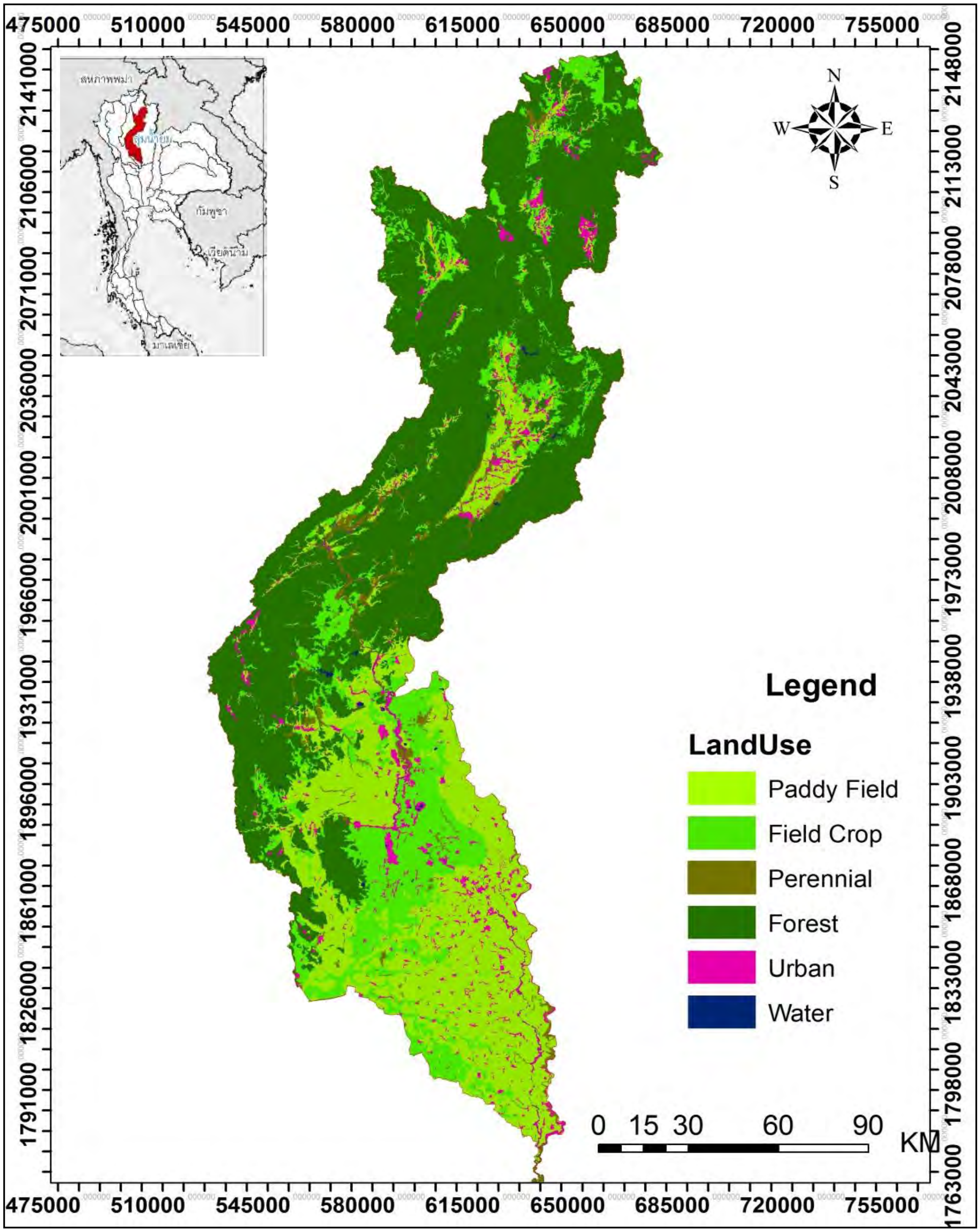


Figure 4-4 Land use Classification of land use categories in Yom River Basin in 2003.

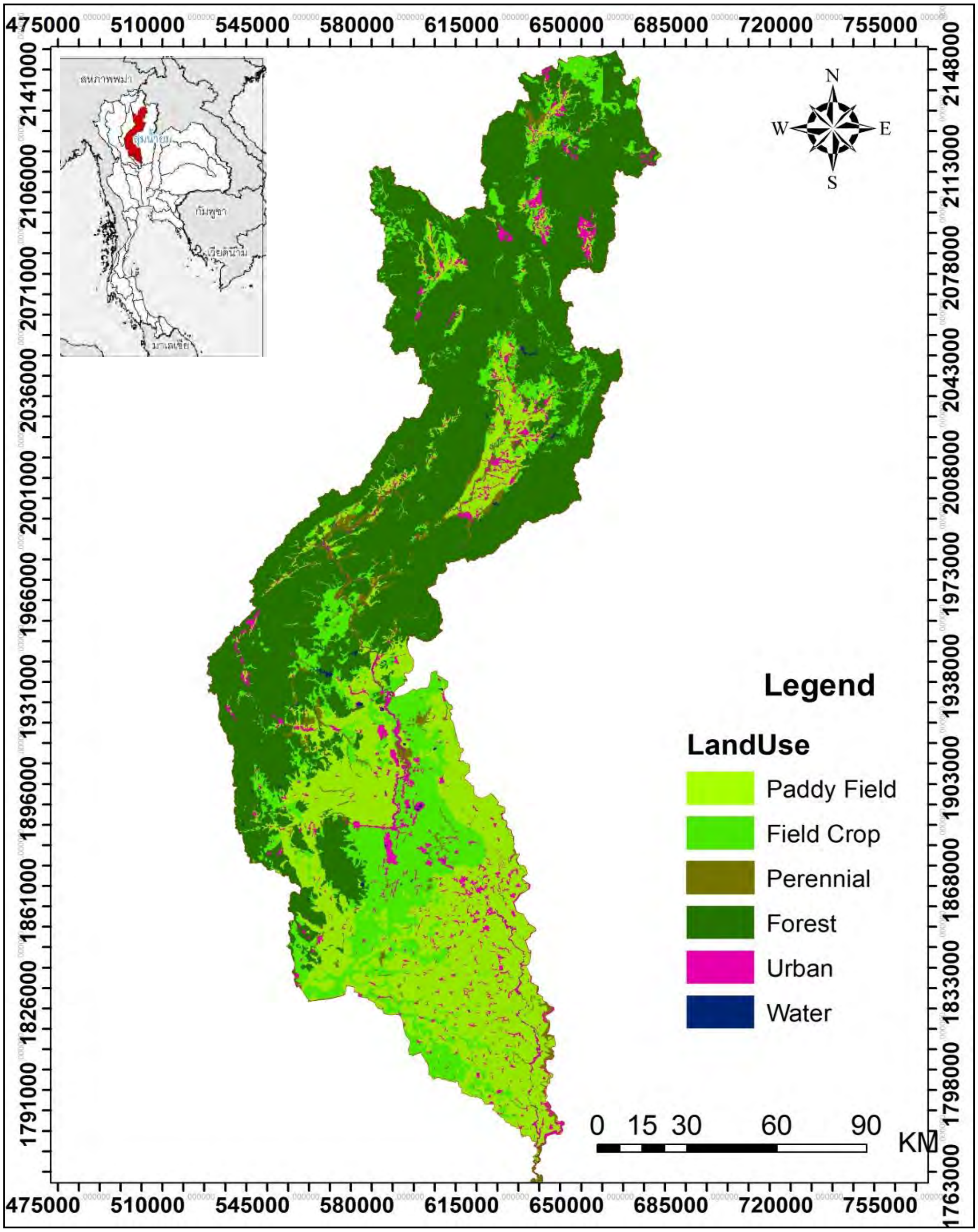


Figure 4-5 Land use Classification of land use categories in Yom River Basin in 2009.

4.2 Dynamic spatial patterns of land use changes in the Yom River Basin

The combination bands (R:G:B = 5:4:3) of Landsat 5TM in 1988, 1995, 2003 and 2009 with supervised classification process were used for land use classification. The classification of land use categories in the Yom River Basin was presented in Chapter 3.7.3. This part showed dynamic spatial patterns of land use changes that were interpreted from Landsat 5TM satellite images in the year 1988, 1995, 2003 and 2009.

Change detection technique was calculated cross-tabulated areas between two datasets. This approach used the Tabulate Areas tool in ArcMap GIS version 9.3 to produce a cross-tabulation table and Microsoft Excel for graphing. This was used to compare and calculate coincident areas. As an example, using Tabulate Area, one could calculate the area of each land use category in each zoning district. The first input was a land use raster, and the second was zoning (ESRI, 2010).

Detecting of land use changes in the Yom River Basin was conducted by import map of land use in the year 1988, 1995, 2003 and 2009 into GIS database as raster format to overlay with land use map for all 4 years by using tabulate area, the Raster Calculation and intersection technique and intersection in spatial analysis. Land use area for each type was calculated and compared the changing during year 1988 to 1995, year 1995 to 2003 and 2003 to 2009 with the application of cross classification (Figure 4-1).

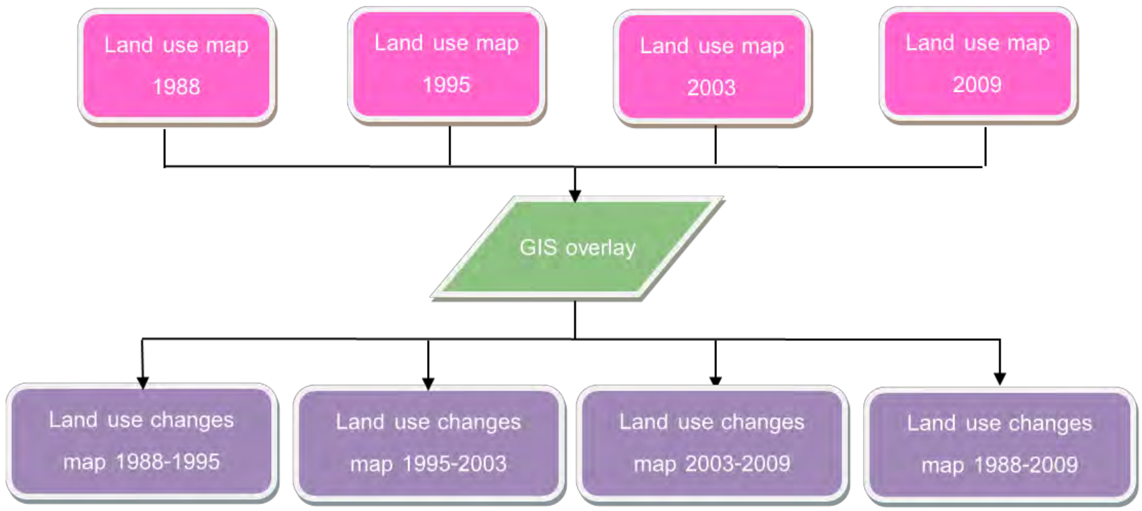


Figure 4-6 Method for land use changes analysis.

Estimation of land use changes was employed on three independent classification results with different time, which were classified results of Landsat 5TM in the year 1988, 1997 and 2007. The change estimation technique is used for identifying the "from-to" change of land use and quantifying the different rates and magnitude of change. The formula to calculate the annual change of land use was:

$$\Delta = \left(\frac{A_2 - A_1}{A_1} \times 100 \right) / \left(T_2 - T_1 \right) \quad \text{(Equation 4-1)}$$

where

Δ = Average annual rates of change (%)

A_1 = Amount of land use category in time 1 (T_1)

A_2 = Amount of land use category in time 2 (T_2)

Land use maps were derived from classification of Landsat 5TM image in the year 1988, 1995, 2003 and 2009. In this study, the images were reclassified in 4 classes (90 x 90 m raster grid resolution) as shown in Figure 4-2. The results of the comparison study on land use changes during 1988 to1995, 1995 to 2003, and 2003 to 2009

The result revealed that the change detection for the land use classification in the year 1988, 1997 and 2007, it could be seen that agricultural land, and urban and built-up land were increasing over time, whereas forest land tended to decrease. Besides, water bodies tended to increase in the year 1997 and decrease in the year 2007 because Thap Salao dam was constructed. The trends of land use changes of the area during 1988-2007 were presented in Table 4-1 and Figure 4-3.

Table 4-2 Comparative land use class 1 in the Yom River Basin in the year 1988, 1995, 2003 and 2009.

LAND USE	1988		1995		2003		2009	
	(Sq.km)	(%)	(Sq.km)	(%)	(Sq.km)	(%)	(Sq.km)	(%)
Paddy Field	6237.16	26.04	6904.51	28.83	6118.47	25.55	6334.18	26.45
Field Crop	2791.91	11.66	2999.03	12.52	3914.12	16.34	3458.88	14.44
perennial	892.17	3.73	603.70	2.52	611.94	2.56	1166.55	4.87
Forest	13133.61	54.84	12562.77	52.46	12308.98	51.40	11710.94	48.90
Urban	701.88	2.93	768.36	3.21	893.96	3.73	998.18	4.17
Water	191.42	0.80	109.78	0.46	100.68	0.42	279.43	1.17
Total	23948.15	100.000	23948.15	100.00	23948.15	100.00	23948.15	100.00

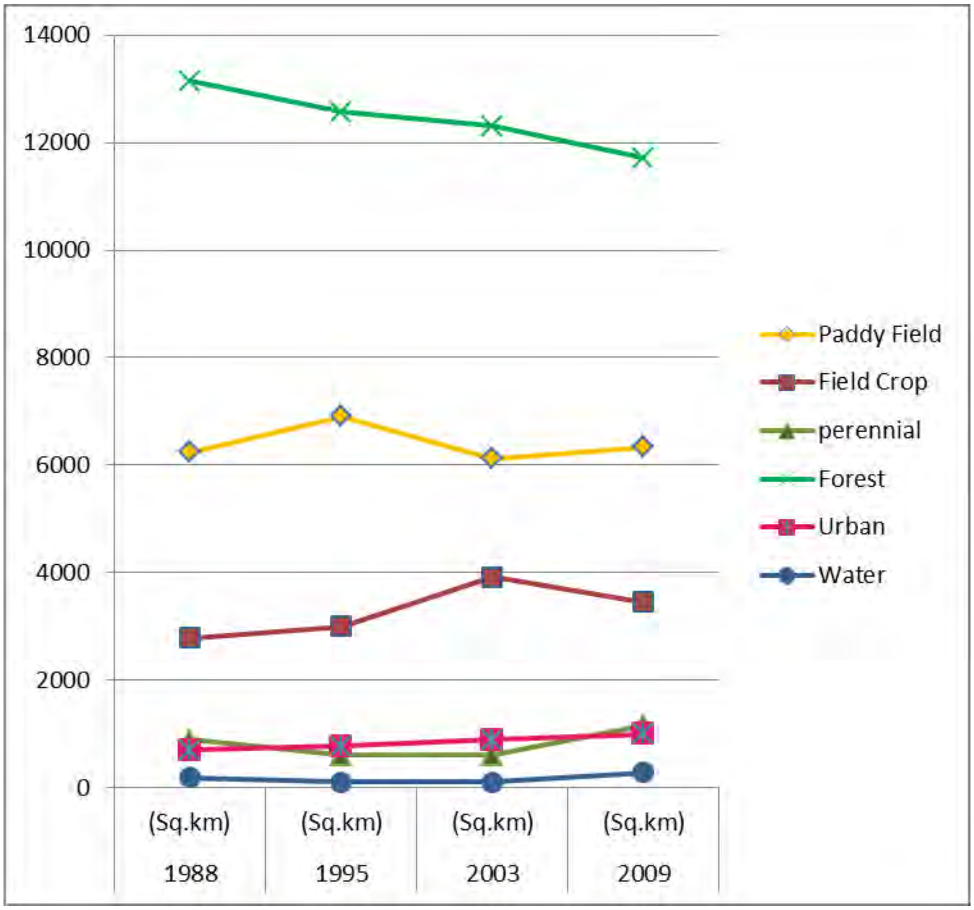


Figure 4-7 Graph showing trend (in percentage) of land use changes in the Yom River Basin during 1988 to 2009.

4.2.1 Land use changes in Upper Part of Yom Sub-basin

4.2.1.1 Land use changes in Upper Part of Yom Sub-basin during 1988 to 1995

Agricultural land was increased with an area of 93.4km^2 or 4.42 of the sub-basin area , paddy field1 14.95 km^2 or 0.71%, field crop 71.80 km^2 or 3.40% and perennial 7.27 km^2 or 0.34%. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 109.24 km^2 or 5.17% of the sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 93.4 km^2 or 4.42 %, followed by water bodies area with an area of 8.10 km^2 or 0.38 % and urban and built-up land with an area of 7.12 km^2 or 0.34 %, respectively.

Urban and built-up land was increased with an area of 18.01 km^2 or 0.85 % of the sub-basin area. Furthermore, the most of urban and built-up land was transformed form agricultural land 10.88 km^2 or 0.52%, followed by forest land 7.12 km^2 or 0.34 %, respectively.

Water body area was increased with an area of 8.10 km^2 or 0.38% of the sub-basin area. The most of water body area were transformed form forest land.

4.2.1.2 Land use changes in Upper Part of Yom Sub-basin during 1995 to 2003

Agricultural land was increased with an area of 202.53 km^2 or 9.58 % of the sub-basin area, paddy field1 18.57 km^2 or 0.88 %, field crop 171.71 km^2 or 8.13 % and perennial 12.25 km^2 or 0.58 %. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 233.97 km^2 or 11.07 % of the sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 202.53 km^2 or 9.58 %, followed by water bodies area with an area of 3.48 km^2 or 0.16 % and urban and built-up land with an area of 27.96 km^2 or 1.32 %, respectively.

Urban and built-up land was increased with an area of 65.56 km^2 or 3.10 %, of the sub-basin area. Furthermore, the most of urban and built-up land was transformed form agricultural land 37.60 km^2 or 1.78 %, followed by forest land 27.96 km^2 or 1.32 %, respectively.

Water bodies area was increased with an area of 3.48 km^2 or 0.16 % of the sub-basin area. The most of water bodies area were transformed form forest land

4.2.1.3 Land use changes in Upper Part of Yom Sub-basin 2003 to 2009

Agricultural land was increased with an area of 119.06 km^2 or 5.63% of the sub-basin area, paddy field1 4.60 km^2 or 0.22%, field crop 95.45 km^2 or 4.52% and perennial 20.01km^2 or 0.95%. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 126.22 km^2 or 5.97% of the sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 119.06 km2 or 5.63% followed by water bodies area with an area of 3.37 km^2 or 0.16% and urban and built-up land with an area of 2.79 km^2 or 0.13%, respectively.

Urban and built-up land was increased with an area of 12.40 km^2 or 0.59%, of the sub-basin area. Furthermore, the most of urban and built-up land was transformed form agricultural land 9.61km^2 or 0.45%, followed by forest land 2.79km^2 or 0.13%, respectively.

Water bodies area was increased with an area of 3.37km^2 or 0.16% of the sub-basin area. The most of water bodies area were transformed form forest land

4.2.1.4 Land use changes in Upper Part of Yom Sub-basin during 1988 to 2009

Agricultural land was increased with an area of 142.80 km^2 or 6.76 % of the sub-basin area, paddy field 13.37 km^2 or 0.63 %, field crop 116.62 km^2 or 5.52 % and perennial 12.81 km^2 or 0.61 %. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 161.61 km^2 or 7.65 % of of the sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 142.80 km^2 or 6.76 %, followed by water bodies area with an area of 4.99 km^2 0.24 % and urban and built-up land with an area of 13.82 km^2 or 0.65 %, respectively.

Urban and built-up land was increased with an area of 34.52 km^2 or 1.63 %, of the land use area. Furthermore, the most of urban and built-up land was transformed form agricultural land 20.70 km^2 or 0.98 %, followed by forest land 13.82 km^2 or 0.65 %, respectively.

Water bodies area was increased with an area of 4.99 km^2 0.24% of the sub-basin area. The most of water bodies area were transformed form forest land

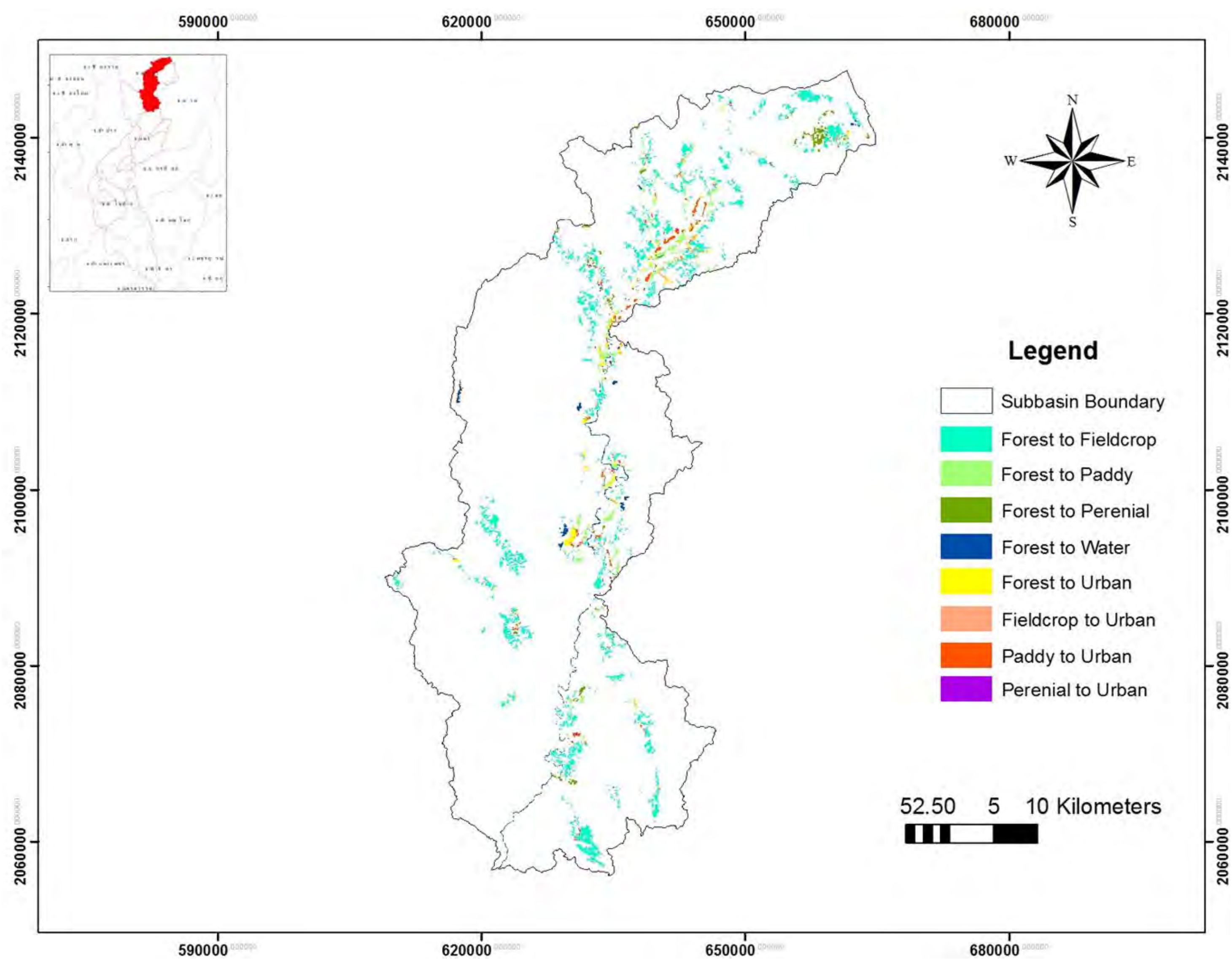


Figure 4-8 Change detection map of Upper Yom Sub-basin from 1988 to 1995

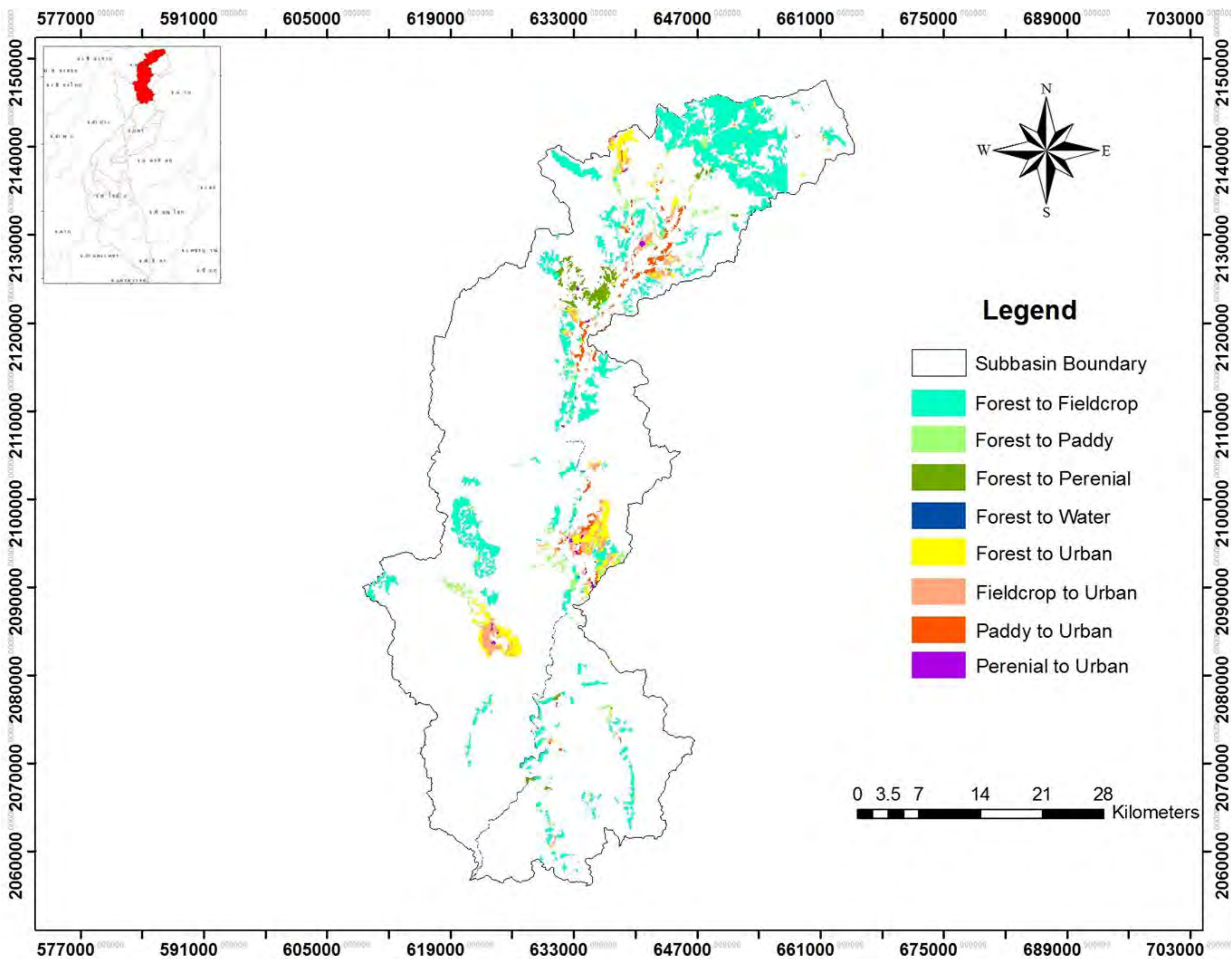


Figure 4-9 **Change detection map of** Upper Yom Sub-basin **from 1995 to 2003**

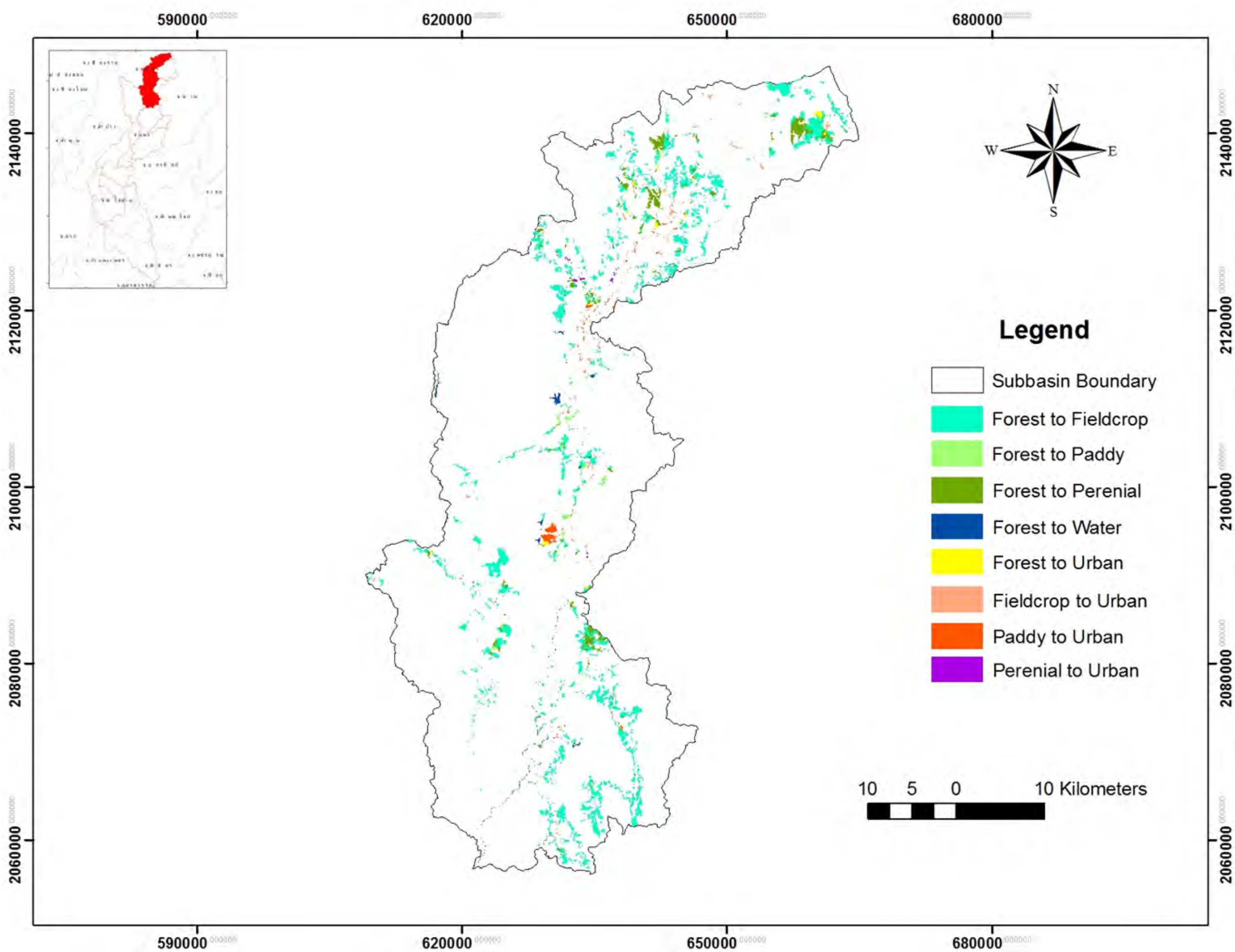


Figure 4-10 Change detection map of Upper Yom Sub-basin from 2003 to 2009

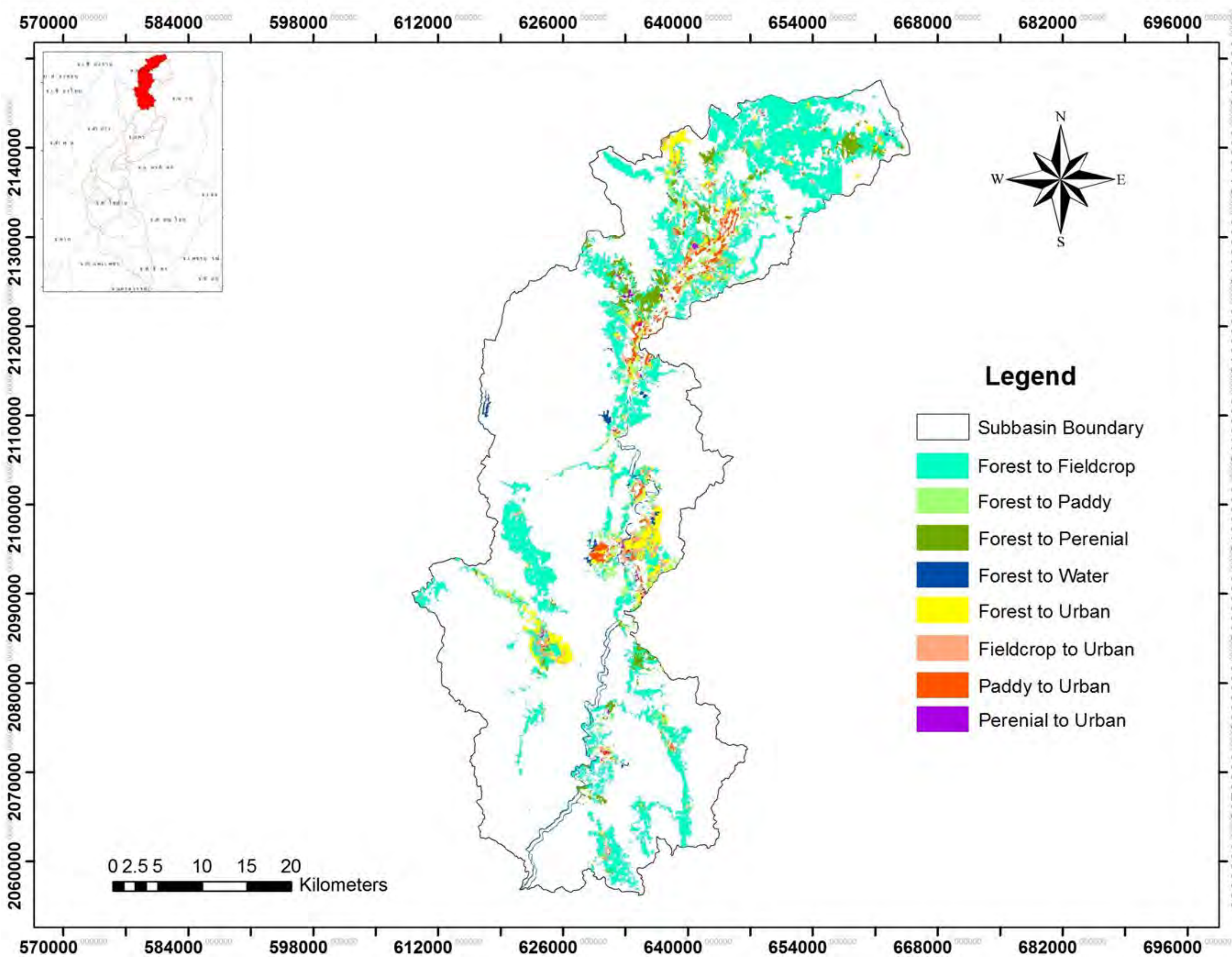


Figure 4-11 Change detection map of Upper Yom Sub-basin from 1988 to 2009

4.2.2 Land use changes Mae Khuan Sub-basin

4.2.2.1 Land use changes in Mae Khuan Sub-basin during 1988 to 1995

Agricultural land was increased with an area of 18.15 km^2 or 2.09 % of the sub-basin area, paddy field 2.43 km^2 or 0.28%, field crop 13.86 km^2 or 1.59% and perennial 1.86 km^2 or 0.21%. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 19.45 km^2 or 2.24% of the sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 18.15 km2 or 2.09 % followed by water bodies area with an area of 0.04 km^2 or 0.005% and urban and built-up land with an area of 1.26km^2 or 0.14%, respectively.

Urban and built-up land was increased with an area of 4.79 km^2 or 0.55%, of the sub-basin area. Furthermore, the most of urban and built-up land was transformed form agricultural land 3.53 km^2 or 0.41%, followed by forest land 1.26 km^2 or 0.14%, respectively.

Water bodies area was increased with an area of 0.04 km^2 or 0.005% of the sub-basin area. The most of water bodies area were transformed form forest land

4.2.2.2 Land use changes in Mae Khuan Sub-basin during 1995 to 2003

Agricultural land was increased with an area of 77.49 km^2 or 8.91% of the sub-basin area, paddy field 12.61 km^2 or 1.45%, field crop 64.40 km^2 or 7.41% and perennial 0.48 km^2 or 0.06%. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 86.57 km^2 or 9.96% of the sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 77.49 km2 or 8.91% followed by water bodies area with an area of 1.04 km^2 or 0.12% and urban and built-up land with an area of 8.04 km^2 or 0.92%, respectively.

Urban and built-up land was increased with an area of 21.81 km^2 or 2.51%, of the sub-basin area. Furthermore, the most of urban and built-up land was transformed form agricultural land 13.77 km^2 or 1.58%, followed by forest land 8.04 km2 or 0.92%, respectively.

Water bodies area was increased with an area of 1.04 km^2 or 0.12% of the sub-basin area. The most of water bodies area were transformed form forest land.

4.2.2.3 Land use changes in Mae Khuan Sub-basin during 2003 to 2009

Agricultural land was increased with an area of 80.98 km^2 or 9.31% of the sub-basin area, paddy field 3.99 km^2 or 0.46 %, field crop 72.89 km^2 or 8.38 % and perennial 4.10 km^2 or 0.47%. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 82.42 km^2 or 9.48% of the sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 80.98 km2 or 9.31% followed by water bodies area with an area of 0.15 km^2 or 0.02% and urban and built-up land with an area of 1.28 km^2 or 0.15%, respectively.

Urban and built-up land was increased with an area of 3.69 km^2 or 0.42%, of the sub-basin area. Furthermore, the most of urban and built-up land was transformed form agricultural land 2.41 km^2 or 0.28%, followed by forest land 1.28 km2 or 0.15%, respectively.

Water bodies area was increased with an area of 0.15 km2 or 0.02% of the sub-basin area. The most of water bodies area were transformed form forest land.

4.2.2.4 Land use changes in Mae Khuan Sub-basin during 1988 to 2009

Agricultural land was increased with an area of 58.71 km^2 or 6.75 % of the sub-basin area, paddy field 6.75 km^2 or 0.78 %, field crop 49.98 km^2 or 5.75 % and perennial 1.98 km^2 or 0.23 %. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 63.01 km^2 or 7.25 % of the sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 58.71 km^2 or 6.75 %, followed by water bodies area with an area of 0.45 km^2 or 0.05 % and urban and built-up land with an area of 3.85 km^2 or 0.44 %, respectively.

Urban and built-up land was increased with an area of 10.96 km^2 or 1.26%, of the sub-basin area. Furthermore, the most of urban and built-up land was transformed form agricultural land 7.11km^2 or 0.82%, followed by forest land 3.85 km2 or 0.44 %, respectively.

Water bodies area was increased with an area of 3.48 km^2 or 0.16 % of the sub-basin area. The most of water bodies area were transformed form forest land.

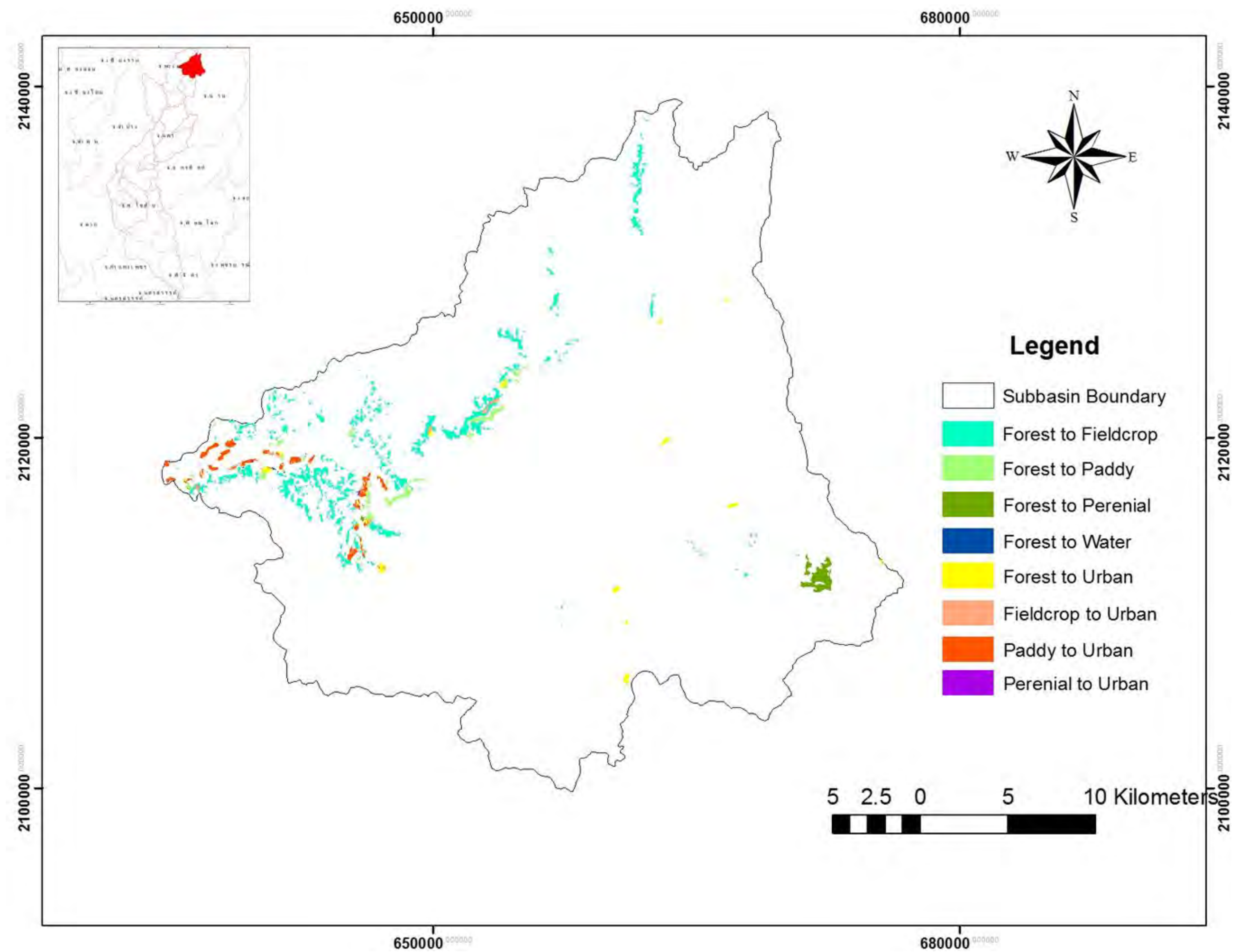


Figure 4-12 Change detection map of Mae Khuan Sub-basin from 1988 to 1995

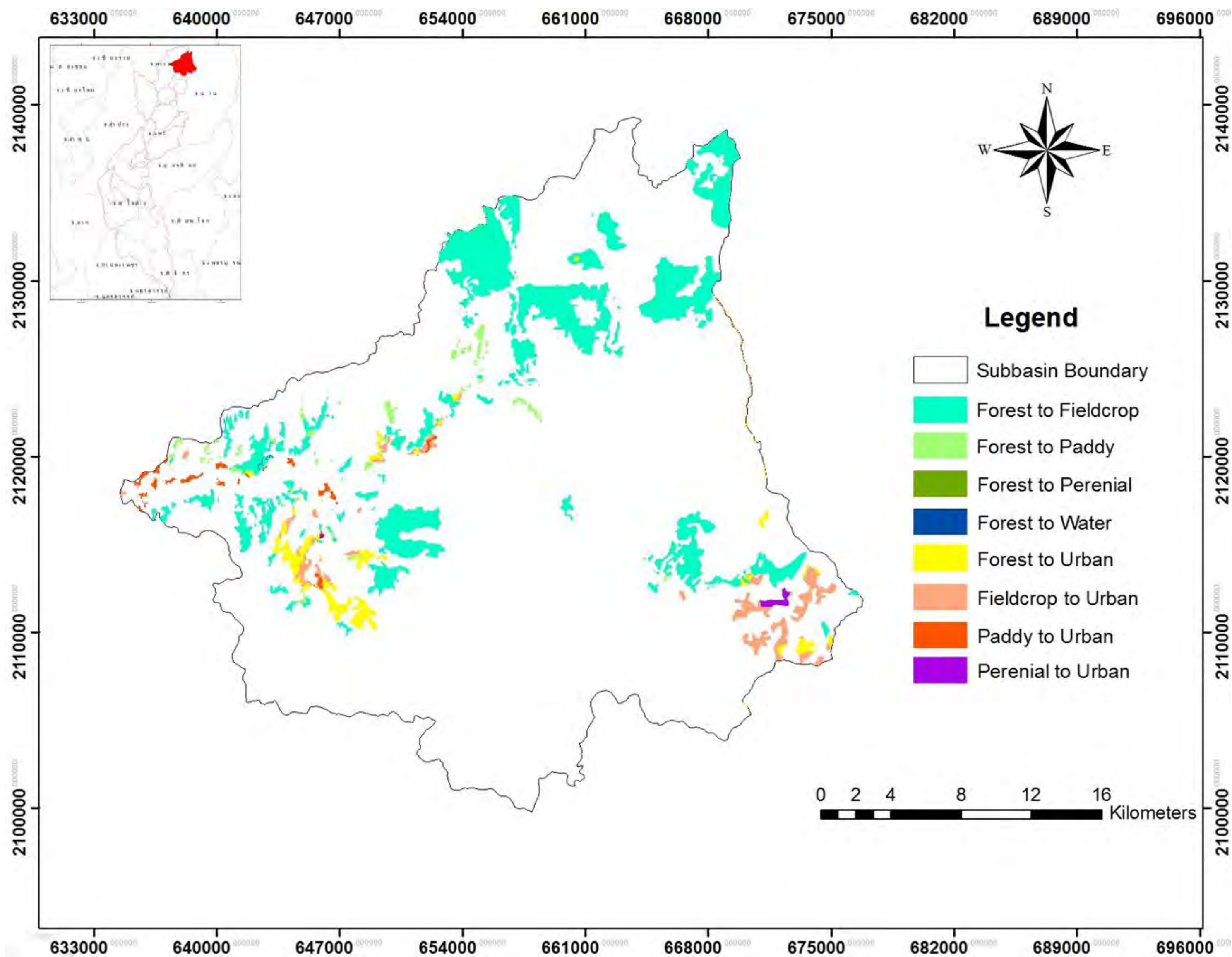


Figure 4-13 **Change detection map of** Mae Khuan Sub-basin **from 1995 to 2003**

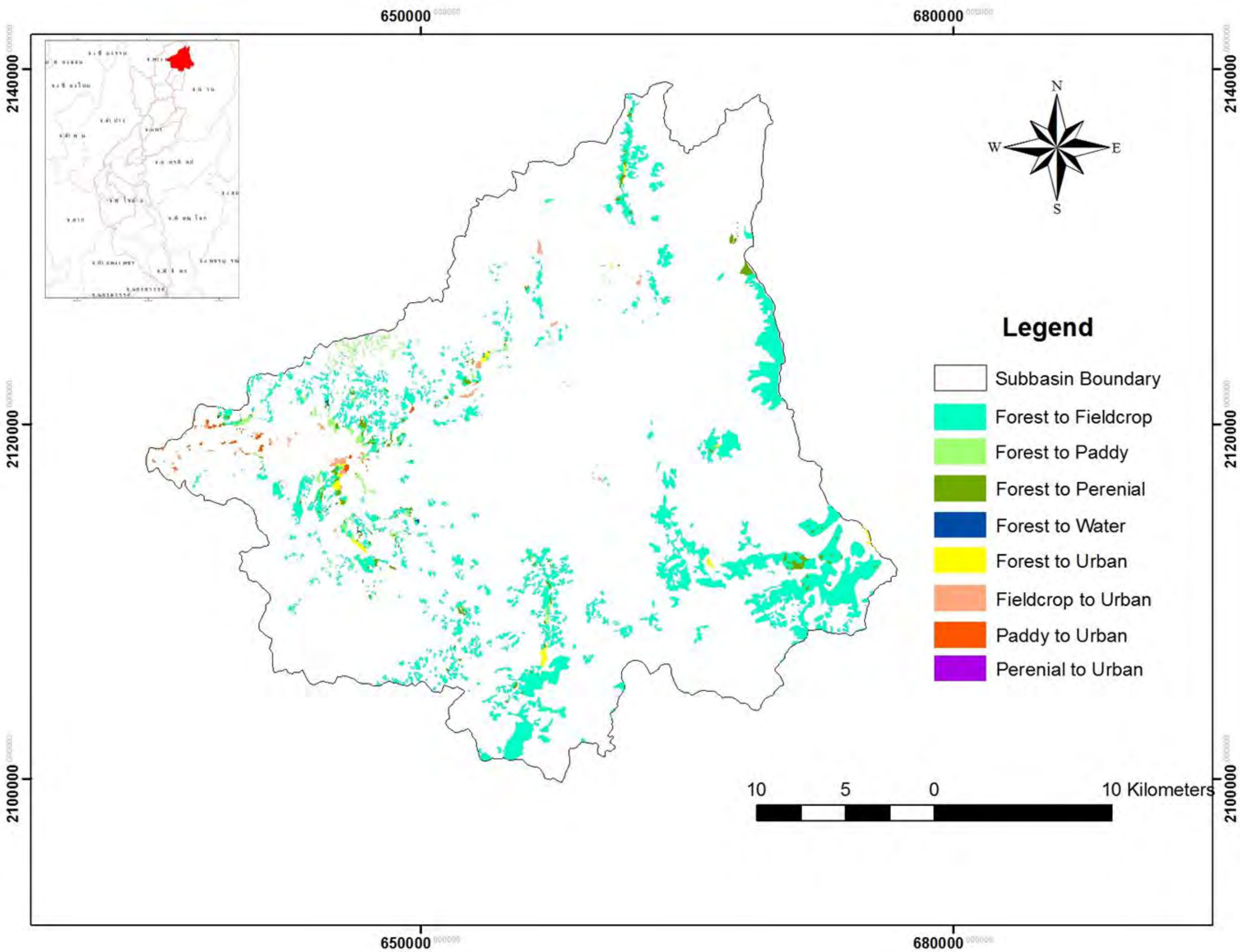


Figure 4-14 Change detection map of Mae Khuan Sub-basin from 2003 to 2009

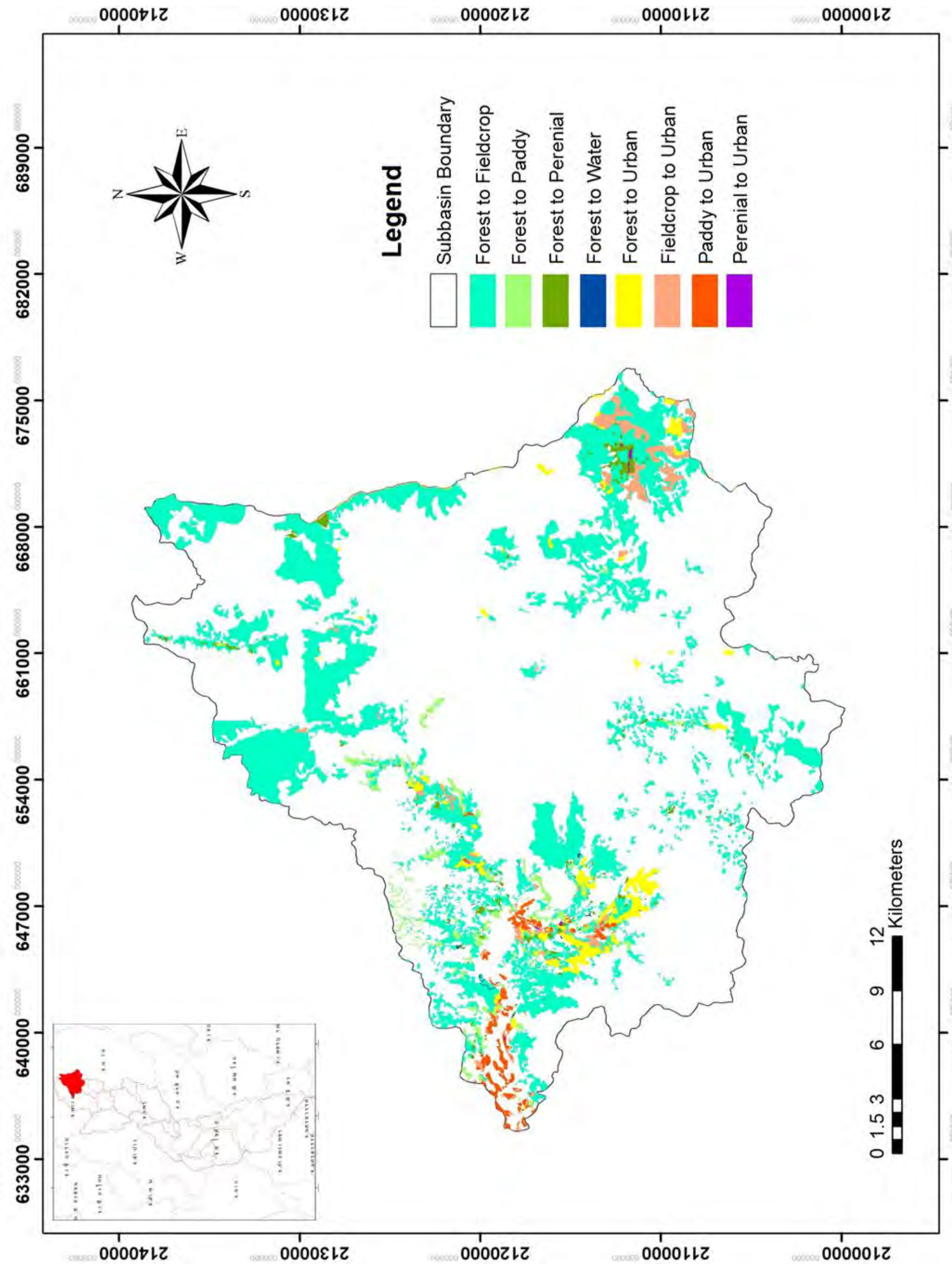


Figure 4-15 Change detection map of Mae Khuan Sub-basin from 1988 to 2009

4.2.3 Land use changes Nam Pi Sub-basin

4.2.3.1 Land use changes in Nam Pi Sub-basin during 1988 to 1995

Agricultural land was increased with an area of 34.78 km^2 or 5.29 % of the land use changes, paddy field 2.52 km^2 or 0.38%, field crop 31.15 km^2 or 4.74 % and perennial 1.11 km^2 or 0.17%. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 36.93 km^2 or 5.62% of the land use changes. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 34.78 km2 or 5.29 %, followed by water bodies area with an area of 1.36 km^2 or 0.21% and urban and built-up land with an area of 0.78 km^2 or 0.12 %, respectively.

Urban and built-up land was increased with an area of 8.15 km^2 or 1.24%, of the land use changes. Furthermore, the most of urban and built-up land was transformed form agricultural land 7.37 km^2 or 1.12%, followed by forest land 0.78 km2 or 0.12 %, respectively.

Water bodies area was increased with an area of 1.36 km2 or 0.21% of the land use changes. The most of water bodies area were transformed form forest land.

4.2.3.2 Land use changes in Nam Pi Sub-basin during 1995 to 2003

Agricultural land was increased with an area of 9.73 km^2 or 1.48% of the land use changes, paddy field 3.41 km^2 or 0.52%, field crop 6.32 km^2 or 0.96%. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 17.86 km^2 or 2.72% of the land use changes. Furthermore, the most of forest land was transformed to be agricultural land (paddy field and field crop) with an area of 9.73 km2 or 1.48%, followed by water bodies area with an area of 0.36 km^2 or 0.06 % and urban and built-up land with an area of 7.77km^2 or 1.18%, respectively.

Urban and built-up land was increased with an area of 52.39 km^2 or 7.97%, of the land use changes. Furthermore, the most of urban and built-up land was transformed form agricultural land 44.62 km^2 or 6.79%, followed by forest land 7.77km2 or 1.18 %, respectively.

Water bodies area was increased with an area of 0.36 km2 or 0.06 % of the land use changes. The most of water bodies area were transformed form forest land.

4.2.3.3 Land use changes in Nam Pi Sub-basin during 2003 to 2009

Agricultural land was increased with an area of 80.08 km^2 or 12.19% of the land use changes, paddy field 1.22 km^2 or 0.19%, field crop 73.73 km^2 or 11.22 % and perennial 5.31 km^2 or 0.81%. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 81.18 km^2 or 12.35% of the land use changes. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 80.08 km2 or 12.19%, followed by water bodies area with an area of 0.52 km^2 or 0.08 % and urban and built-up land with an area of 0.41 km^2 or 0.06%, respectively.

Urban and built-up land was increased with an area of 2.18 km^2 or 0.33 %, of the land use changes. Furthermore, the most of urban and built-up land was transformed form agricultural land 1.78 km^2 or 0.27%, followed by forest land 0.41 km^2 or 0.06%, respectively.

Water bodies area was increased with an area of 3.48 km^2 or 0.16 % of the land use changes. The most of water bodies area were transformed form forest land.

4.2.3.4 Land use changes in Nam Pi Sub-basin during 1988 to 2009

Agricultural land was increased with an area of 38.23 km^2 or 5.82 % of the sub-basin area , paddy field 2.49 km^2 or 0.38 %, field crop 33.86 km^2 or 5.15 % and perennial 1.89 km^2 or 0.29 %. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 42.31 km^2 or 6.44 % of the sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 38.23 km^2 or 5.82 %, followed by water bodies area with an area of 0.74 km^2 or 0.11 % and urban and built-up land with an area of 3.34 km^2 or 0.51%, respectively.

Urban and built-up land was increased with an area of 23.30 km^2 or 3.55 %, of the sub-basin area. Furthermore, the most of urban and built-up land was transformed form agricultural land 19.96 km^2 or 3.04 %, followed by forest land 3.34 km^2 or 0.51%, respectively.

Water bodies area was decreased with an area of 88.01 km^2 or 0.36% of the sub-basin area. Furthermore, the most of water bodies area were transformed form forest land.

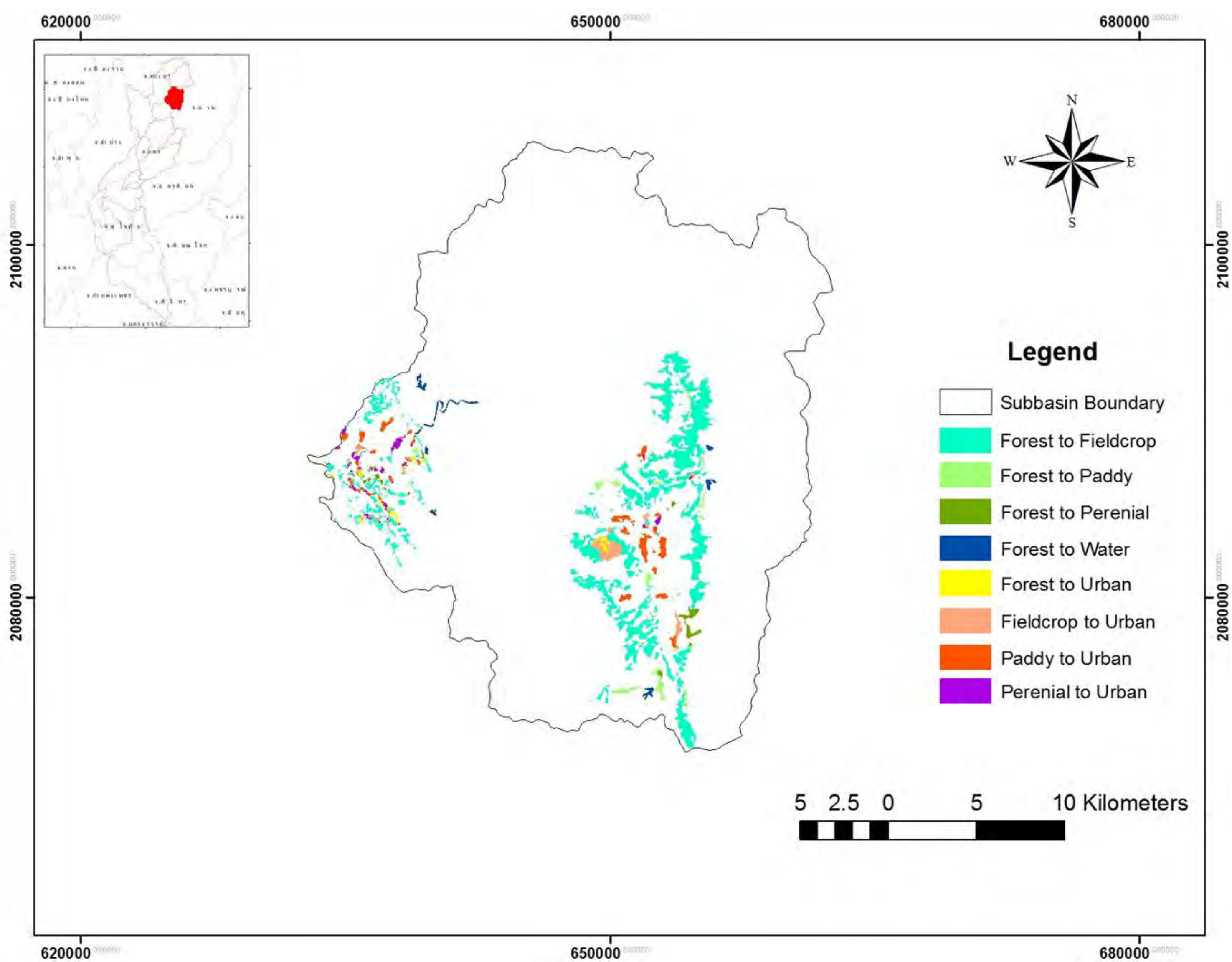


Figure 4-16 Change detection map of Nam Pi Sub-basin from 1988 to 1995

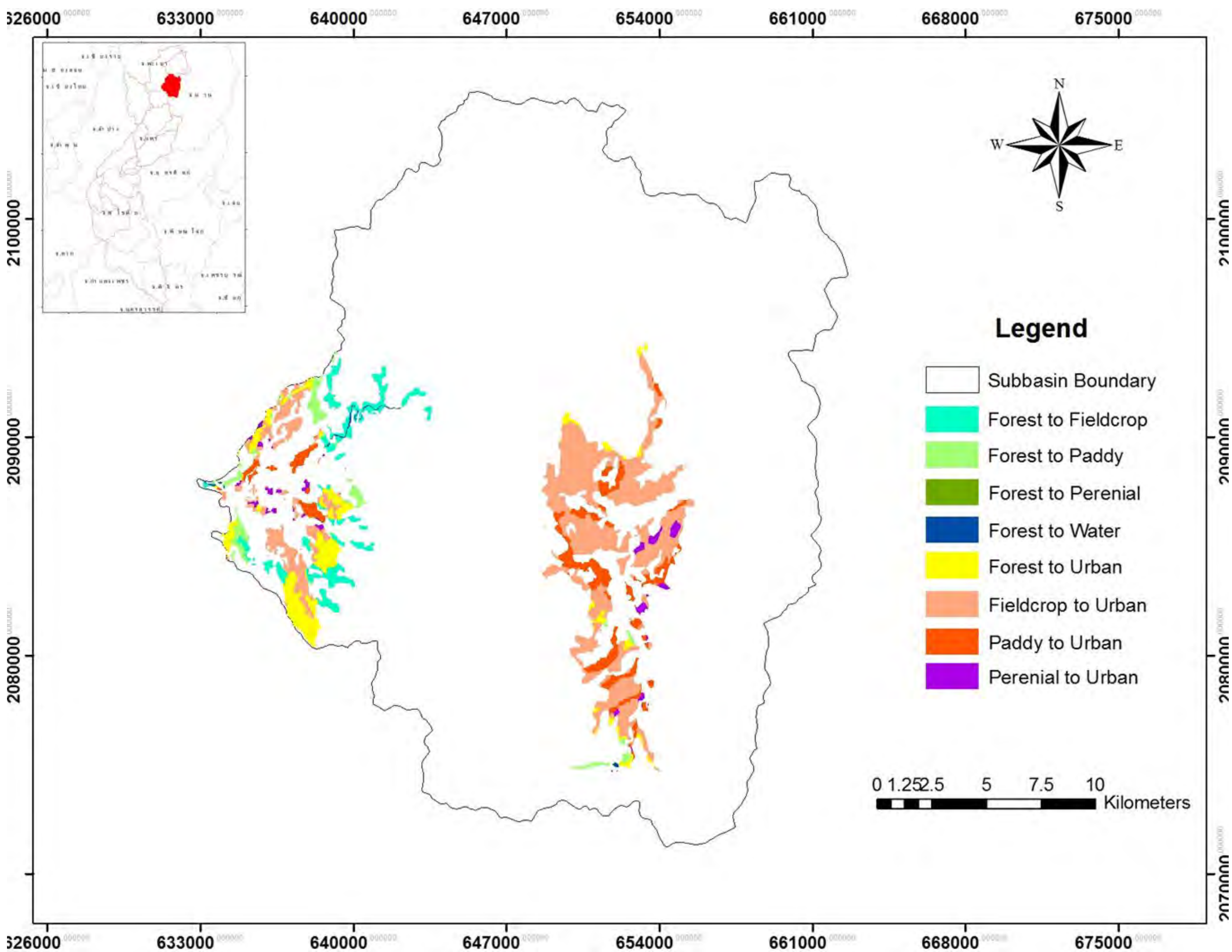


Figure 4-17 Change detection map of Nam Pi Sub-basin from 1995 to 2003

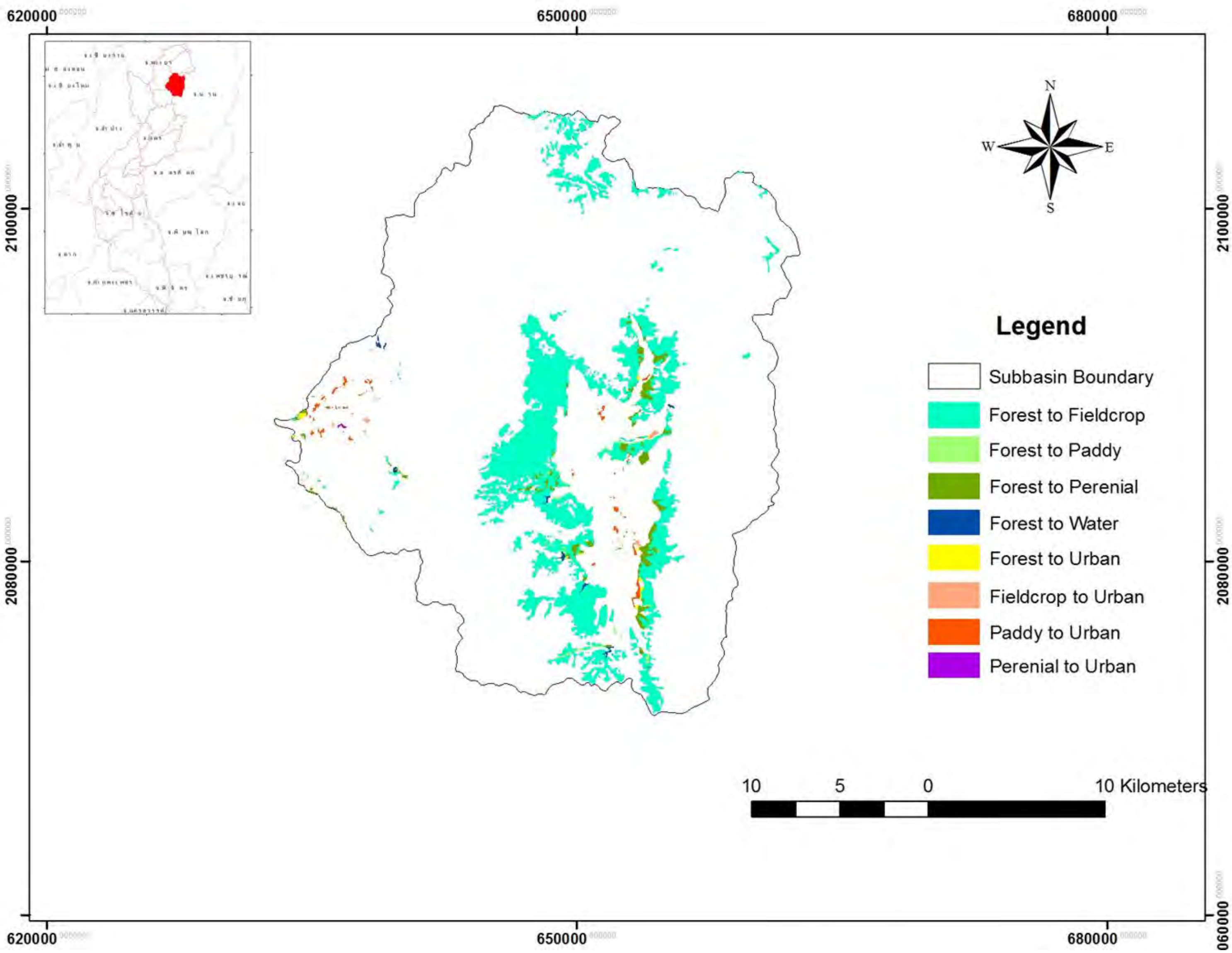


Figure 4-18 Change detection map of Nam Pi Sub-basin from 2003 to 2009

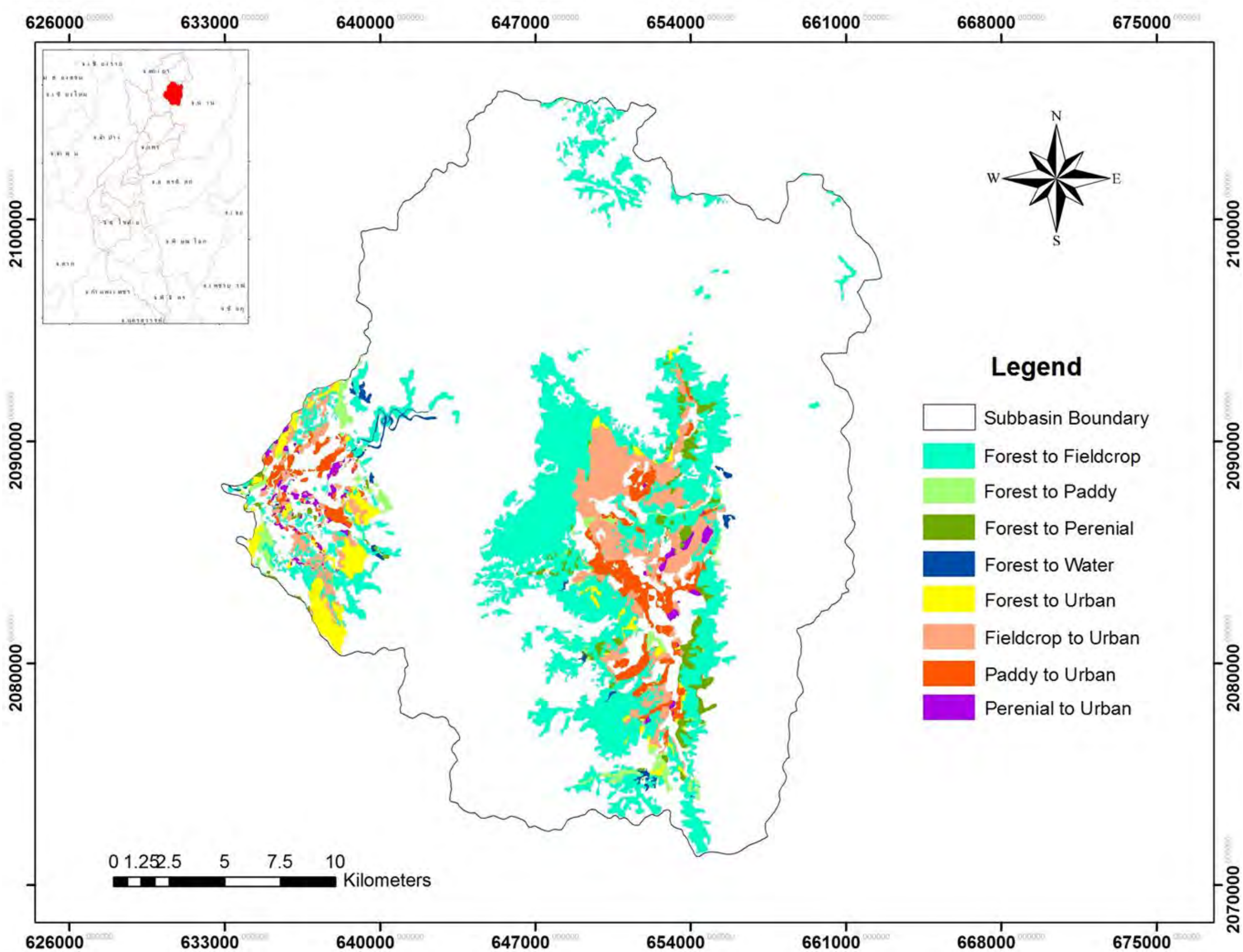


Figure 4-19 Change detection map of Nam Pi Sub-basin from 1988 to 2009

4.2.4 Land use changes Mae Ngao Sub-basin

4.2.4.1 Land use changes in Mae Ngao Sub-basin during 1988 to 1995

Agricultural land was increased with an area of 73.84 km^2 or 4.22 % of the land use changes, paddy field 71.32 km^2 or 4.07 %, field crop 0.01km^2 or 0.0005 % and perennial 2.51 km^2 or 0.14 %. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 102.92 km2 or 5.88 % of the land use changes. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 73.84 km2 or 4.22 %, followed by water bodies area with an area of 1.21 km^2 or 0.07 % and urban and built-up land with an area of 27.88 km^2 or 1.59 %, respectively.

Urban and built-up land was increased with an area of 29.79 km^2 or 1.70 %, of the land use changes. Furthermore, the most of urban and built-up land was transformed form forest land 27.88 km2 or 1.59 %, followed by agricultural land 1.91 km^2 or 0.11 %, respectively.

Water bodies area was increased with an area of 1.21 km^2 or 0.07 % of the land use changes. The most of water bodies area were transformed form forest land.

4.2.4.2 Land use changes in Mae Ngao Sub-basin during 1995 to 2003

Agricultural land was increased with an area of 87.71 km^2 or 5.01 % of the land use changes, paddy field 4.38 km^2 or 0.25 %, field crop 83.33 km^2 or 4.76 % .The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 96.61 km^2 or 5.52% of the land use changes. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 87.71 km2 or 5.01 %, followed by water bodies area with an area of 0.08 km^2 or 0.004 % and urban and built-up land with an area of 8.83 km^2 or 0.50%, respectively.

Urban and built-up land was increased with an area of 22.08 km^2 or 1.26 %, of the land use changes. Furthermore, the most of urban and built-up land was transformed form agricultural land 13.25 km^2 or 0.76 %, followed by forest land 8.83 km^2 or 0.50%, respectively.

Water bodies area was increased with an area of 8.83 km^2 or 0.50% of the land use changes. The most of water bodies area were transformed form forest land.

4.2.4.3 Land use changes in Mae Ngao Sub-basin during 2003 to 2009

Agricultural land was increased with an area of 79.56 km^2 or 4.54 % of the land use changes, paddy field 7.05 km^2 or 0.40 %, field crop 59.04 km^2 or 3.37 % and perennial 13.47 km^2 or 0.77%. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 85.70 km^2 or 4.90% of the land use changes. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 79.56 km^2 or 4.54 %, followed by water bodies area with an area of 1.04 km^2 or 0.06 % and urban and built-up land with an area of 5.10 km^2 or 0.29 %, respectively.

Urban and built-up land was increased with an area of 16.13 km^2 or 0.92 %, of the land use changes. Furthermore, the most of urban and built-up land was transformed form agricultural land 11.03 km^2 or 0.63, followed by forest land 5.10 km^2 or 0.29 %,, respectively.

Water bodies area was increased with an area of 5.10 km2 or 0.29 % of the land use changes. The most of water bodies area were transformed form forest land.

4.2.4.4 Land use changes in Mae Ngao Sub-basin during 1988 to 2009

Agricultural land was increased with an area of 80.76 km^2 or 4.61 % of the sub-basin area, paddy field 27.46 km^2 or 1.57 %, field crop 48.62 km^2 or 2.78 % and perennial 4.68 km^2 or 0.27 %. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 95.60 km^2 or 5.46 % of the sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 80.76 km2 or 4.61 %, followed by water bodies area with an area of 0.73 km^2 0.04 % and urban and built-up land with an area of 14.11 km^2 or 0.81 %, respectively.

Urban and built-up land was increased with an area of 22.95 km^2 or 1.31 %, of the sub-basin area. Furthermore, the most of urban and built-up land was transformed form forest land 14.11 km2 or 0.81 %, followed by agricultural land 8.83 km^2 or 0.50 %, respectively.

Water bodies area was increased with an area of 0.73 km2 0.04 of the sub-basin area. The most of water bodies area were transformed form forest land.

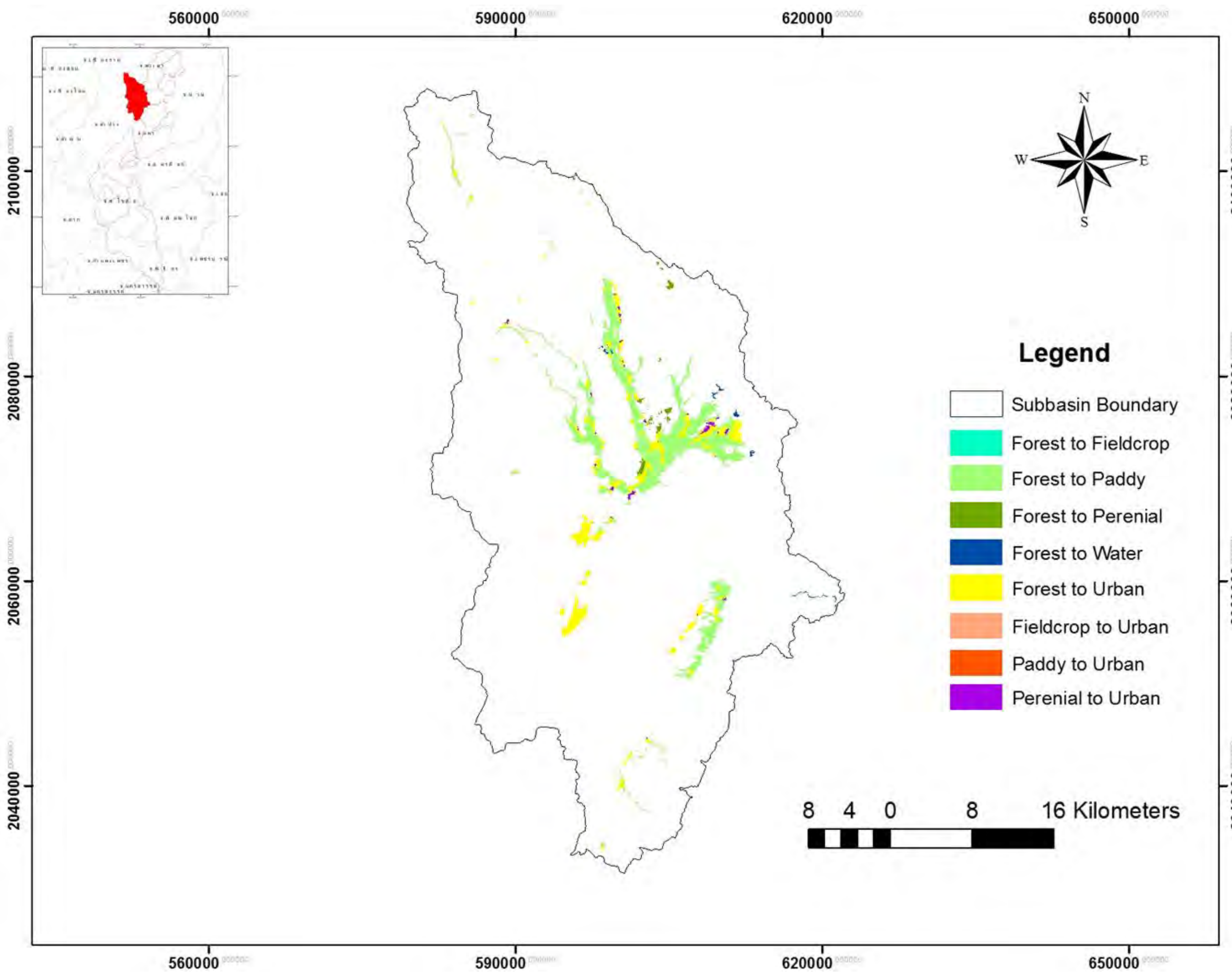


Figure 4-20 Change detection map of Mae Ngao Sub-basin from 1988 to 1995

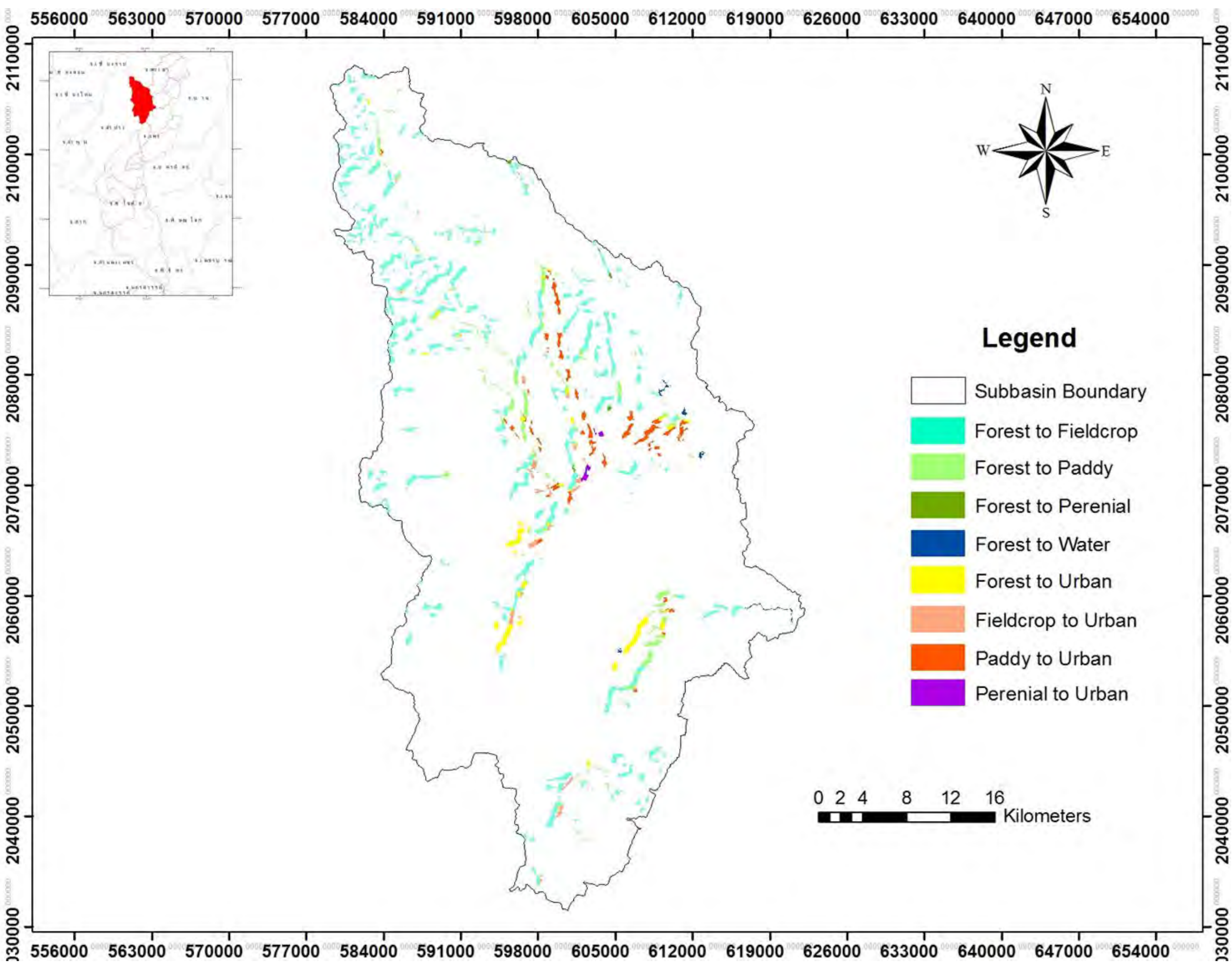


Figure 4-21 Change detection map of Mae Ngao Sub-basin from 1995 to 2003

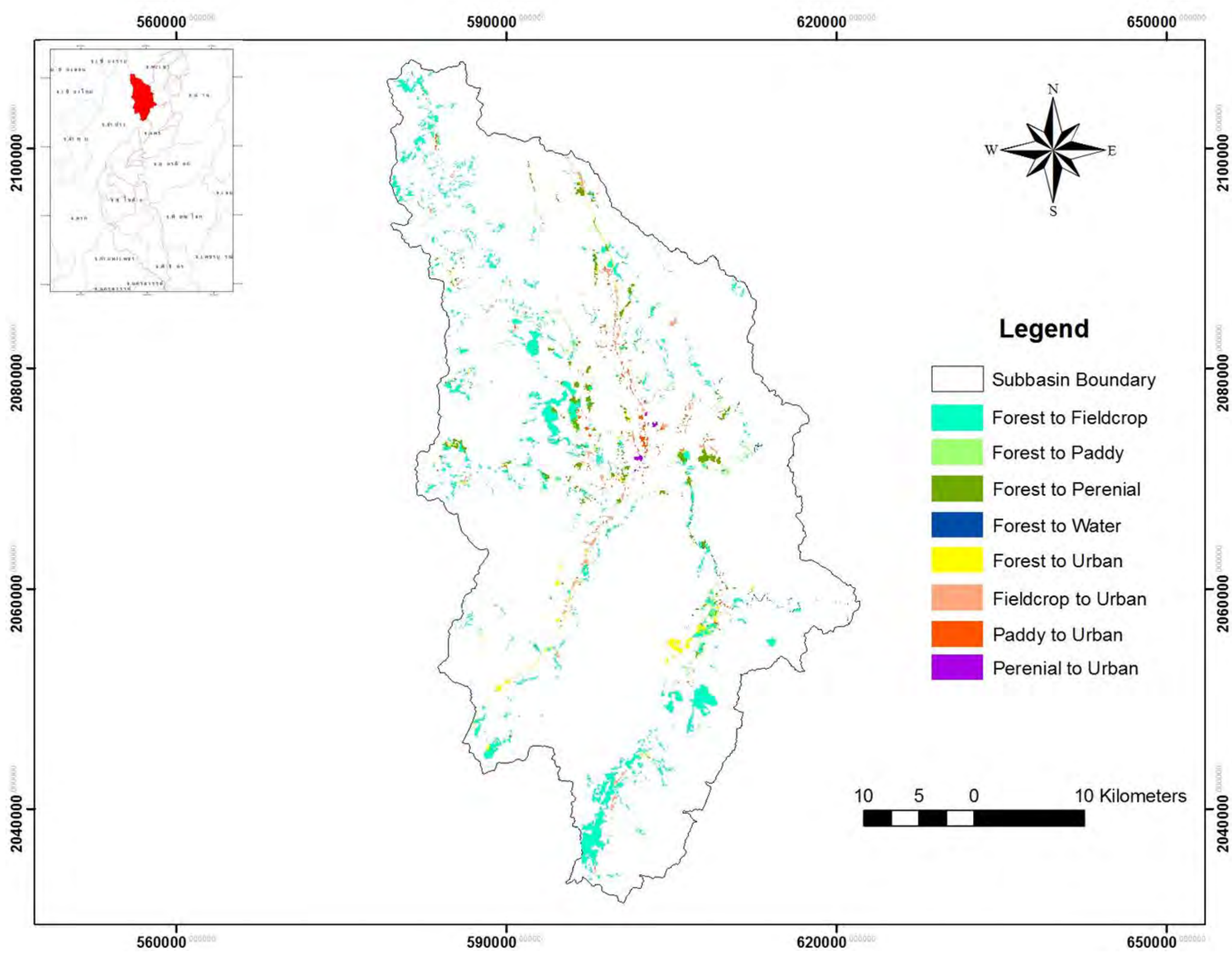


Figure 4-22 Change detection map of Mae Ngao Sub-basin from 2003 to 2009

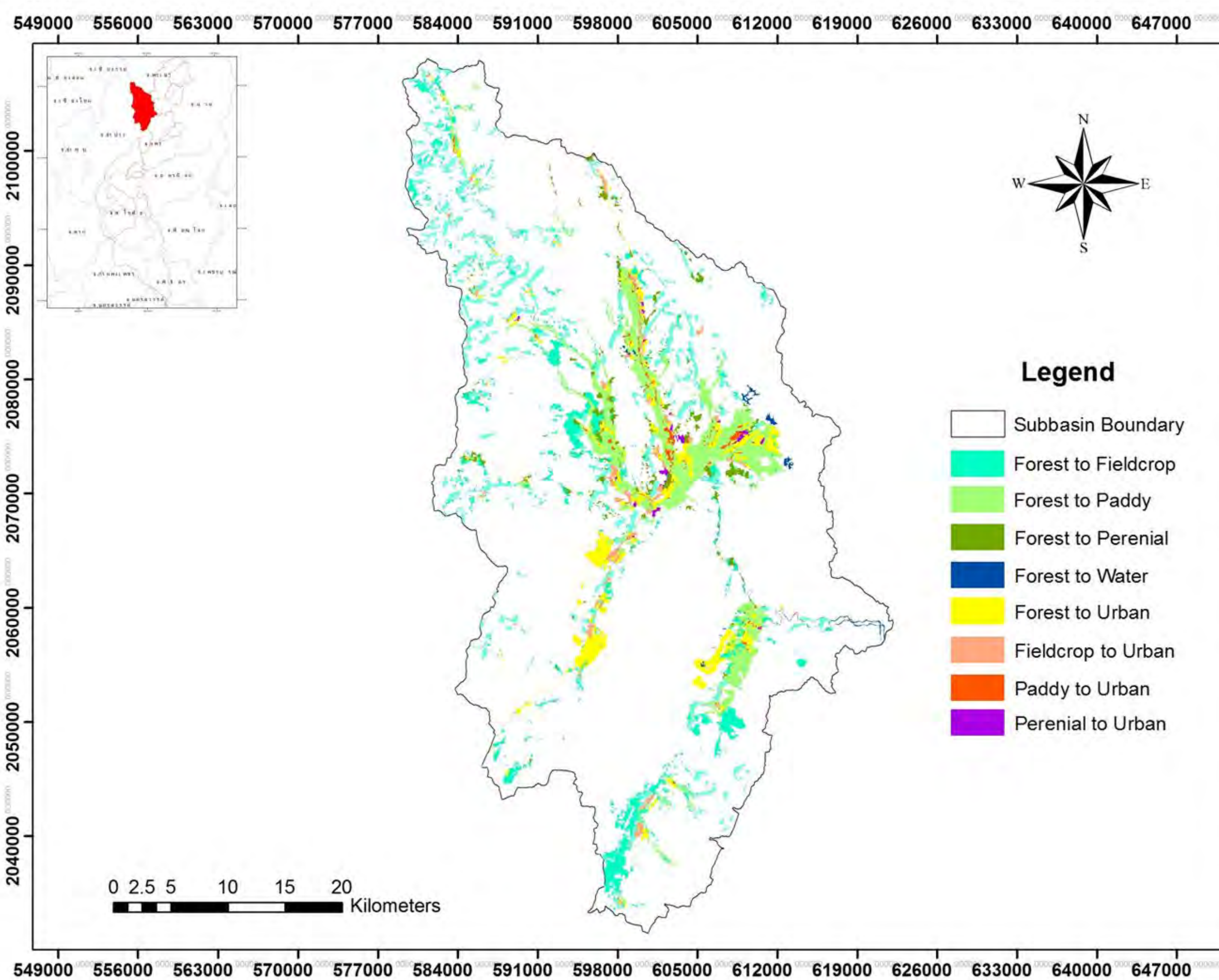


Figure 4-23 Change detection map of Mae Ngao Sub-basin from 1988 to 2009

4.2.5 Land use changes Middle Part of Yom Sub-basin

4.2.5.1 Land use changes in Middle Part of Yom Sub-basin during 1988 to 1995

Agricultural land was increased with an area of 146.61 km^2 or 4.77 % of the sub-basin area, paddy field 40.98 km^2 or 1.33%, field crop 73.81 km^2 or 2.40 % and perennial 31.82 km^2 or 1.04%. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 176.86 km^2 or 5.75 % of the sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 146.61 km^2 or 4.77 %, followed by water bodies area with an area of 15.02 km^2 or 0.49% and urban and built-up land with an area of 15.23 km^2 or 0.50 %, respectively.

Urban and built-up land was increased with an area of 86.87 km^2 or 2.83 %, of the sub-basin area. Furthermore, the most of urban and built-up land was transformed form agricultural land 71.64 km^2 or 2.33%, followed by forest land 15.23 km^2 or 0.50 %, respectively.

Water bodies area was increased with an area of 3.48 km^2 or 0.16 % of the sub-basin area. The most of water bodies area were transformed form forest land.

4.2.5.2 Land use changes in Middle Part of Yom Sub-basin 1995 to 2003

Agricultural land was increased with an area of 94.18 km^2 or 3.06 % of the sub-basin ara, paddy field 14.62 km^2 or 0.48 %, field crop 56.66 km^2 or 1.84 % and perennial 22.90 km^2 or 0.75%. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 108.44 km^2 or 3.53% of the sub-basin ara. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 94.18 km^2 or 3.06 %, followed by water bodies area with an area of 8.51 km^2 or 0.28 % and urban and built-up land with an area of 5.75 km^2 or 0.19%, respectively.

Urban and built-up land was increased with an area of 62.43 km^2 or 2.03%, of the sub-basin area. Furthermore, the most of urban and built-up land was transformed form agricultural land 56.68 km^2 or 1.84%, followed by forest land 5.75 km2 or 0.19%, respectively.

Water bodies area was increased with an area of 8.51 km2 or 0.28 % of the sub-basin area. The most of water bodies area were transformed form forest land.

4.2.5.3 Land use changes in Middle Part of Yom Sub-basin 2003 to 2009

Agricultural land was increased with an area of 150.64 km^2 or 4.90 % of the sub-basin ara, paddy field 8.53 km^2 or 0.28 %, field crop 111.03 km^2 or 3.61 % and perennial 31.08 km^2 or 1.01 %. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 168.13 km^2 or 5.47% of the sub-basin ara. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 150.64 km^2 or 4.90 %, followed by water bodies area with an area of 7.80 km^2 or 0.25 % and urban and built-up land with an area of 9.69 km^2 or 0.32 %, respectively.

Urban and built-up land was increased with an area of 69.03 km^2 or 2.25 %, of the sub-basin ara. Furthermore, the most of urban and built-up land was transformed form agricultural land 59.34 km^2 or 1.93 %, followed by forest land 23.38 km^2 or 0.10%, respectively.

Water bodies area was increased with an area of 9.69 km^2 or 0.32 % of the sub-basin ara. The most of water bodies area were transformed form forest land.

4.2.5.4 Land use changes in Middle Part of Yom Sub-basin 1988 to 2009

Agricultural land was increased with an area of 127.79 km^2 or 4.16 % of the sub-basin ara, paddy field 21.66 km^2 or 0.70 %, field crop 77.91 km^2 or 2.53 % and perennial 28.21 km^2 or 0.92 %. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 148.30 km^2 or 4.82 % of of the sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 127.79 km2 or 4.16 %, followed by water bodies area with an area of 10.48 km^2 or 0.34 % and urban and built-up land with an area of 10.04 km^2 or 0.33 %, respectively.

Urban and built-up land was increased with an area of 72.46 km^2 or 2.36 %, of the sub-basin area. Furthermore, the most of urban and built-up land was transformed form forest land 10.04 km2 or 0.33 %, followed by agricultural land 62.42 km^2 or 2.03 %, respectively.

Water bodies area was increased with an area of 10.48 km2 or 0.34 % of the sub-basin area. The most of water bodies area were transformed form forest land.

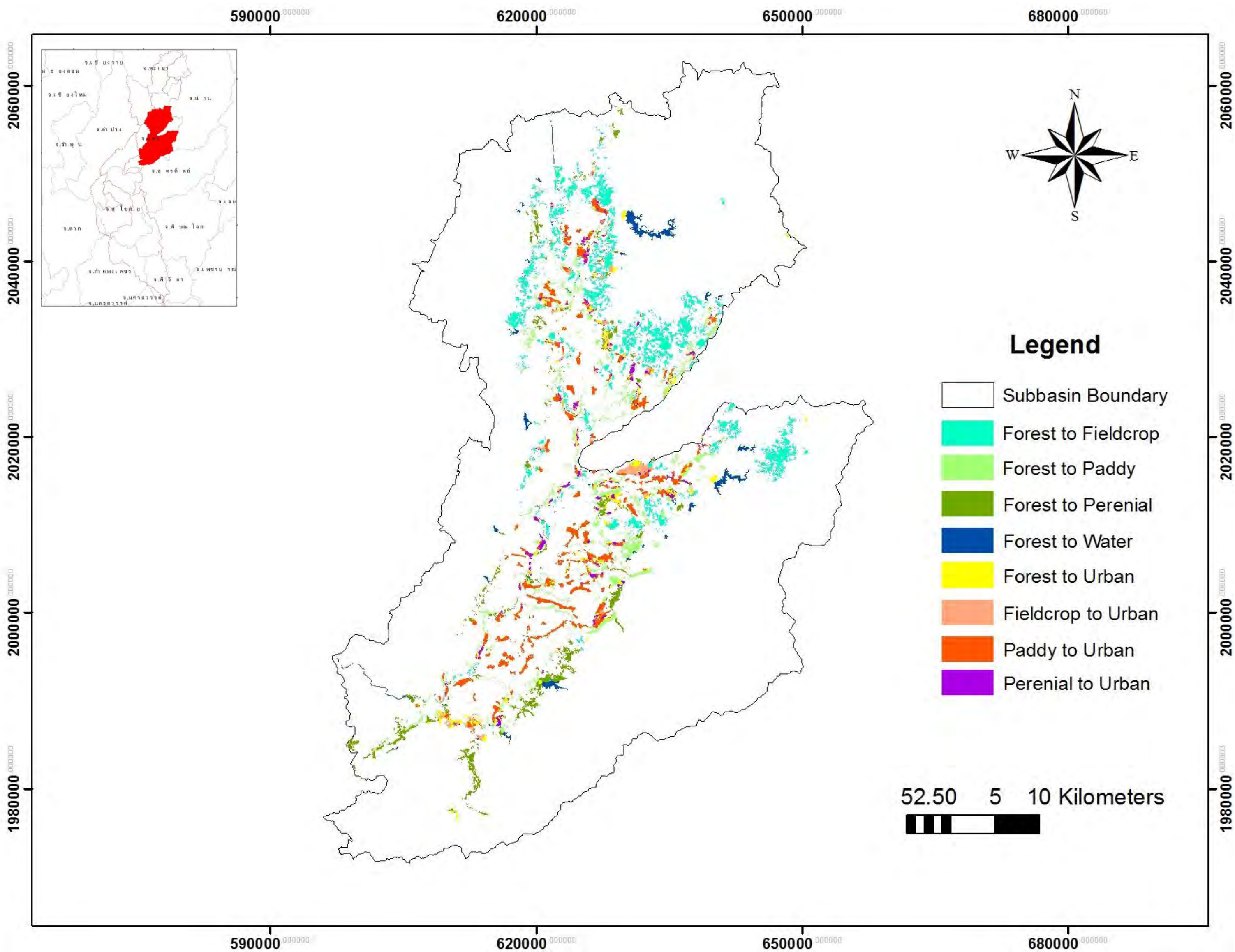


Figure 4-24 Change detection map of Middle Part of Yom Sub-basin from 1988 to 1995

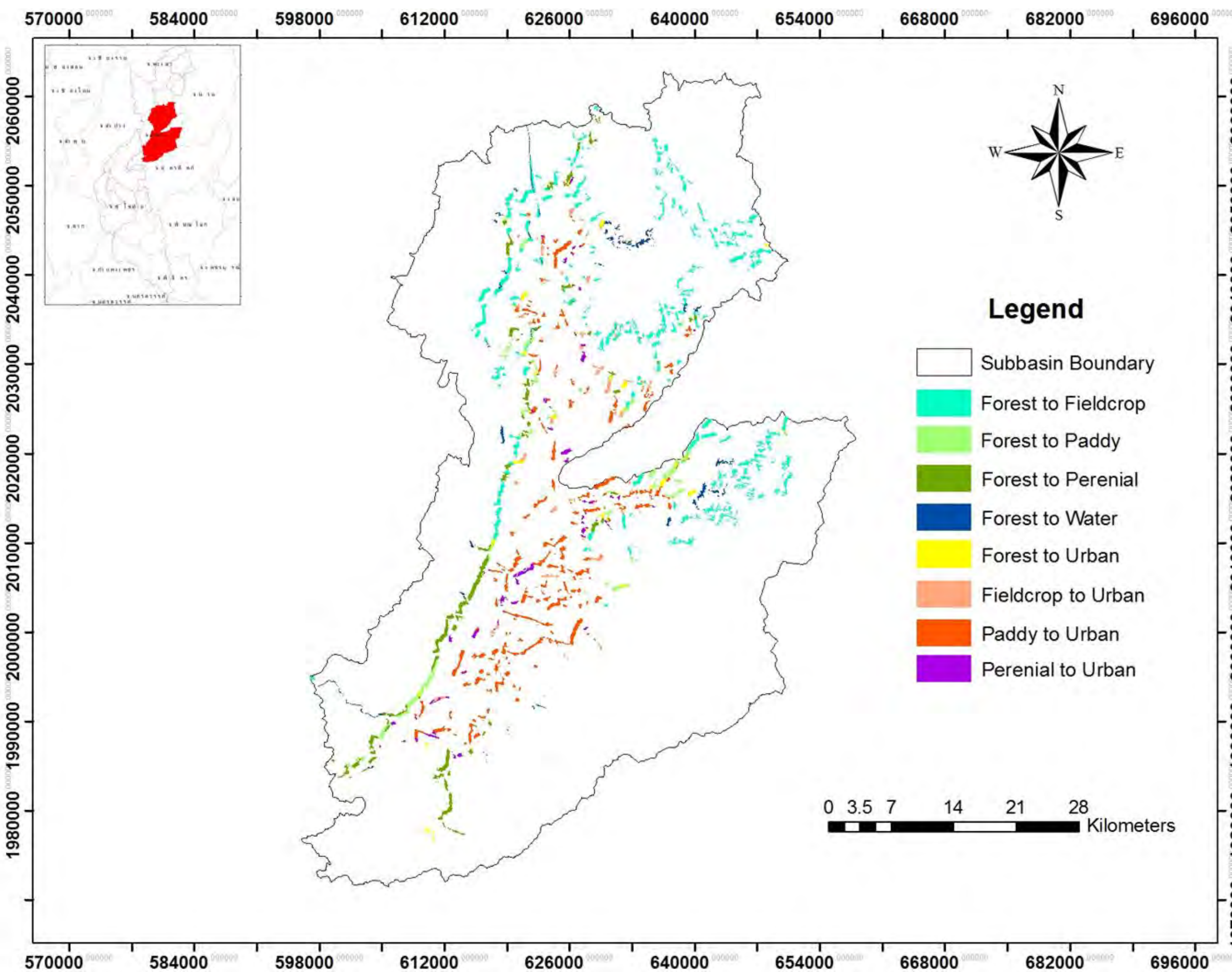


Figure 4-25 Change detection map of Middle Part of Yom Sub-basin from 1995 to 2003

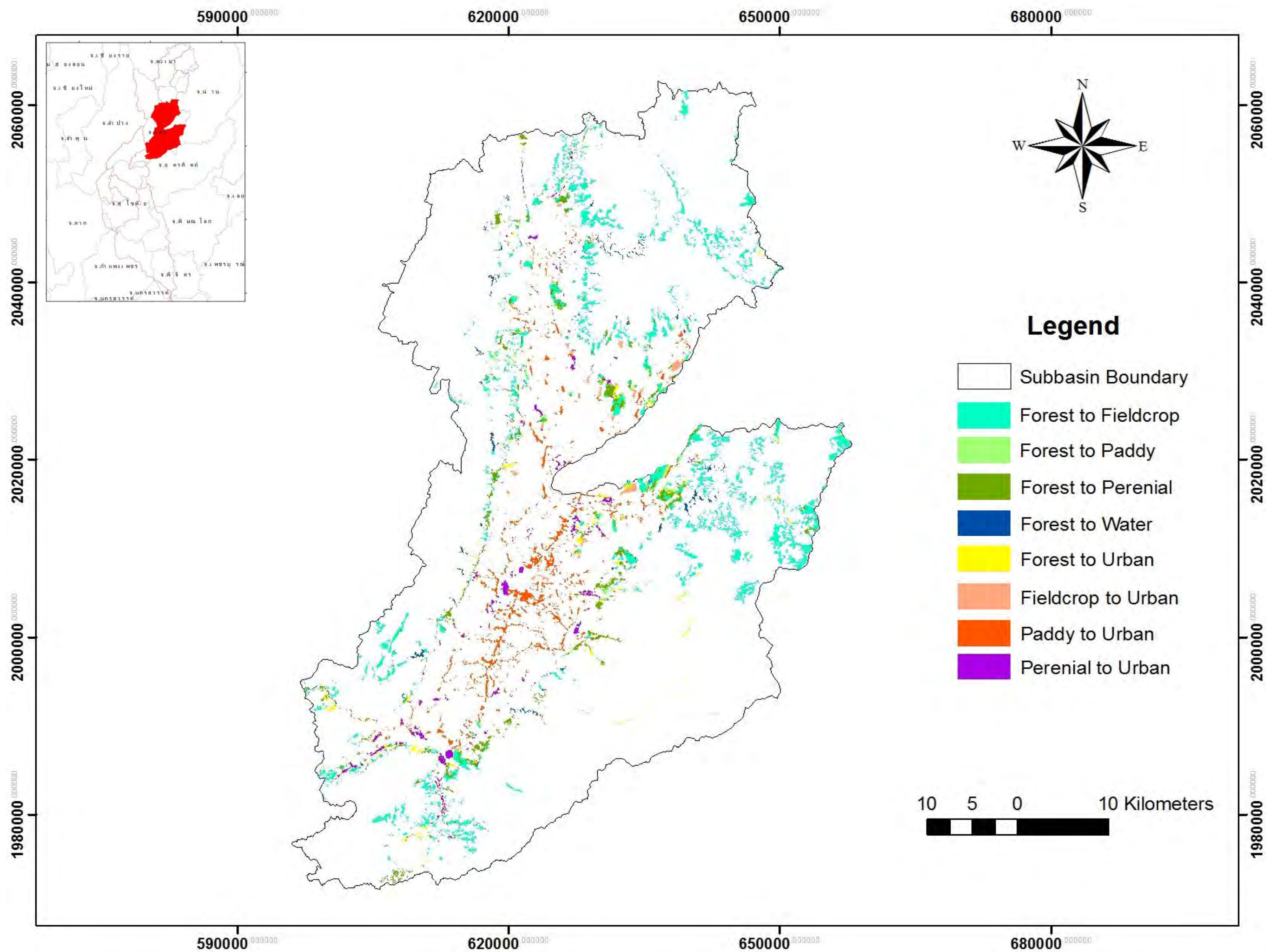


Figure 4-26 Change detection map of Middle Part of Yom Sub-basin from 2003 to 2009

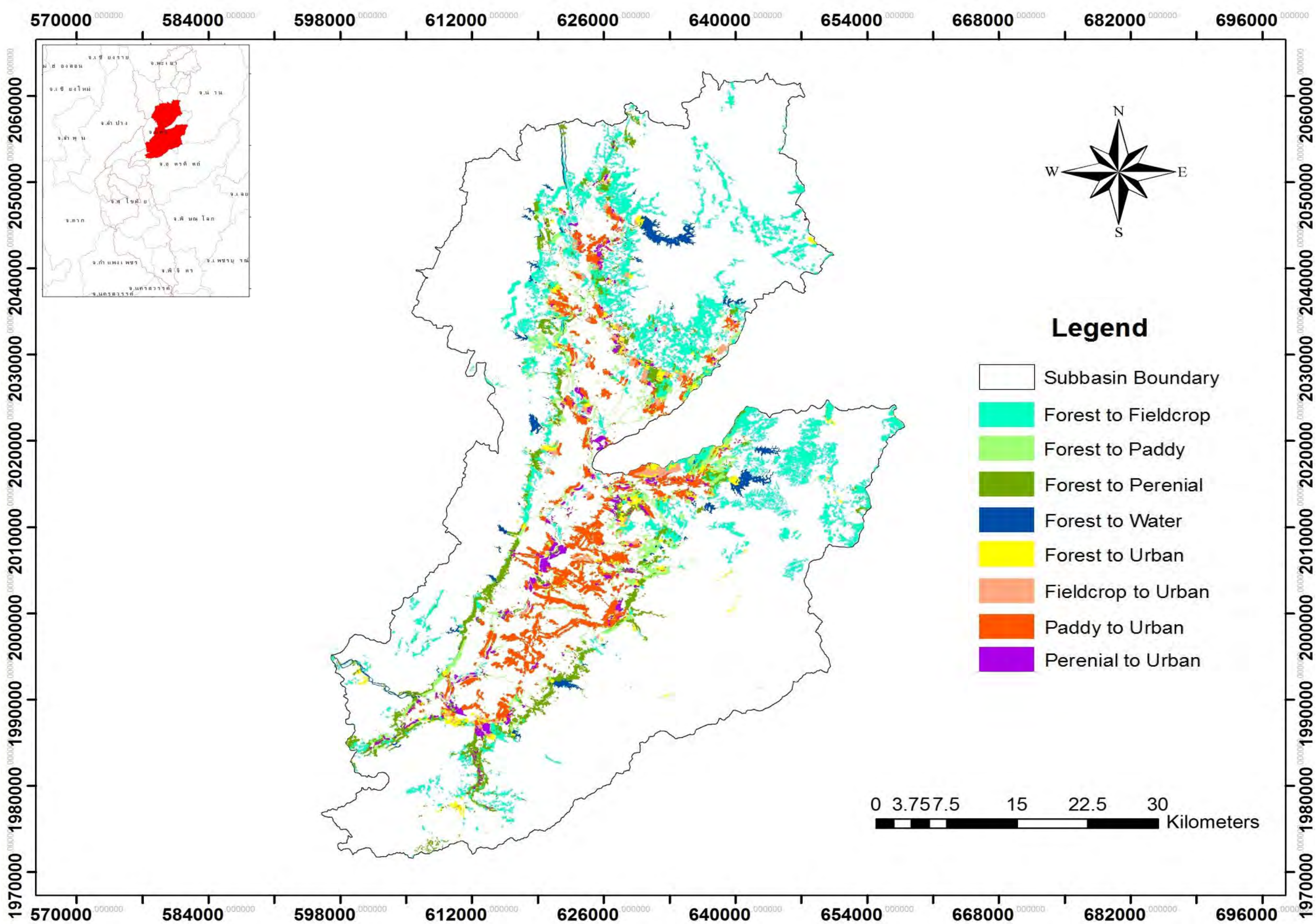


Figure 4-27 Change detection map of Middle Part of Yom Sub-basin from 1988 to 2009

4.2.6 Land use changes Mae Kham mee Sub-basin

4.2.6.1 Land use changes in Mae Kham mee Sub-basin during 1988 to 1995

Agricultural land was increased with an area of 18.72 km^2 or 4.14 % of the sub-basin area, paddy field 6.47 km^2 or 1.43 %, field crop 6.22 km^2 or 1.37% and perennial 6.03 km^2 or 1.33 %. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 22.48 km^2 or 4.97 % of of the sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 18.72 km2 or 4.14 %, followed by water bodies area with an area of 0.15 km^2 or 0.03 % and urban and built-up land with an area of 3.61 km^2 or 0.80 %, respectively.

Urban and built-up land was increased with an area of 15.81 km^2 or 3.50%, of the sub-basin area. Furthermore, the most of urban and built-up land was transformed form agricultural land 12.20 km^2 or 2.70%, followed by forest land of 3.61 km^2 or 0.80 %, respectively.

Water bodies area was increased with an area of 3.48 km^2 or 0.16 % o of the sub-basin area. The most of water bodies area were transformed form forest land.

4.2.6.2 Land use changes in Mae Kham mee Sub-basin during 1995 to 2003

Agricultural land was increased with an area of 25.19 km^2 or 5.57 % of the sub-basin area, paddy field 0.91 km^2 or 0.20 %, field crop 22.44 km^2 or 4.96 % and perennial 1.84 km^2 or 0.41 %. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 27.10 km^2 or 5.99 % of the sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 25.19 km2 or 5.57 %, followed by urban and built-up land with an area of 1.91 km^2 or 0.42 %, respectively.

Urban and built-up land was increased with an area of 11.69 km^2 or 2.58 %, of the sub-basin area. Furthermore, the most of urban and built-up land was transformed form agricultural land 9.79 km^2 or 2.16%, followed by forest land 1.91 km2 or 0.42 %, respectively.

Water bodies area were not transformed form during this period.

4.2.6.3 Land use changes in Mae Kham mee Sub-basin during 2003 to 2009

Agricultural land was increased with an area of 52.1 km^2 or 11.52 % of the sub-basin area, paddy field 2.05 km^2 or 0.45 %, field crop 44.46 km^2 or 9.83 % and perennial 5.59 km^2 or 1.24%. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 56.29 km^2 or 12.44% of of the sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 52.1 km2 or 11.52 %, followed by water bodies area with an area of 0.50 km^2 or 0.11 % and urban and built-up land with an area of 3.69 km^2 or 0.82 %, respectively.

Urban and built-up land was increased with an area of 13.64 km^2 or 3.02 %, of the sub-basin area. Furthermore, the most of urban and built-up land was transformed form agricultural land 9.95 km^2 or 2.20 %, followed by forest land 3.69 km^2 or 0.82 %, respectively.

Water bodies area was increased with an area of 3.69 km2 or 0.82 % of the sub-basin area. The most of water bodies area were transformed form forest land.

4.2.6.4 Land use changes in Mae Kham Mee Sub-basin during 1988 to 2009

Agricultural land was increased with an area of 30.72 km^2 or 6.79 % of the sub-basin area, paddy field 3.09 km^2 or 0.68 %, field crop 23.33 km^2 or 5.16 % and perennial 4.31 km^2 or 0.95 %. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 33.90 km^2 or 7.49 % of the sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 30.72 km^2 or 6.79 %, followed by water bodies area with an area of 0.19 km^2 or 0.04 % and urban and built-up land with an area of 2.99 km^2 or 0.66 %, respectively.

Urban and built-up land was increased with an area of 13.62 km^2 or 3.01 %, of the sub-basin area. Furthermore, the most of urban and built-up land was transformed form agricultural land 10.64 km^2 or 2.35 %, followed by forest land 2.99 km2 or 0.66 %, respectively.

Water bodies area was increased with an area of 0.19 km^2 or 0.04 % of the sub-basin area. The most of water bodies area were transformed form forest land.

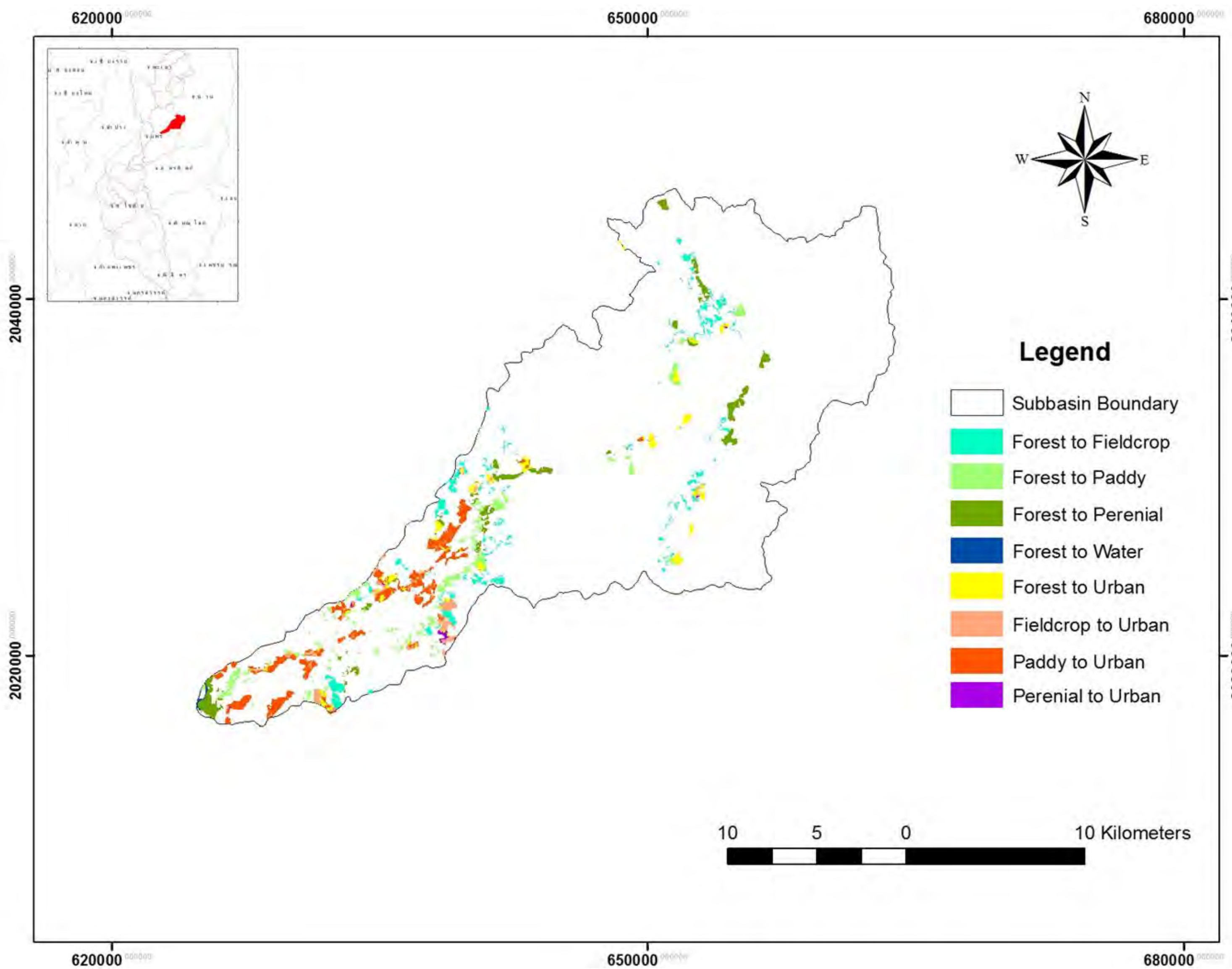


Figure 4-28 Change detection map of Mae Kham mee Sub-basin from 1988 to 1995

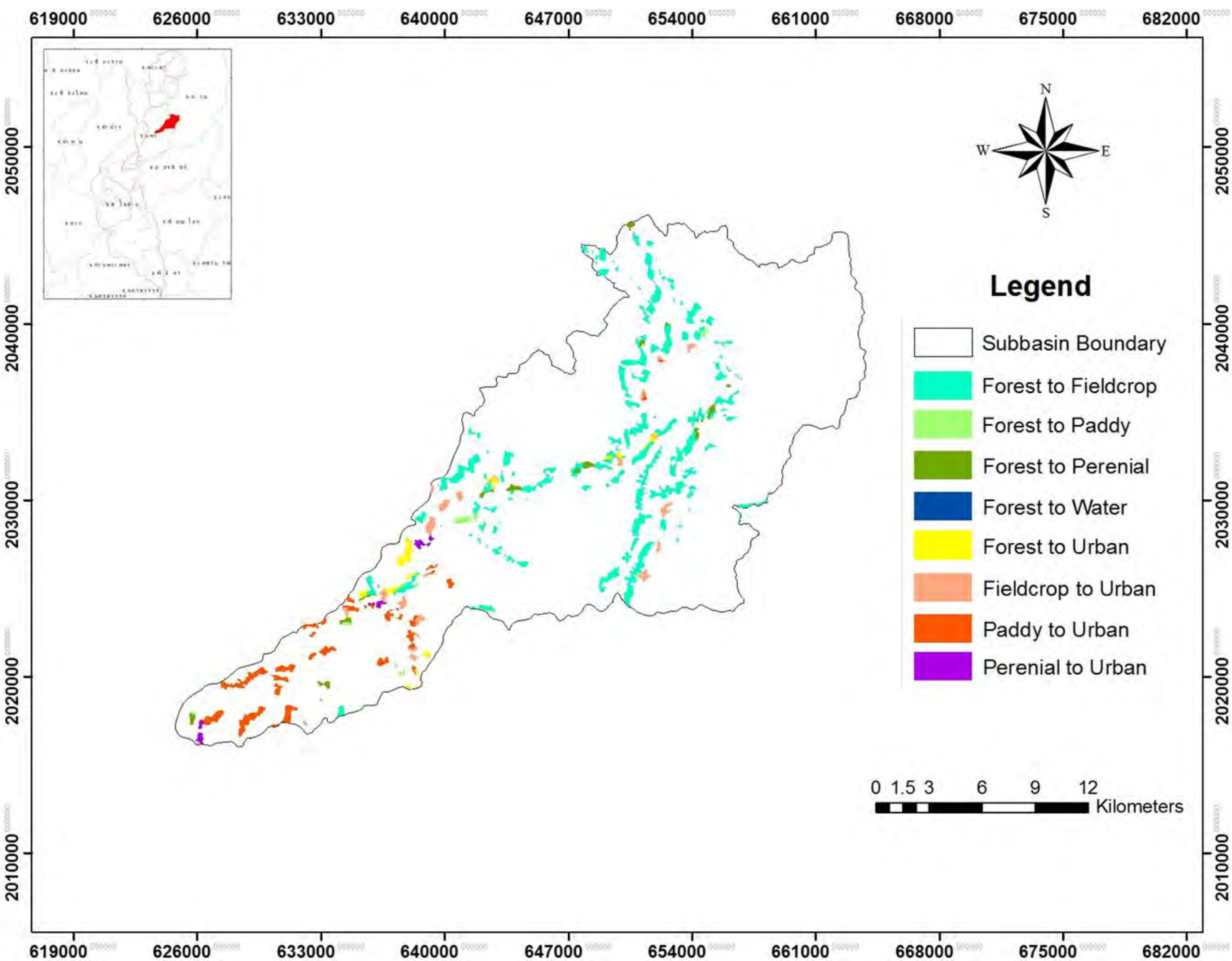


Figure 4-29 Change detection map of Mae Kham mee Sub-basin from 1995 to 2003

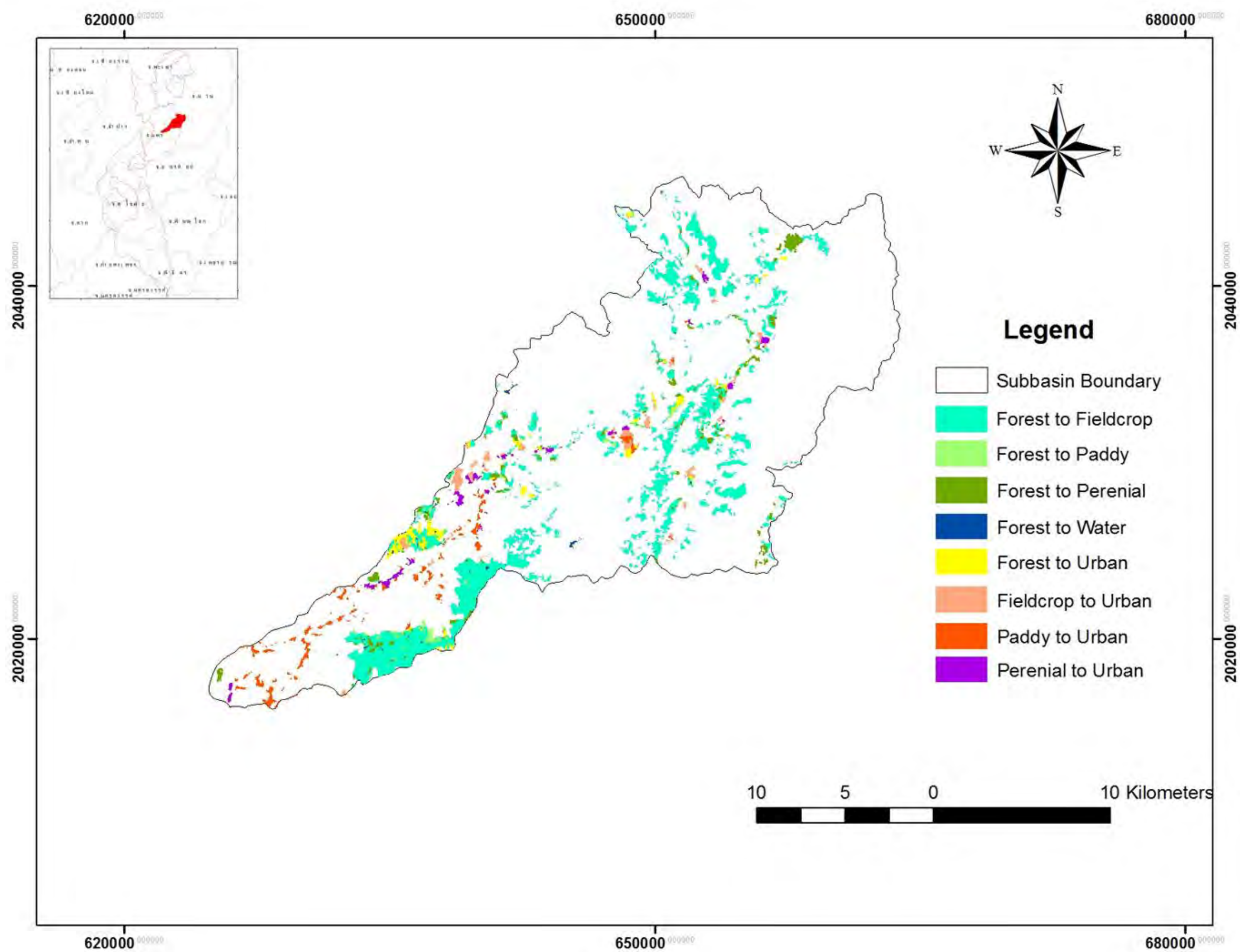


Figure 4-30 Change detection map of Mae Kham mee Sub-basin from 2003 to 2009

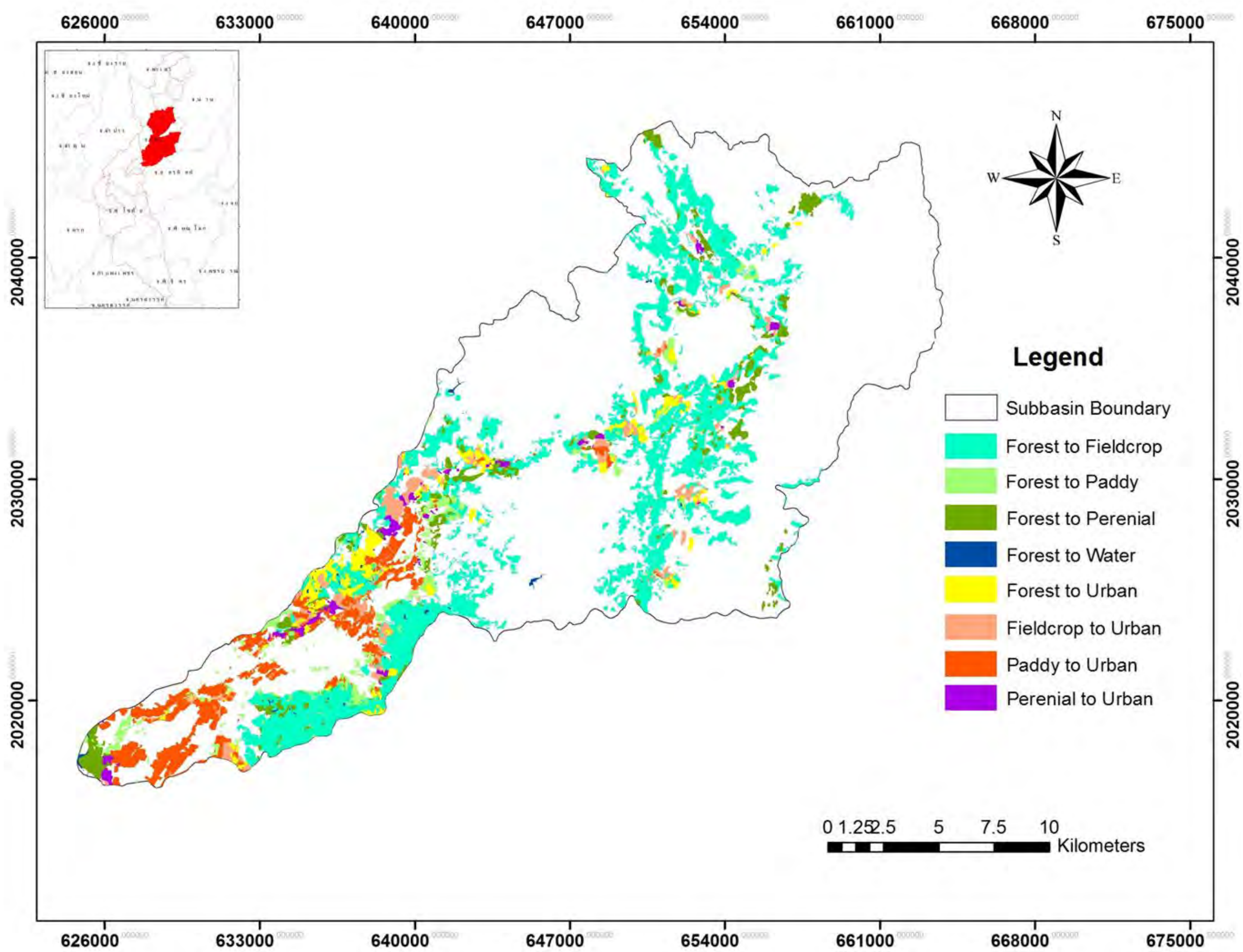


Figure 4-31 Change detection map of Mae Kham mee Sub-basin from 2003 to 2009

4.2.7 Land use changes Mae Ta Sub-basin

4.2.7.1 Land use changes in Mae Ta Sub-basin during 1988 to 1995

Agricultural land was increased with an area of 12.46 km^2 or 2.41 % of sub-basin area , paddy field 8.88 km^2 or 1.72 %, field crop 3.41 km^2 or 0.66 % and perennial 0.17 km^2 or 0.03 %. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 14.51 km^2 or 2.81% of sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 12.46 km2 or 2.41 %, followed by water bodies area with an area of 0.10 km^2 or 0.02 % and urban and built-up land with an area of 1.94 km^2 or 0.38 %, respectively.

Urban and built-up land was increased with an area of 3.59 km^2 or 0.70%, of sub-basin area. Furthermore, the most of urban and built-up land was transformed form forest land 1.94 km^2 or 0.38 %, followed by agricultural land 1.65 km^2 or 0.32%, respectively.

Water bodies area was increased with an area of 0.10 km2 or 0.02 % of sub-basin area. The most of water bodies area were transformed form forest land.

4.2.7.2 Land use changes in Mae Ta Sub-basin during 1995 to 2003

Agricultural land was increased with an area of 9.98 km^2 or 1.93 % of sub-basin area, paddy field 8.42 km^2 or 1.63%, field crop 1.36 km^2 or 0.26 % and perennial 0.20 km^2 or 0.04 %. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 10.93 km^2 or 2.12 % of sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 9.98 km^2 or 1.93 %, followed by water bodies area with an area of 0.10 km^2 or 0.02 % and urban and built-up land with an area of 0.85 km^2 or 0.16 %, respectively.

Urban and built-up land was increased with an area of 2.38 km^2 or 0.46 %, of sub-basin area. Furthermore, the most of urban and built-up land was transformed form agricultural land 1.53 km^2 or 0.30%, followed by forest land 0.85 km2 or 0.16 %, respectively.

Water bodies area was increased with an area of 0.10 km2 or 0.02 % of sub-basin area. The most of water bodies area were transformed form forest land.

4.2.7.3 Land use changes in Mae Ta Sub-basin during 2003 to 2009

Agricultural land was increased with an area of 53.14 km^2 or 10.30 % of of sub-basin area, paddy field 13.73 km^2 or 2.66%, field crop 38.22 km^2 or 7.41 % and perennial 1.19 km^2 or 0.23%. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 56.00 km^2 or 10.85% of sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 53.14 km2 or 10.30 %, followed by water bodies area with an area of 0.84 km^2 or 0.16 % and urban and built-up land with an area of 2.02 km^2 or 0.39 %, respectively.

Urban and built-up land was increased with an area of 3.45 km^2 or 0.67%, of sub-basin area. Furthermore, the most of urban and built-up land was transformed form forest land 2.02 km^2 or 0.39 %, followed by agricultural land 1.43 km^2 or 0.28%, respectively.

Water bodies area was increased with an area of 0.84 km^2 or 0.16 % of sub-basin area. The most of water bodies area were transformed form forest land.

4.2.7.4 Land use changes in Mae Ta Sub-basin during 1988 to 2009

Agricultural land was increased with an area of 23.14 km^2 or 4.49 % of sub-basin area, paddy field 10.09 km^2 or 1.96 %, field crop 12.58 km^2 or 2.44 % and perennial 0.47 km^2 or 0.09 %. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 25.00 km^2 or 4.85 % of sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 23.14 km2 or 4.49 %, followed by water bodies area with an area of 0.31 km^2 or 0.06 % and urban and built-up land with an area of 1.55 km^2 or 0.30 %, respectively.

Urban and built-up land was increased with an area of 3.09 km^2 or 0.60 %, of sub-basin area. Furthermore, the most of urban and built-up land was transformed form forest land 1.55 km^2 or 0.30 %, followed by agricultural land 1.54 km^2 or 0.30%, respectively.

Water bodies area was increased with an area of 0.31 km^2 or 0.06 % of sub-basin area. The most of water bodies area were transformed form forest land.

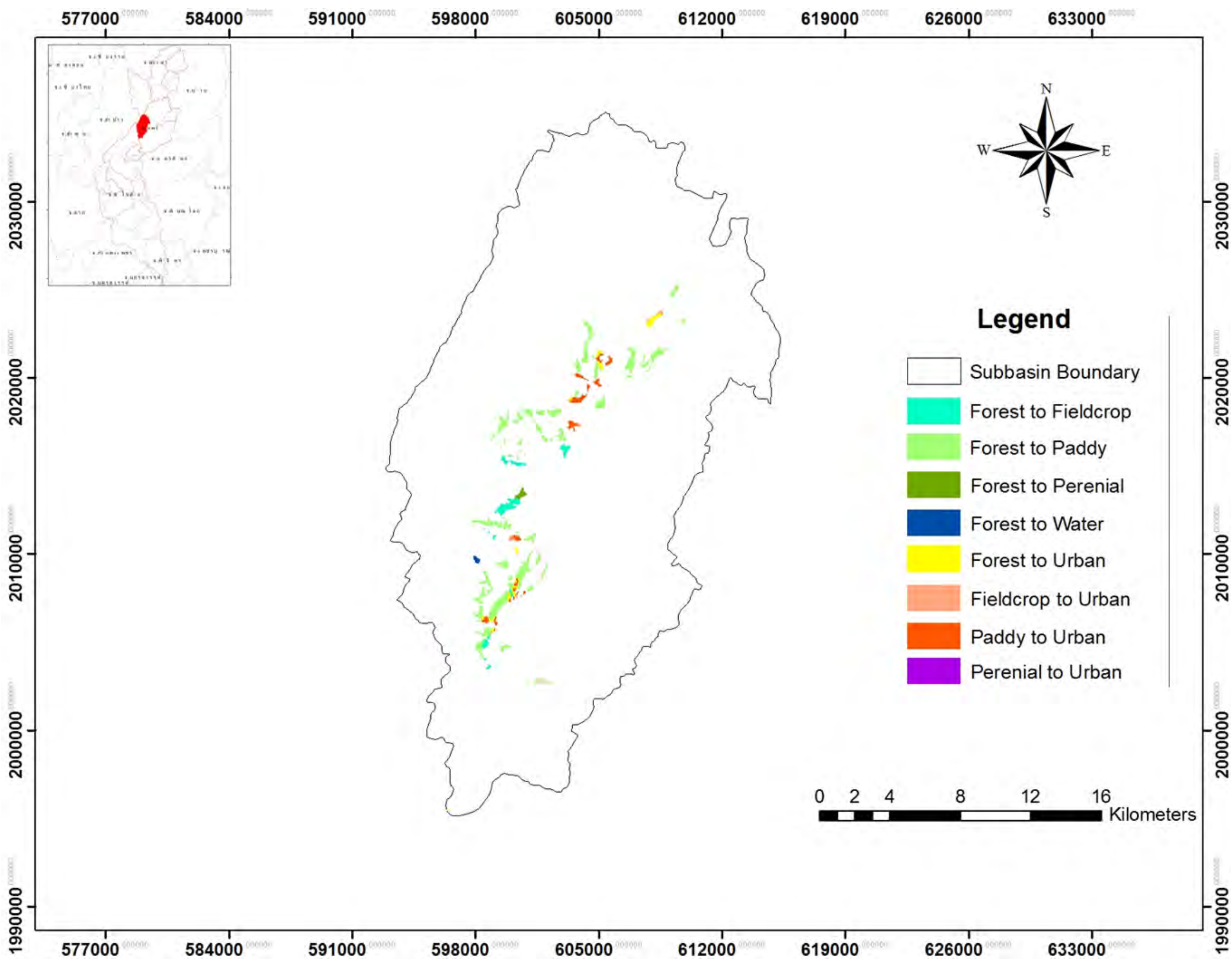


Figure 4-32 Change detection map of Mae Ta Sub-basin from 1988 to 1995

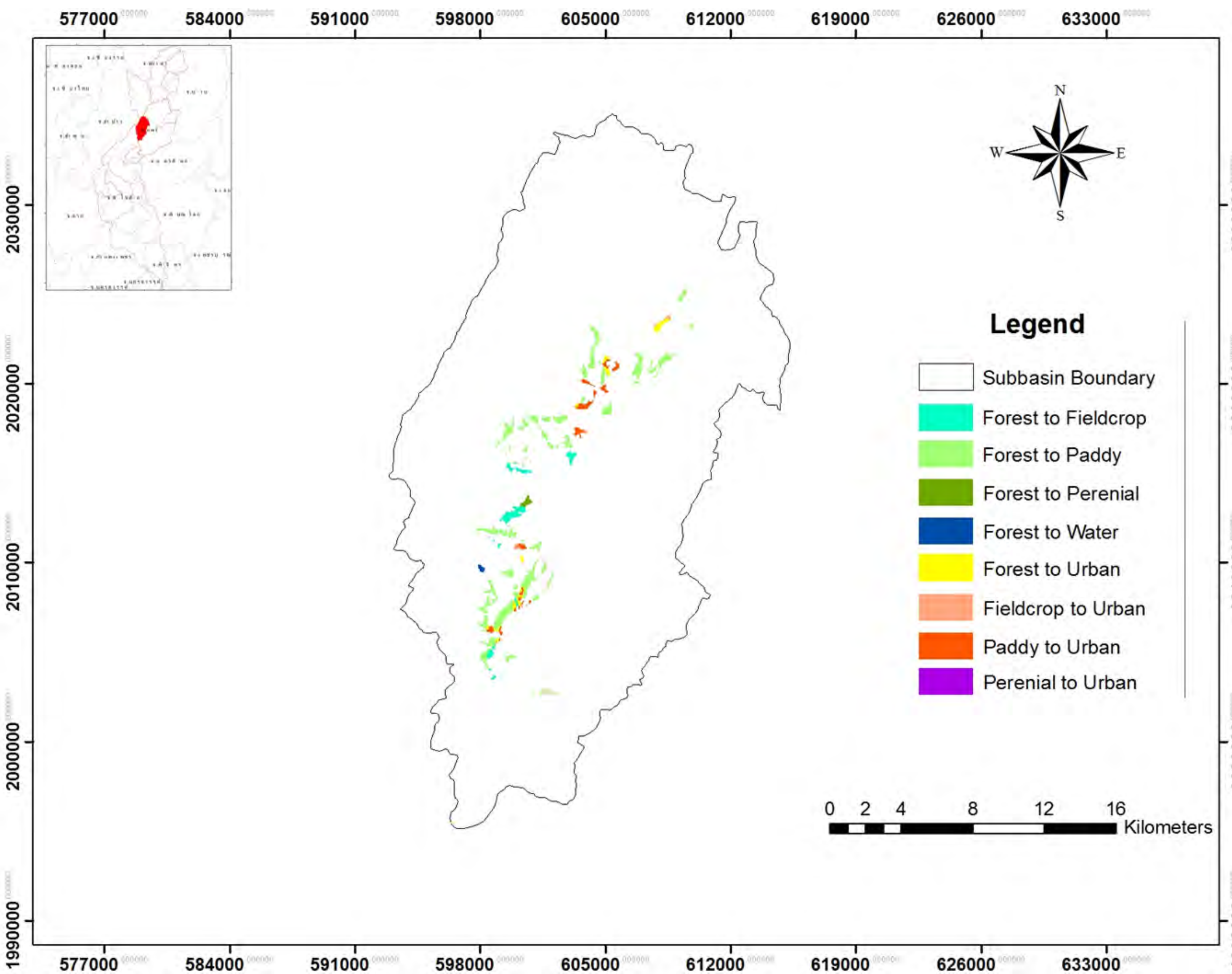


Figure 4-33 Change detection map of Mae Ta Sub-basin from 1995 to 2003

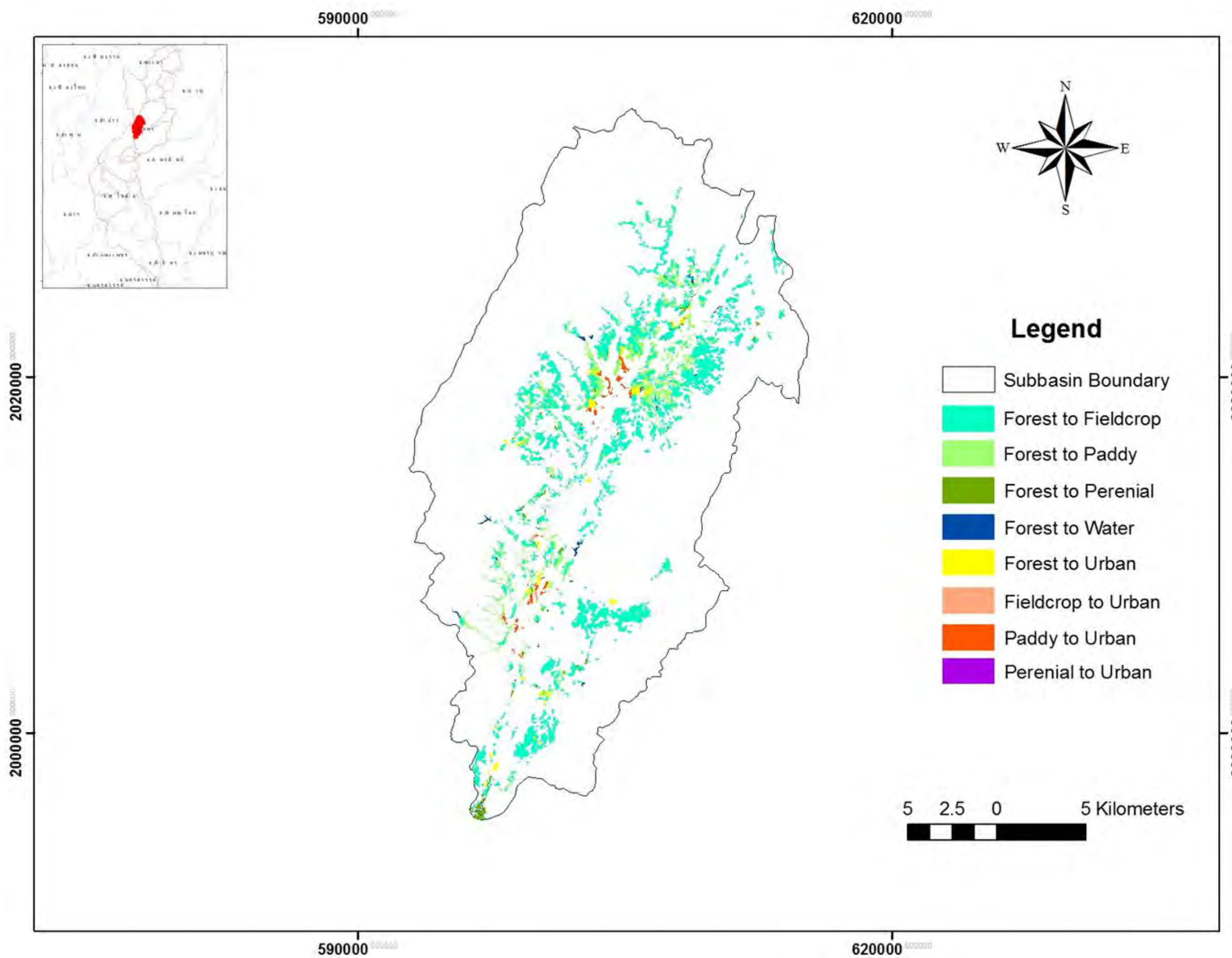


Figure 4-34 Change detection map of Mae Ta Sub-basin from 2003 to 2009

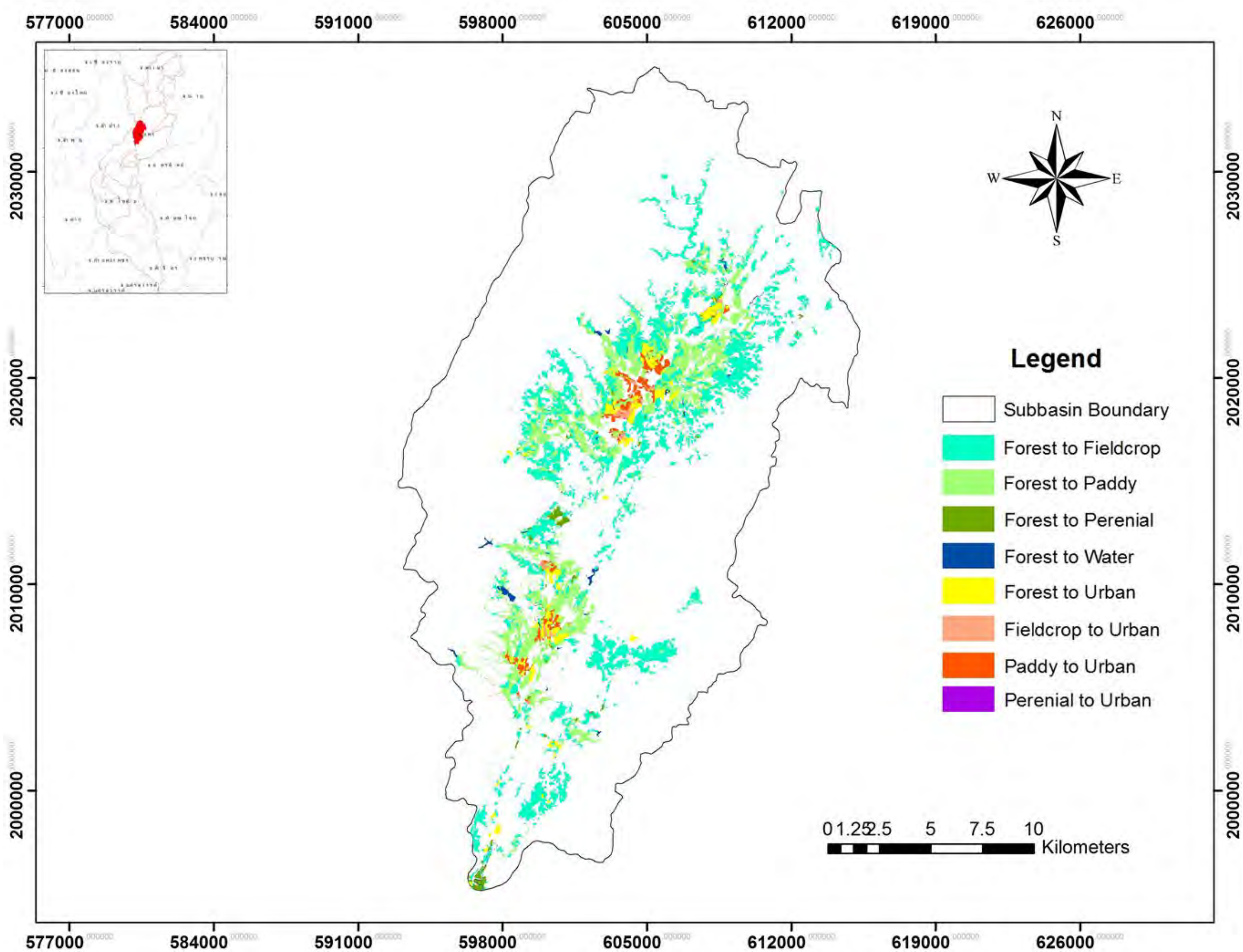


Figure 4-35 Change detection map of Mae Ta Sub-basin from 1988 to 2009

4.2.8 Land use changes Huay Mae Sin Sub-basin

4.2.8.1 Land use changes in Huay Mae Sin Sub-basin during 1988 to 1995

Agricultural land was increased with an area of 24.79 km^2 or 4.64 % of sub-basin area, paddy field 5.24 km^2 or 0.98%, field crop 4.00 km^2 or 0.75 % and perennial 15.55 km^2 or 2.91%. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 25.82 km^2 or 4.84% of sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 24.79 km^2 or 4.64 %, followed by water bodies area with an area of 0.17 km^2 or 0.03 % and urban and built-up land with an area of 0.87 km^2 or 0.16%, respectively.

Urban and built-up land was increased with an area of 2.57 km^2 or 0.48%, of sub-basin area. Furthermore, the most of urban and built-up land was transformed form agricultural land 1.69 km^2 or 0.32%, followed by forest land 0.87 km^2 or 0.16%, respectively.

Water bodies area was increased with an area of 0.17 km^2 or 0.03 % of the land use changes. The most of water bodies area were transformed form forest land.

4.2.8.2 Land use changes in Huay Mae Sin Sub-basin during 1995 to 2003

Agricultural land was increased with an area of 28.51 km^2 or 5.34 % of sub-basin area, paddy field 3.77 km^2 or 0.71 %, field crop 10.43 km^2 or 1.95 % and perennial 14.31 km^2 or 2.68 %. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 29.88 km^2 or 5.60% of sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 28.51 km^2 or 5.34 %, followed by water bodies area with an area of 0.17 km^2 or 0.03 % and urban and built-up land with an area of 1.20 km^2 or 0.22%, respectively.

Urban and built-up land was increased with an area of 2.54 km^2 or 0.48 %, of sub-basin area. Furthermore, the most of urban and built-up land was transformed form agricultural land 1.34 km^2 or 0.25%, followed by forest land 1.20 km^2 or 0.22%, respectively.

Water bodies area was increased with an area of 0.17 km^2 or 0.03 % of the land use changes. The most of water bodies area were transformed form forest land.

4.2.8.3 Land use changes in Huay Mae Sin Sub-basin during 2003 to 2009

Agricultural land was increased with an area of 51.55 km^2 or 9.65 % of sub-basin area, paddy field 4.41 km^2 or 0.83%, field crop 27.65 km^2 or 5.18% and perennial 19.49 km^2 or 3.65 %. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 53.68 km^2 or 10.05% of sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 51.55 km^2 or 9.65 %, followed by water bodies area with an area of 1.02 km^2 or 0.19 % and urban and built-up land with an area of 1.11 km^2 or 0.21%, respectively.

Urban and built-up land was increased with an area of 4.55 km^2 or 0.85%, of sub-basin area. Furthermore, the most of urban and built-up land was transformed form agricultural land 3.44 km^2 or 0.64%, followed by forest land 1.11 km^2 or 0.21%, respectively.

Water bodies area was increased with an area of 1.02 km^2 or 0.19 % of sub-basin area. The most of water bodies area were transformed form forest land.

4.2.8.4 Land use changes in Huay Mae Sin Sub-basin during 1988 to 2009

Agricultural land was increased with an area of 33.85 km^2 or 6.34 % of sub-basin area, paddy field 4.44 km^2 or 0.83 %, field crop 13.21 km^2 or 2.47 % and perennial 16.20 km^2 or 3.03 %. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 35.33 km^2 or 6.62 % of sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of of 33.85 km2 or 6.34 %, followed by water bodies area with an area of 0.41 km^2 or 0.08 % and urban and built-up land with an area of 1.07 km^2 or 0.20 %, respectively.

Urban and built-up land was increased with an area of 3.12 km^2 or 0.58 %, of sub-basin area. Furthermore, the most of urban and built-up land was transformed form forest land 1.07 km2 or 0.20%, followed by agricultural land 2.06 km^2 or 0.39 %, respectively.

Water bodies area was increased with an area of 0.41 km2 or 0.08 % of sub-basin area. The most of water bodies area were transformed form forest land.

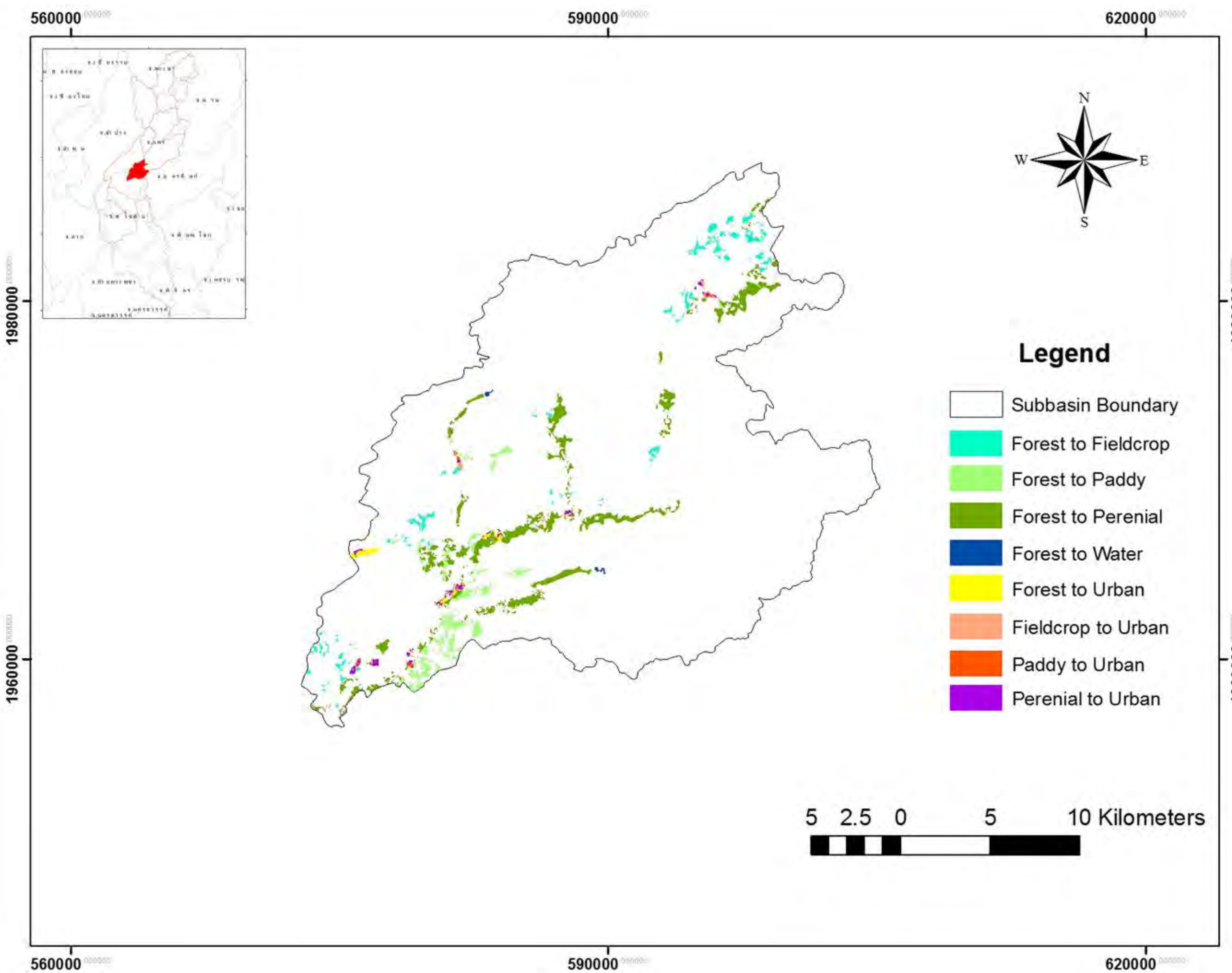


Figure 4-36 Change detection map of Mae sin Sub-basin from 1988 to 1995

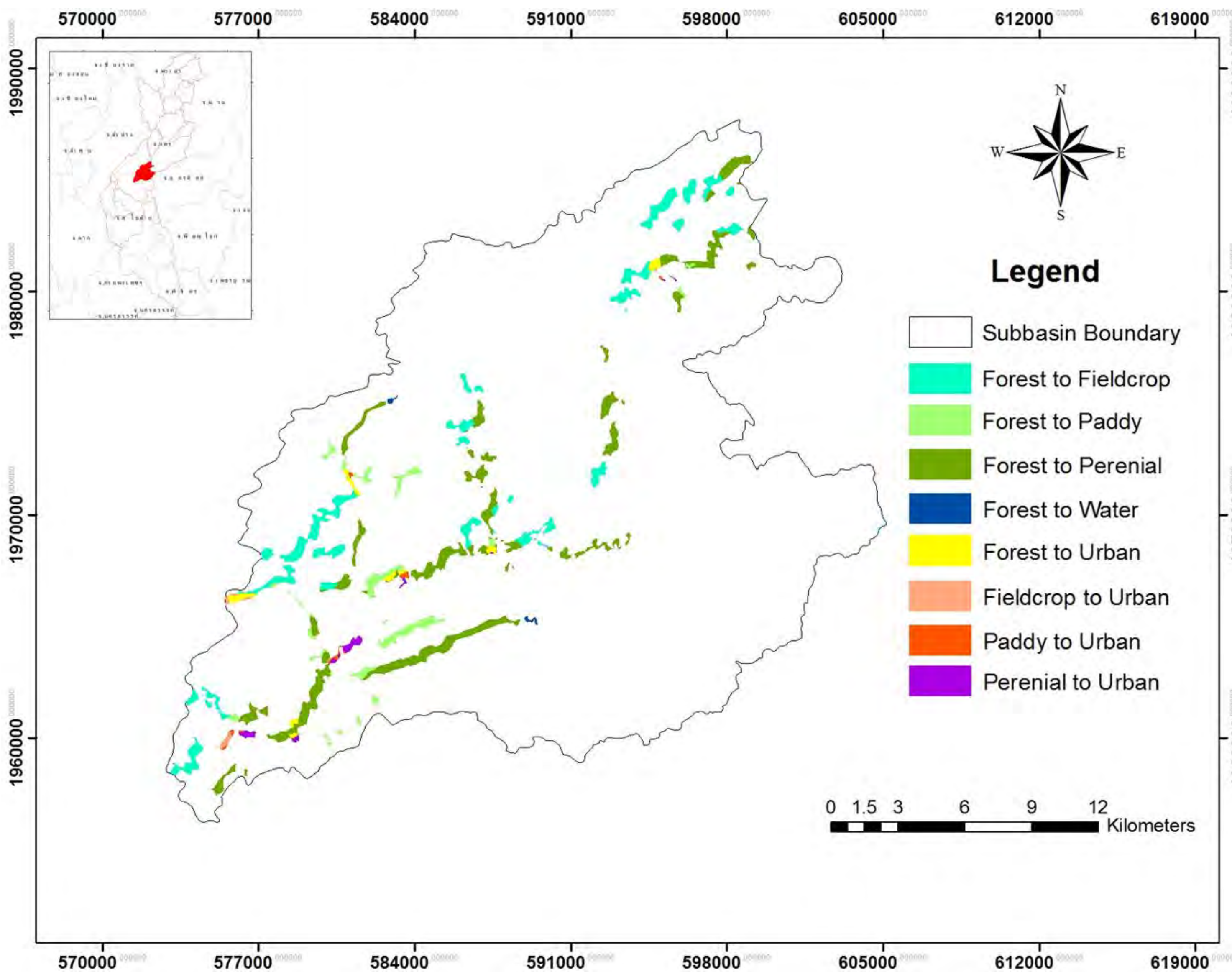


Figure 4-37 Change detection map of Mae sin Sub-basin from 1995 to 2003

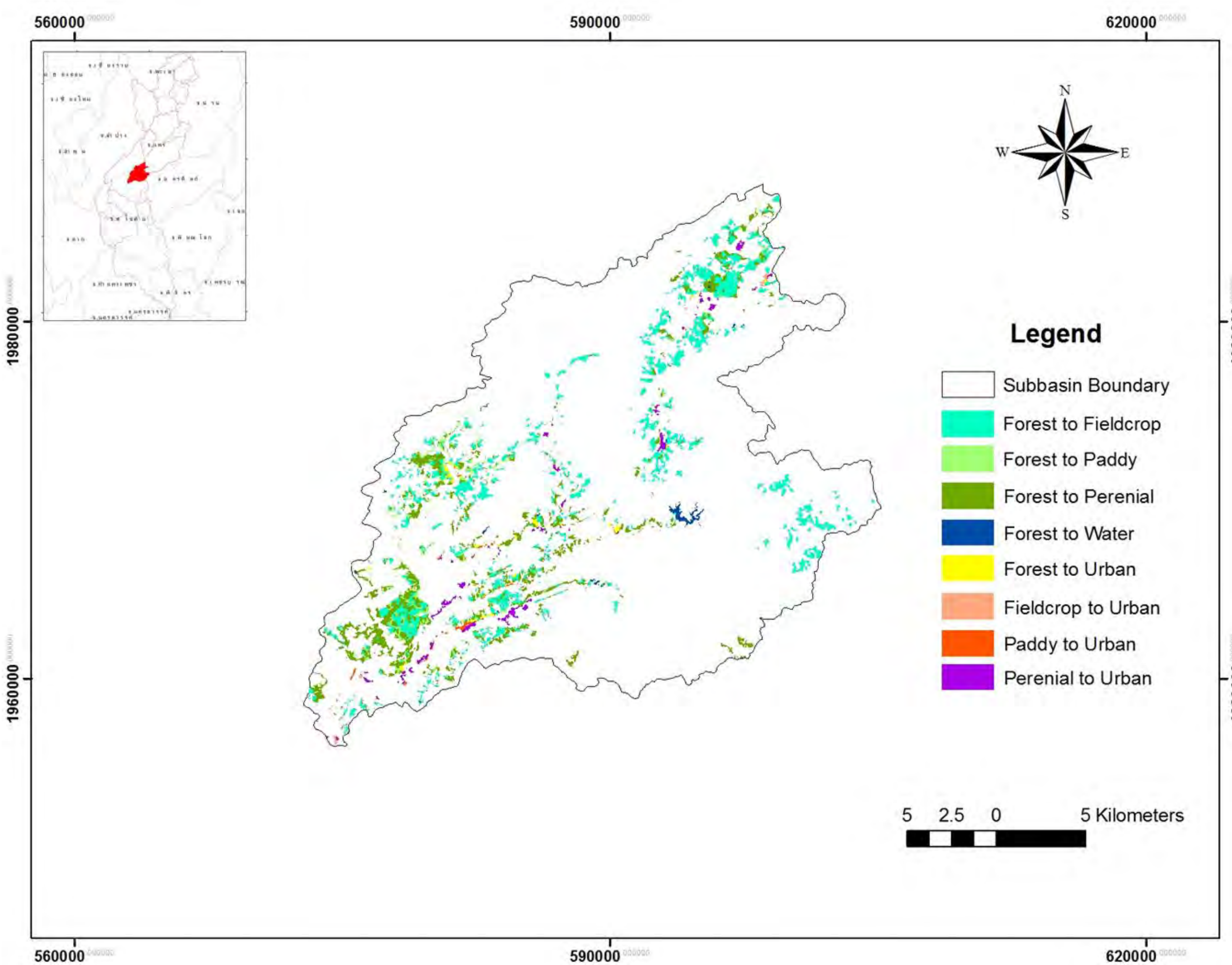


Figure 4-38 Change detection map of Mae Sin Sub-basin from 2003 to 2009

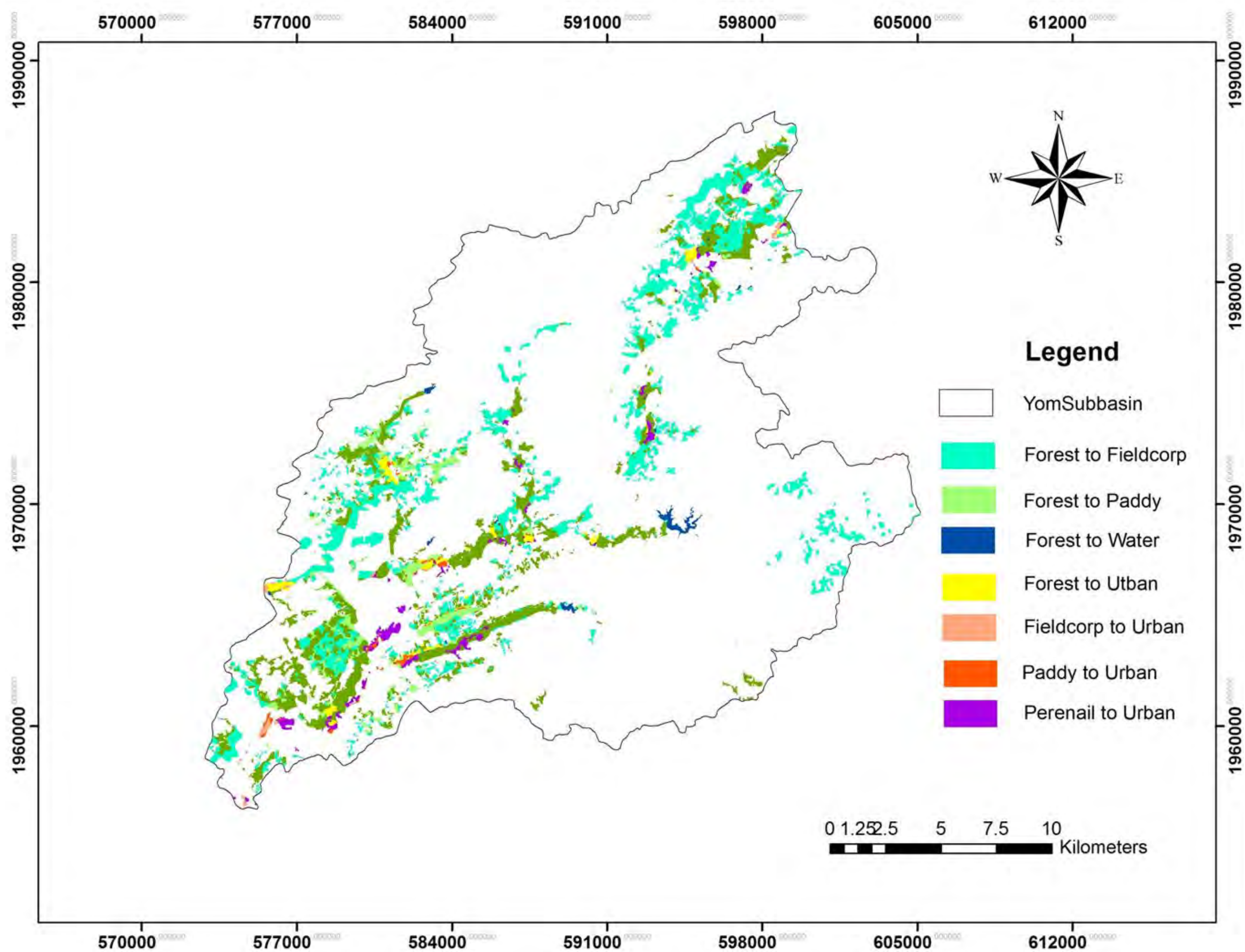


Figure 4-39 Change detection map of Mae sin Sub-basin from 1988 to 2009

4.2.9 Land use changes Mae Mok Sub-basin

4.2.9.1 Land use changes in Mae Mok Sub-basin during 1988 to 1995

Agricultural land was increased with an area of 41.32 km^2 or 3.71 % of sub-basin area, paddy field 23.15 km^2 or 2.08 %, field crop 5.89 km^2 or 0.53 % and perennial 12.28 km^2 or 1.10%. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 65.37 km^2 or 5.87 % of sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 41.32 km2 or 3.71 %, followed by water bodies area with an area of 1.86 km^2 or 0.17% and urban and built-up land with an area of 22.20 km^2 or 1.99 %, respectively.

Urban and built-up land was increased with an area of 37.50 km^2 or 3.37%, of sub-basin area. Furthermore, the most of urban and built-up land was transformed form forest land 22.20 km^2 or 1.99 %, followed by agricultural land 15.30 km^2 or 1.37%, respectively.

Water bodies area was increased with an area of 1.86 km^2 or 0.17% of sub-basin area. The most of water bodies area were transformed form forest land.

4.2.9.2 Land use changes in Mae Mok Sub-basin during 1995 to 2003

Agricultural land was increased with an area of 41.02 km^2 or 3.68 % of sub-basin area, paddy field 17.25 km^2 or 1.55 %, field crop 15.26 km^2 or 1.37% and perennial 8.51 km^2 or 0.76%. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 56.91 km^2 or 5.11% of of sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 41.02 km^2 or 3.68 %, followed by water bodies area with an area of 1.28 km^2 or 0.11 % and urban and built-up land with an area of 14.61 km^2 or 1.31 %, respectively.

Urban and built-up land was increased with an area of 22.11 km^2 or 1.98%, of sub-basin area. Furthermore, the most of urban and built-up land was transformed form forest land 14.61 km^2 or 1.31 %, followed by agricultural land 7.49 km^2 or 0.67 %, respectively.

Water bodies area was decreased with an area of 14.61 km^2 or 1.31 % of sub-basin area. The most of water bodies area were transformed form forest land.

4.2.9.3 Land use changes in Mae Mok Sub-basin during 2003 to 2009

Agricultural land was increased with an area of 54.4 km^2 or 4.88 % of sub-basin area, paddy field 12.26 km^2 or 1.10 %, field crop 25.93 km^2 or 2.33 % and perennial 16.21 km^2 or 1.46 %. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 16.21 km^2 or 72.84% of sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 54.4 km^2 or 4.88 %, followed by water bodies area with an area of 13.62 km^2 or 1.22 % and urban and built-up land with an area of 4.82 km^2 or 0.43 %, respectively.

Urban and built-up land was increased with an area of 12.62 km^2 or 1.13 %, of sub-basin area. Furthermore, the most of urban and built-up land was transformed form agricultural land 7.80 km^2 or 0.70 %, followed, by forest land 4.82 km2 or 0.43 %, respectively.

Water bodies area was increased with an area of 13.62 km^2 or 1.22 % of sub-basin area. The most of water bodies area were transformed form forest land.

4.2.9.4 Land use changes in Mae Mok Sub-basin during 1988 to 2009

Agricultural land was increased with an area of 44.94 km^2 or 4.03 % of sub-basin area, paddy field 17.79 km^2 or 1.60 %, field crop 15.19 km^2 or 1.36 % and perennial 11.97 km^2 or 1.07 %. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 64.28 km^2 or 5.77 % of sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 44.94 km2 or 4.03 %, followed by water bodies area with an area of 5.00 km^2 or 0.45 % and urban and built-up land with an area of 14.34 km^2 or 1.29 %, respectively.

Urban and built-up land was increased with an area of 24.53 km^2 or 2.20 %, of sub-basin area. Furthermore, the most of urban and built-up land was transformed form forest land 14.34 km2 or 1.29 %, followed by agricultural land 10.19 km^2 or 0.91 %, respectively.

Water bodies area was increased with an area of 5.00 km2 or 0.45 % of sub-basin area. The most of water bodies area were transformed form forest land.

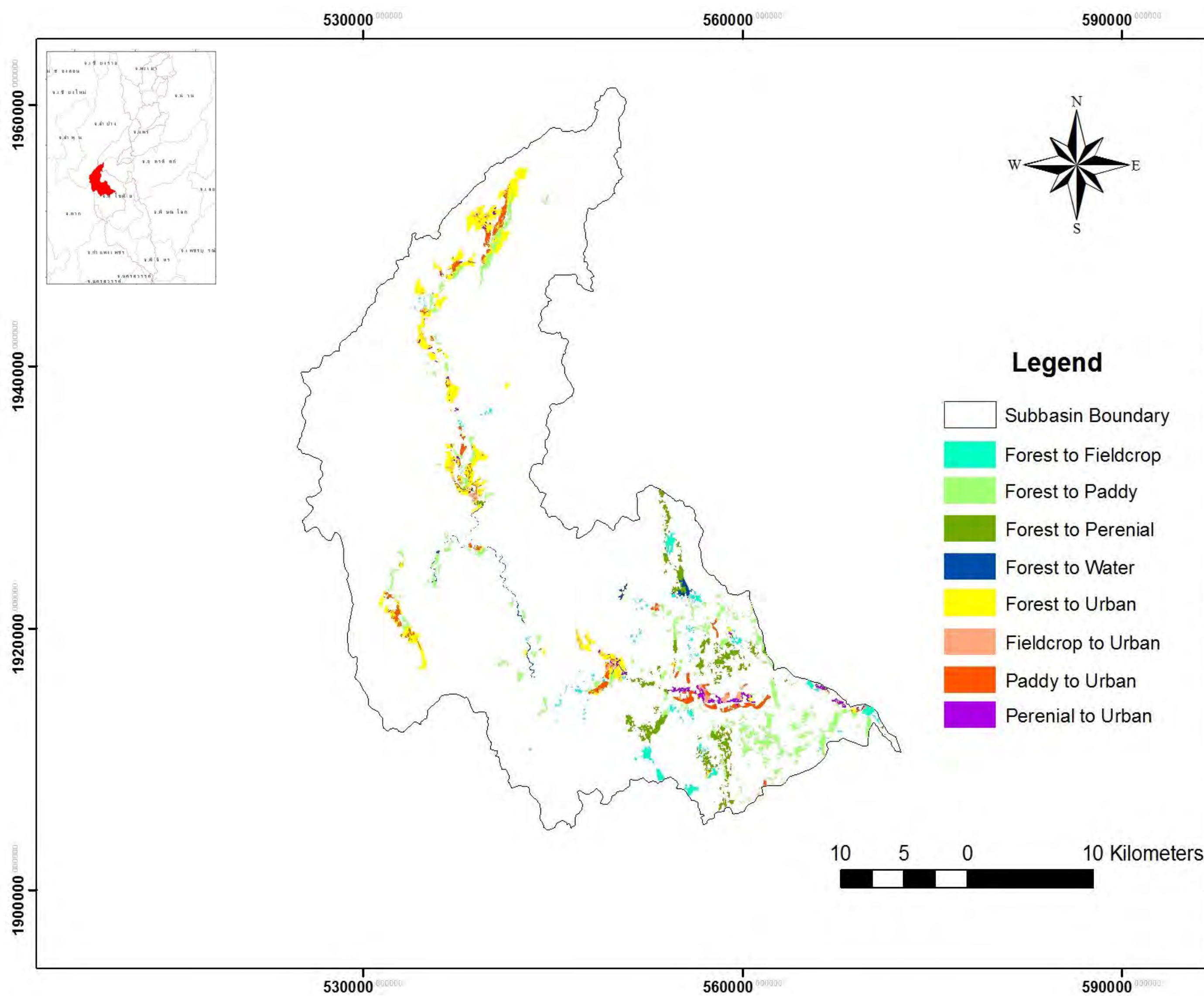


Figure 4-40 Change detection map of Mae Mok Sub-basin from 1988 to 1995

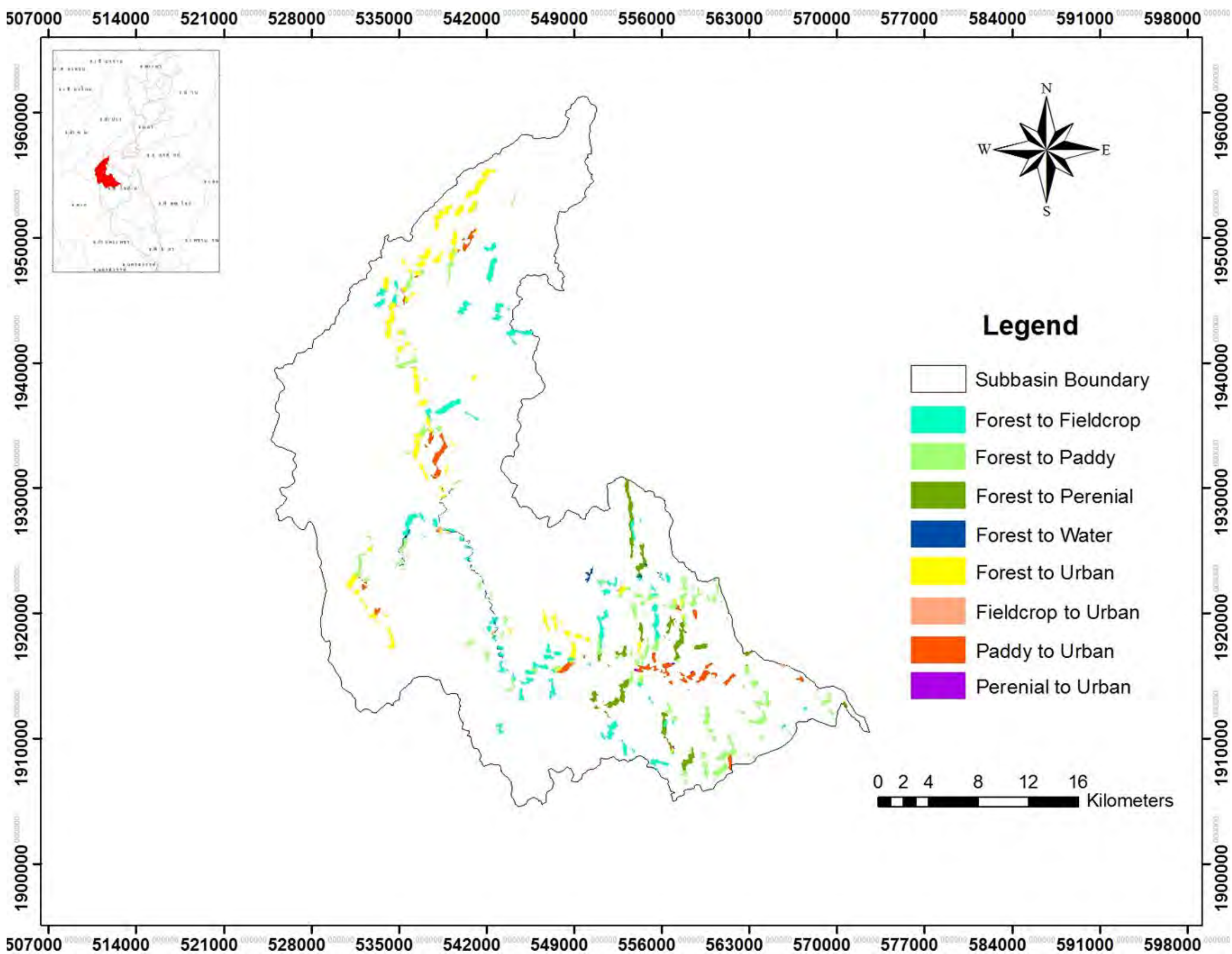


Figure 4-41 Change detection map of Mae Mok Sub-basin from 1995 to 2003

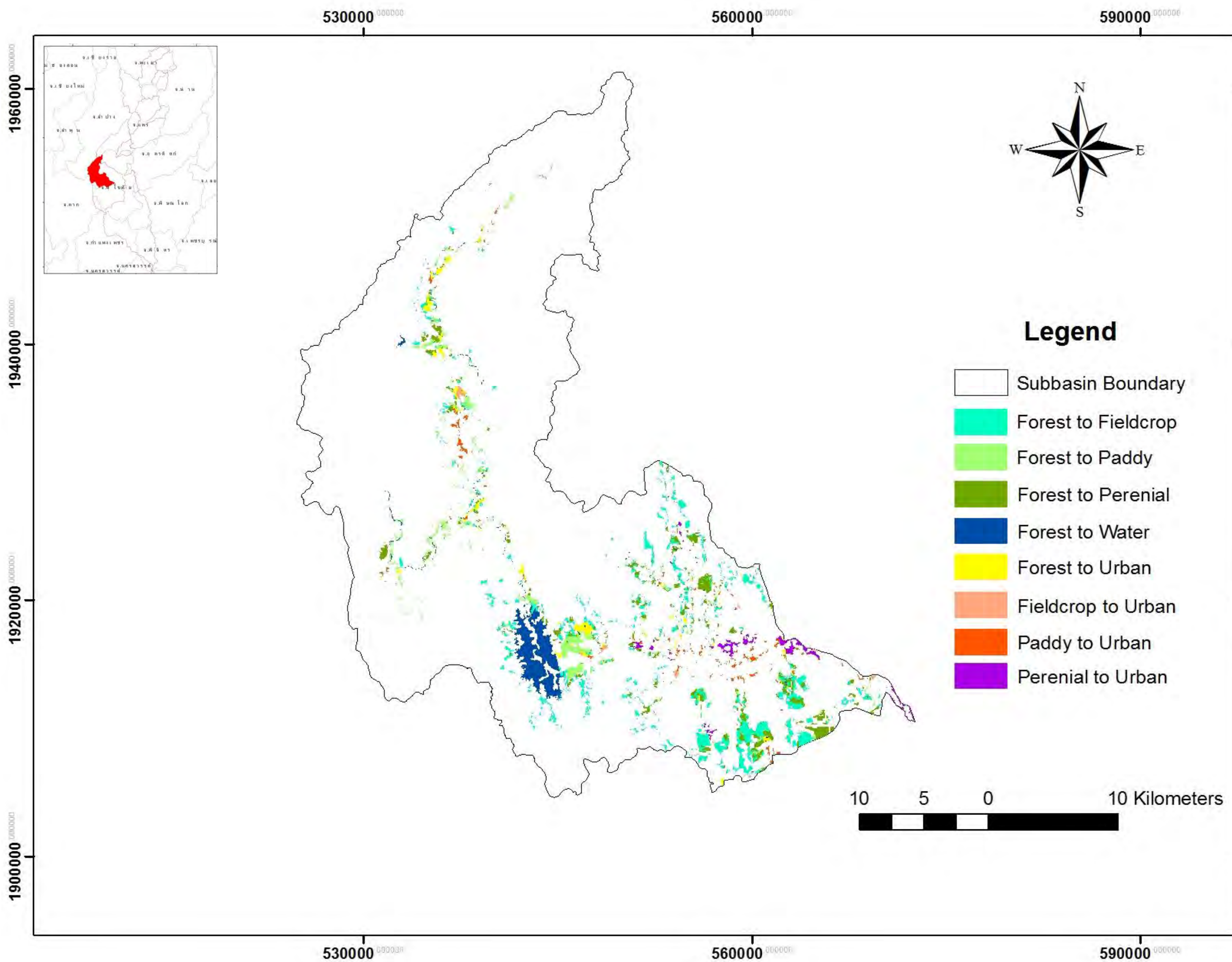


Figure 4-42 Change detection map of Mae Mok Sub-basin from 2003 to 2009

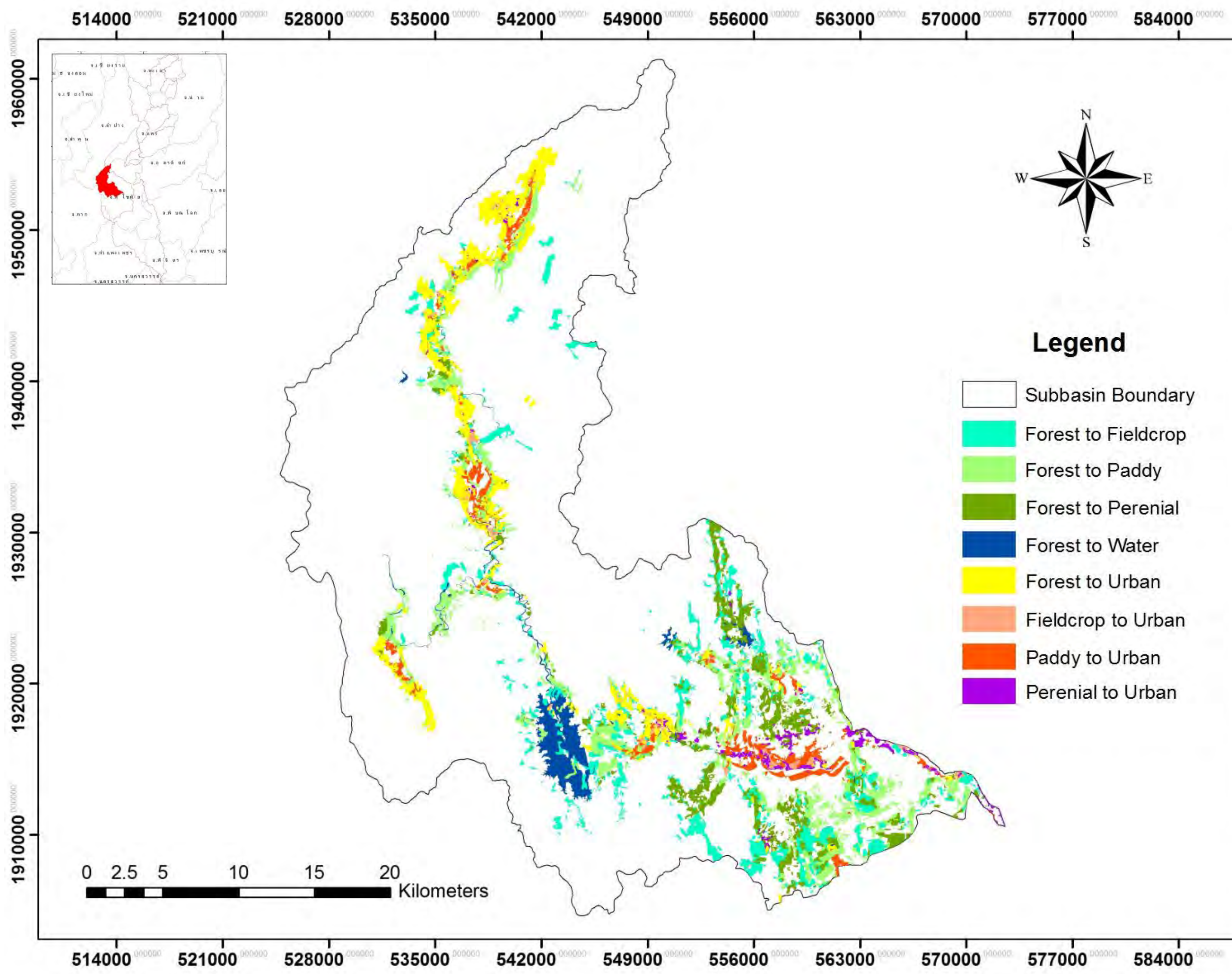


Figure 4-43 Change detection map of Mae Mok Sub-basin from 1988to 2009

4.2.10 Land use changes Mae Ram Phan Sub-basin

4.2.10.1 Land use changes in Mae Ram Phan Sub-basin during 1988 to 1995

Agricultural land was increased with an area of 292.02 km^2 or 10.54 % of sub-basin area, paddy field 118.57 km^2 or 4.28 %, field crop 161.44 km^2 or 5.83 % and perennial 12.01 km^2 or 0.43 %. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 312.84 km^2 or 11.29% of sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 292.02 km^2 or 10.54 %, followed by water bodies area with an area of 5.80 km^2 or 0.21 % and urban and built-up land with an area of 15.02 km^2 or 0.54 %, respectively.

Urban and built-up land was increased with an area of 45.13 km^2 or 1.63 %, of sub-basin area. Furthermore, the most of urban and built-up land was transformed form agricultural land 30.11 km^2 or 1.09%, followed by forest land 15.02 km2 or 0.54 %, respectively.

Water bodies area was increased with an area of 5.80 km2 or 0.21 % of sub-basin area. The most of water bodies area were transformed form forest land.

4.2.10.2 Land use changes in Mae Ram Phan Sub-basin during 1995 to 2003

Agricultural land was increased with an area of 183.13 km^2 or 6.61 % of sub-basin area, paddy field 110.54 km^2 or 3.99%, field crop 65.23 km^2 or 2.35 % and perennial 7.36 km^2 or 0.27 %. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 191.02 km^2 or 6.89 % of sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 183.13 km2 or 6.61 %, followed by water bodies area with an area of 3.31 km^2 or 0.12% and urban and built-up land with an area of 4.57km^2 or 0.17%, respectively.

Urban and built-up land was increased with an area of 40.29 km^2 or 1.45 %, of sub-basin area. Furthermore, the most of urban and built-up land was transformed form agricultural land 35.71 km^2 or 1.29%, followed by forest land 4.57km2 or 0.17%, respectively.

Water bodies area was increased with an area of 3.31 km^2 or 0.12% of sub-basin area. The most of water bodies area were transformed form forest land.

4.2.10.3 Land use changes in Mae Ram Phan Sub-basin during 2003 to 2009

Agricultural land was increased with an area of 201.95 km^2 or 7.29 % of of sub-basin area, paddy field 22.79 km^2 or 0.82%, field crop 151.13 km^2 or 5.45 % and perennial 28.03 km^2 or 1.01 %. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 213.71 km^2 or 7.71% of sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 201.95 km2 or 7.29 %, followed by water bodies area with an area of 3.54 km^2 or 0.13% and urban and built-up land with an area of 8.22 km^2 or 0.30%, respectively.

Urban and built-up land was increased with an area of 73.05 km^2 or 2.64%, of sub-basin area. Furthermore, the most of urban and built-up land was transformed form agricultural land 64.82 km^2 or 2.34%, followed by forest land 8.22 km^2 or 0.30%, respectively.

Water bodies area was increased with an area of 3.54 km^2 or 0.13% of sub-basin area. The most of water bodies area were transformed form forest land.

4.2.10.4 Land use changes in Mae Ram Phan Sub-basin during 1988 to 2009

Agricultural land was increased with an area of 224.80 km^2 or 8.11 % of sub-basin area, paddy field 88.15 km^2 or 3.18 %, field crop 121.84 km^2 or 4.40 % and perennial 14.81 km^2 or 0.53%. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 238.11 km^2 or 8.59 % of sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 224.80 km^2 or 8.11 %, followed by water bodies area with an area of 4.21 km^2 or 0.15 % and urban and built-up land with an area of 9.10 km^2 or 0.33%, respectively.

Urban and built-up land was increased with an area of 51.26 km^2 or 1.85 %, of sub-basin area. Furthermore, the most of urban and built-up land was transformed form forest land 9.10 km^2 or 0.33%, followed by agricultural land 42.16 km^2 or 1.52 %, respectively.

Water bodies area was increased with an area of 4.21 km^2 or 0.15 % of sub-basin area. The most of water bodies area were transformed form forest land.

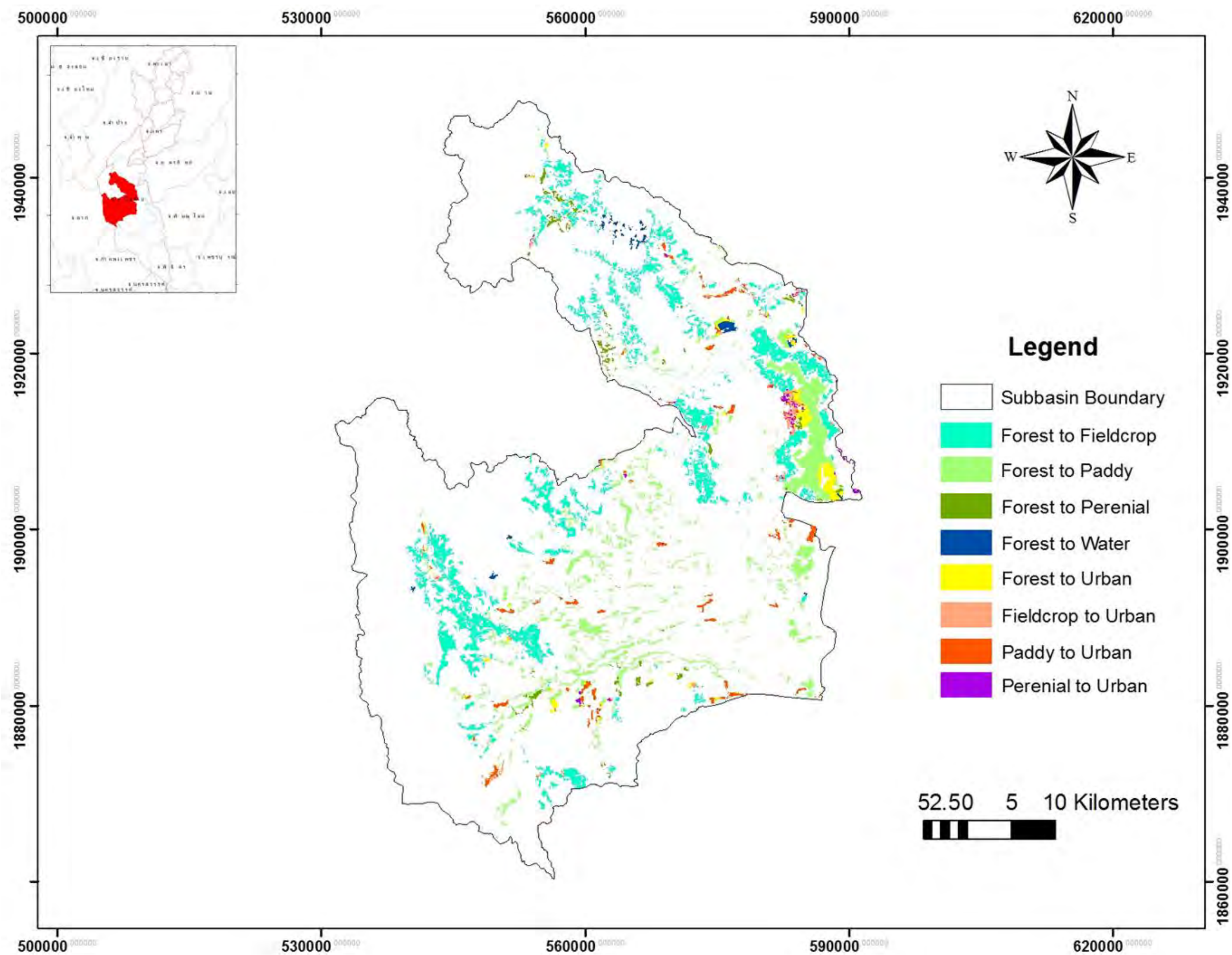


Figure 4-44 **Change detection map of** Mae Ram Phan Sub-basin **from 1988to 1995**

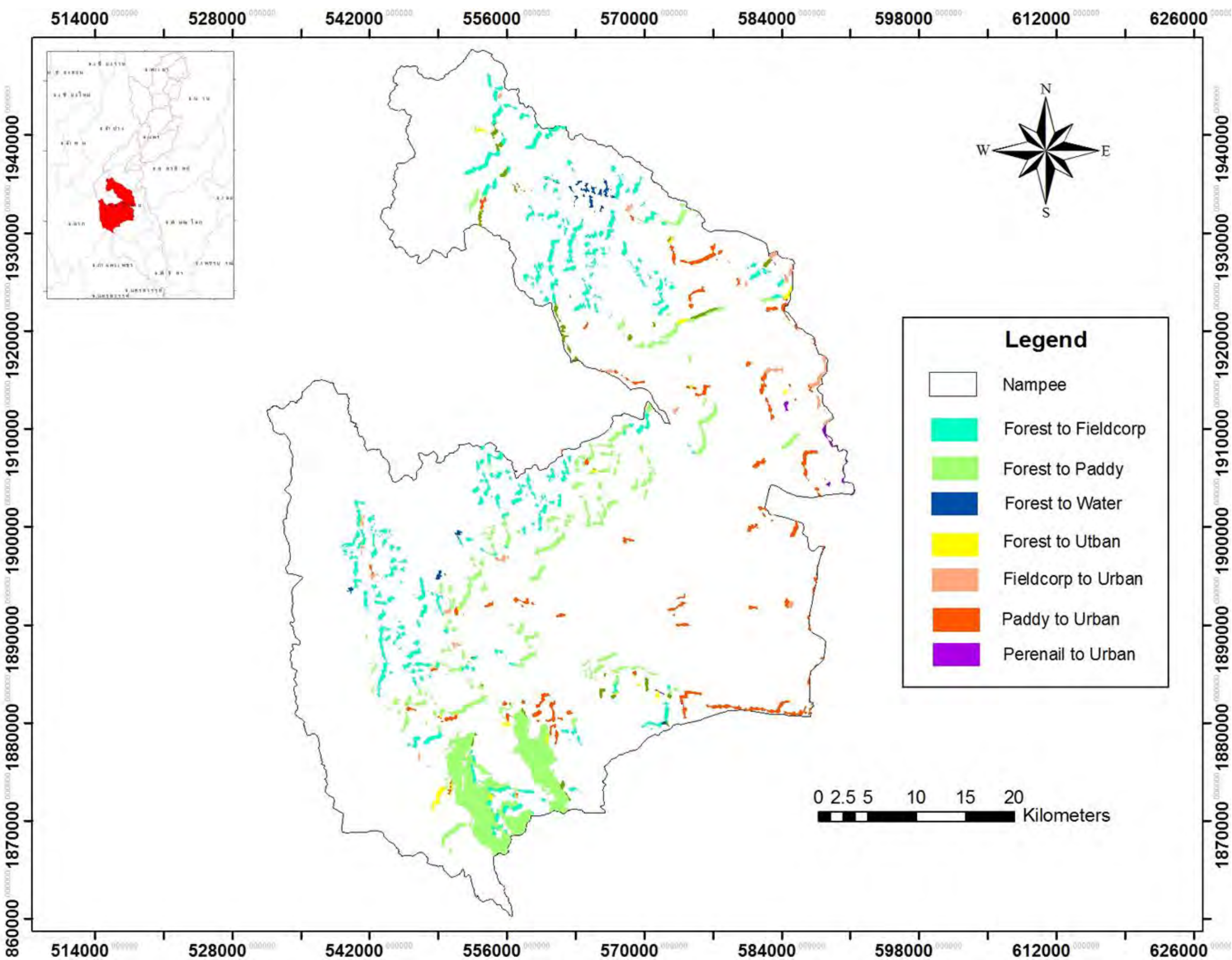


Figure 4-45 **Change detection map of** Mae Ram Phan Sub-basin **from 1995 to 2003**

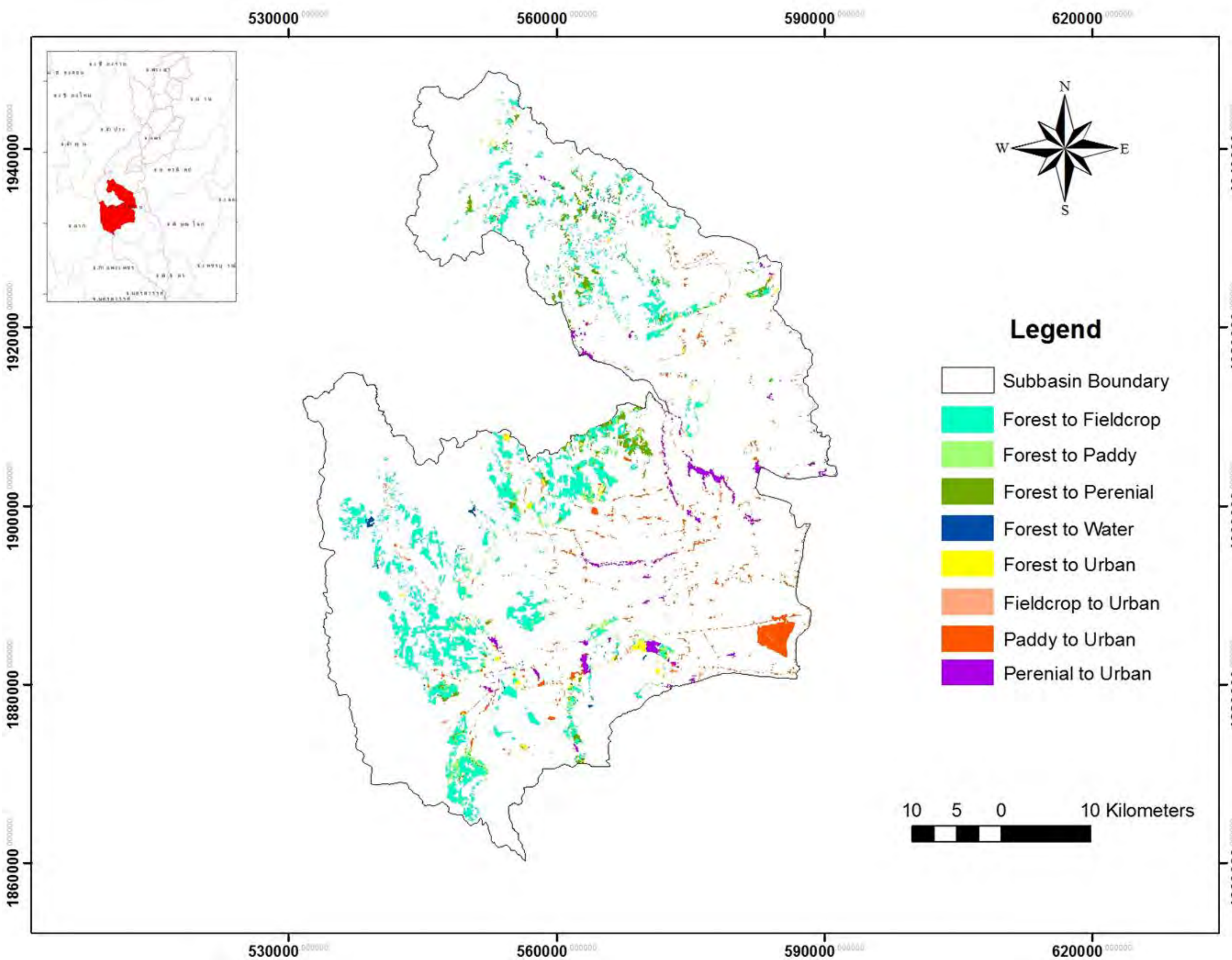


Figure 4-46 Change detection map of Mae Ram Phan Sub-basin from 2003 to 2009

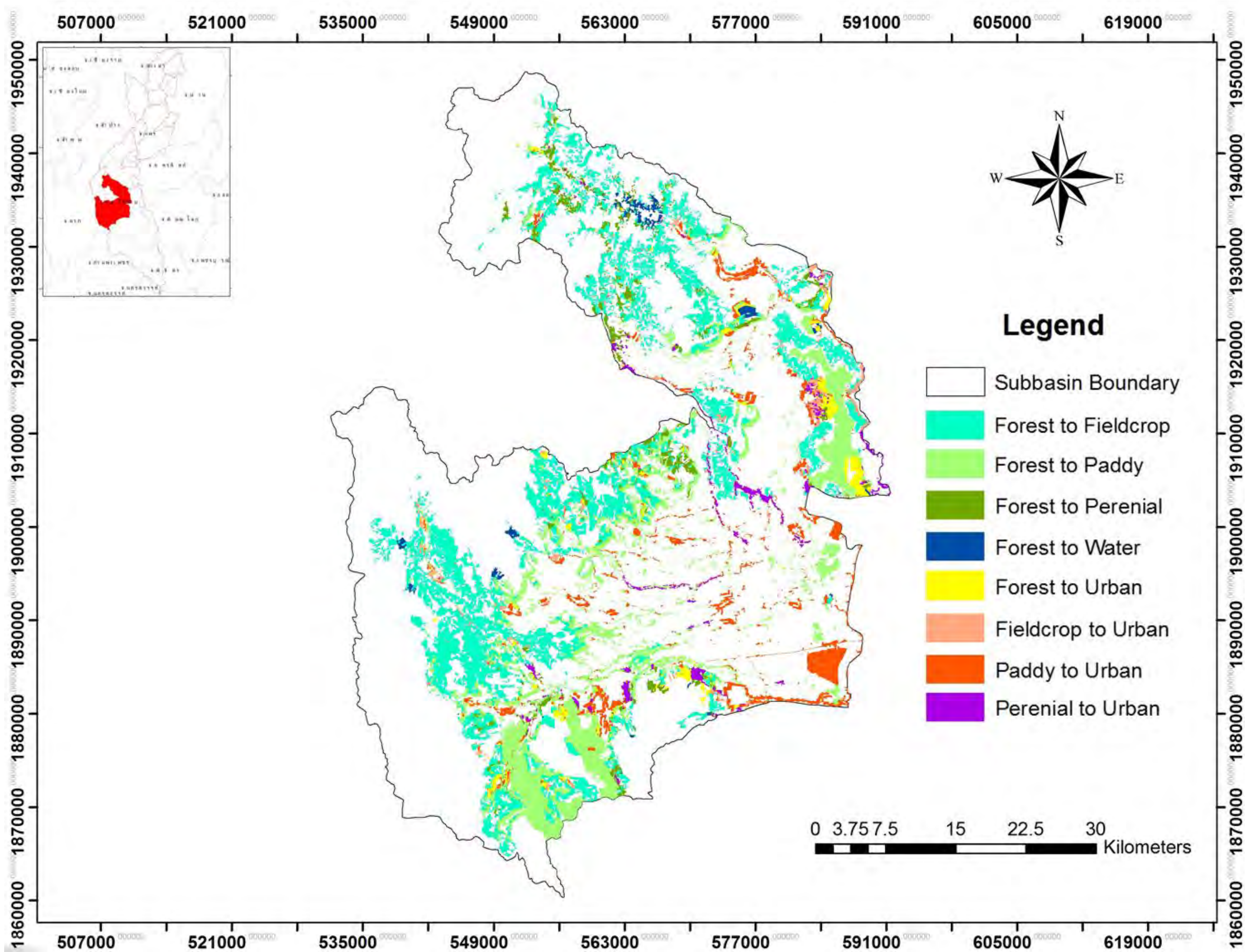


Figure 4-47 Change detection map of Mae Ram Phan Sub-basin from 1988 to 2009

4.2.11 Land use changes Lower Part of Yom Sub-basin

4.2.11.1 Land use changes in Lower Part of Yom Sub-basin during 1988 to 1995

Agricultural land was increased with an area of 1069.36 km^2 or 10.59 % of sub-basin area, paddy field 156.10 km^2 or 1.55 %, field crop 845.60 km^2 or 8.38 % and perennial 67.66 km^2 or 0.67%. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 1093.24 km^2 or 10.83 % of sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 1069.36 km^2 or 10.59 %, followed by water bodies area with an area of 6.21 km^2 or 0.06 % and urban and built-up land with an area of 17.67 km^2 or 0.17 %, respectively.

Urban and built-up land was increased with an area of 342.02 km^2 or 3.39 %, of sub-basin area. Furthermore, the most of urban and built-up land was transformed form agricultural land 324.36 km^2 or 3.21 %, followed by forest land 17.67 km^2 or 0.17 %, respectively.

Water bodies area was increased with an area of 6.21 km2 or 0.06 % of sub-basin area. The most of water bodies area were transformed form forest land.

4.2.11.2 Land use changes in Lower Part of Yom Sub-basin during 1995 to 2003

Agricultural land was increased with an area of 265.51 km^2 or 2.63 % of sub-basin area, paddy field 134.64 km^2 or 1.33 %, field crop 91.62 km^2 or 0.91 % and perennial 39.25 km^2 or 0.39 %. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 282.39 km^2 or 2.80 % of sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 265.51 km^2 or 2.63 %, followed by water bodies area with an area of 4.85 km^2 or 0.05 % and urban and built-up land with an area of 12.03 km^2 or 0.12%, respectively.

Urban and built-up land was increased with an area of 259.21 km^2 or 2.57%, of sub-basin area. Furthermore, the most of urban and built-up land was transformed form agricultural land 247.18 km^2 or 2.45%, followed by forest land 12.03 km^2 or 0.12%, respectively.

Water bodies area was increased with an area of 4.85 km^2 or 0.05 % of sub-basin area. The most of water bodies area were transformed form forest land.

4.2.11.3 Land use changes in Lower Part of Yom Sub-basin during 2003 to 2009

Agricultural land was increased with an area of 284.04 km^2 or 2.81 % of sub-basin area, paddy field 55.95 km^2 or 0.55%, field crop 106.66 km^2 or 1.06 % and perennial 121.43 km^2 or 1.20%. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 304.69 km^2 or 3.02 % of sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 284.04 km^2 or 2.81 %, followed by water bodies area with an area of 6.06 km^2 or 0.06%and urban and built-up land with an area of 14.58 km^2 or 0.14 %, respectively.

Urban and built-up land was increased with an area of 283.28 km^2 or 2.81 %, of sub-basin area. Furthermore, the most of urban and built-up land was transformed form forest land 14.58 km^2 or 0.14 %, followed by agricultural land 268.70 km^2 or 2.66%, respectively.

Water bodies area was increased with an area of 6.06 km^2 or 0.06% of sub-basin area. The most of water bodies area were transformed form forest land.

4.2.11.4 Land use changes in Lower Part of Yom Sub-basin during 1988 to 2009

Agricultural land was increased with an area of 538.75 km^2 or 5.34 % of sub-basin area, paddy field 119.31 km^2 or 1.18 %, field crop 347.24 km^2 or 3.44 % and perennial 72.20 km^2 or 0.72 %. The most of agricultural land was transformed form forest land.

Forest land was decreased with an area of 559.04 km^2 or 5.54 % of sub-basin area. Furthermore, the most of forest land was transformed to be agricultural land (paddy field, field crop and perennial) with an area of 538.75 km2 or 5.34 %, followed by water bodies area with an area of 5.65 km^2 or 0.06 % and urban and built-up land with an area of 14.64 km^2 or 0.14 %, respectively.

Urban and built-up land was increased with an area of 293.69 km^2 or 2.91 %, of sub-basin area. Furthermore, the most of urban and built-up land was transformed form forest land 14.64 km2 or 0.14 %, followed by agricultural land 279.05 km^2 or 2.76%, respectively.

Water bodies area was increased with an area of 5.65 km2 or 0.06 % of sub-basin area. The most of water bodies area were transformed form forest land.

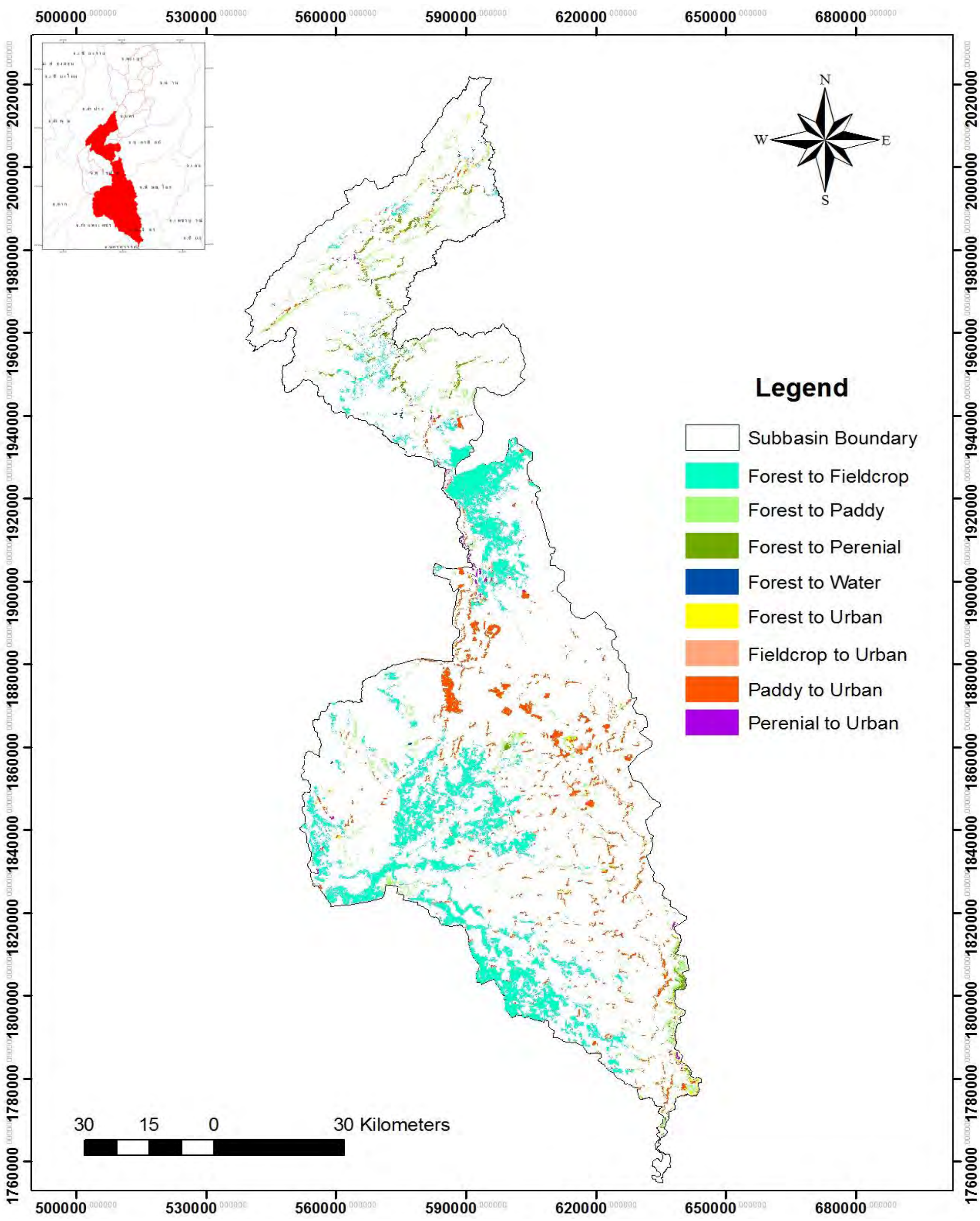


Figure 4-48 **Change detection map of** Lower Part of Yom Sub-basin **from 1988 to 1995**

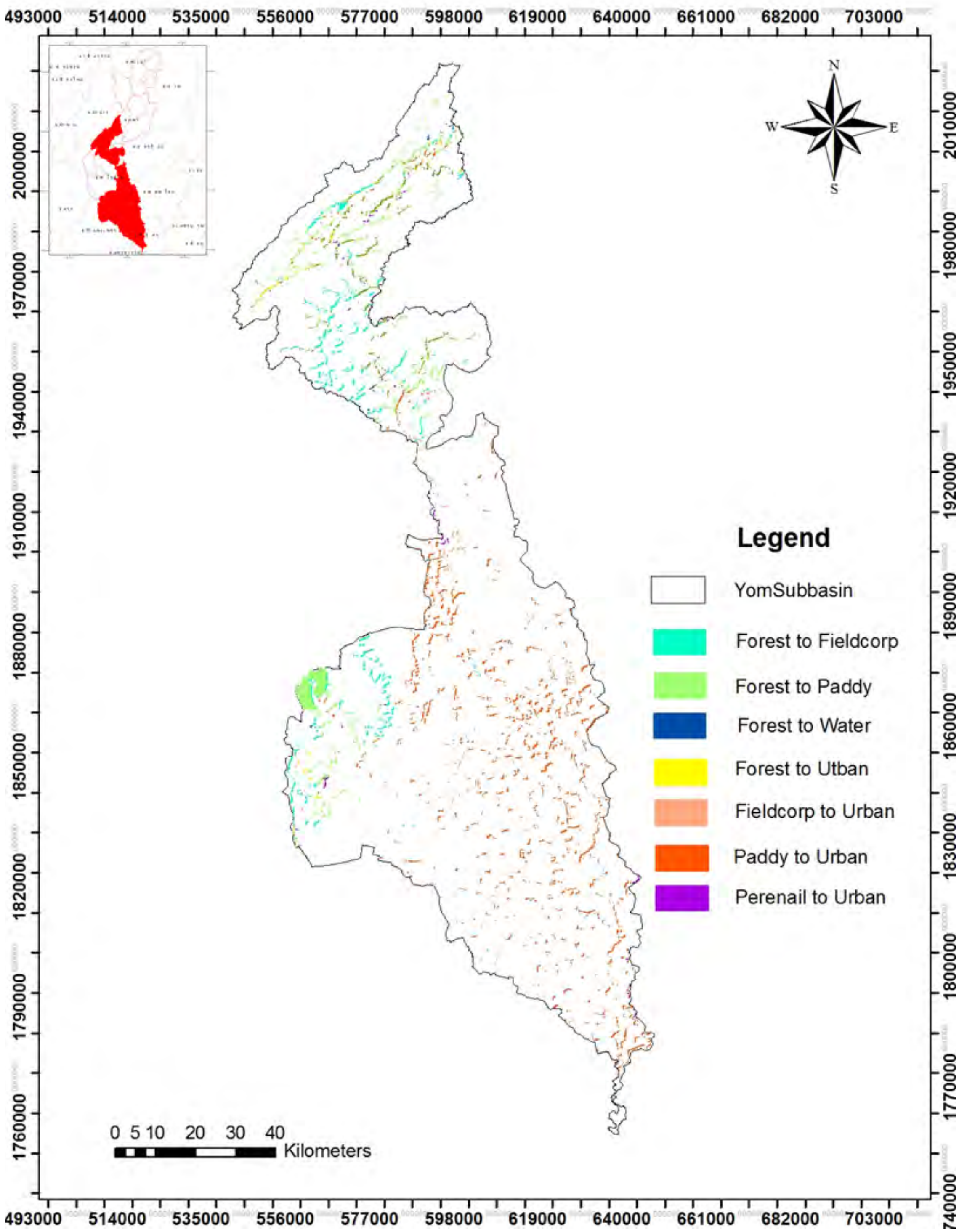


Figure 4-49 **Change detection map of** Lower Part of Yom Sub-basin **from 1995 to 2003**

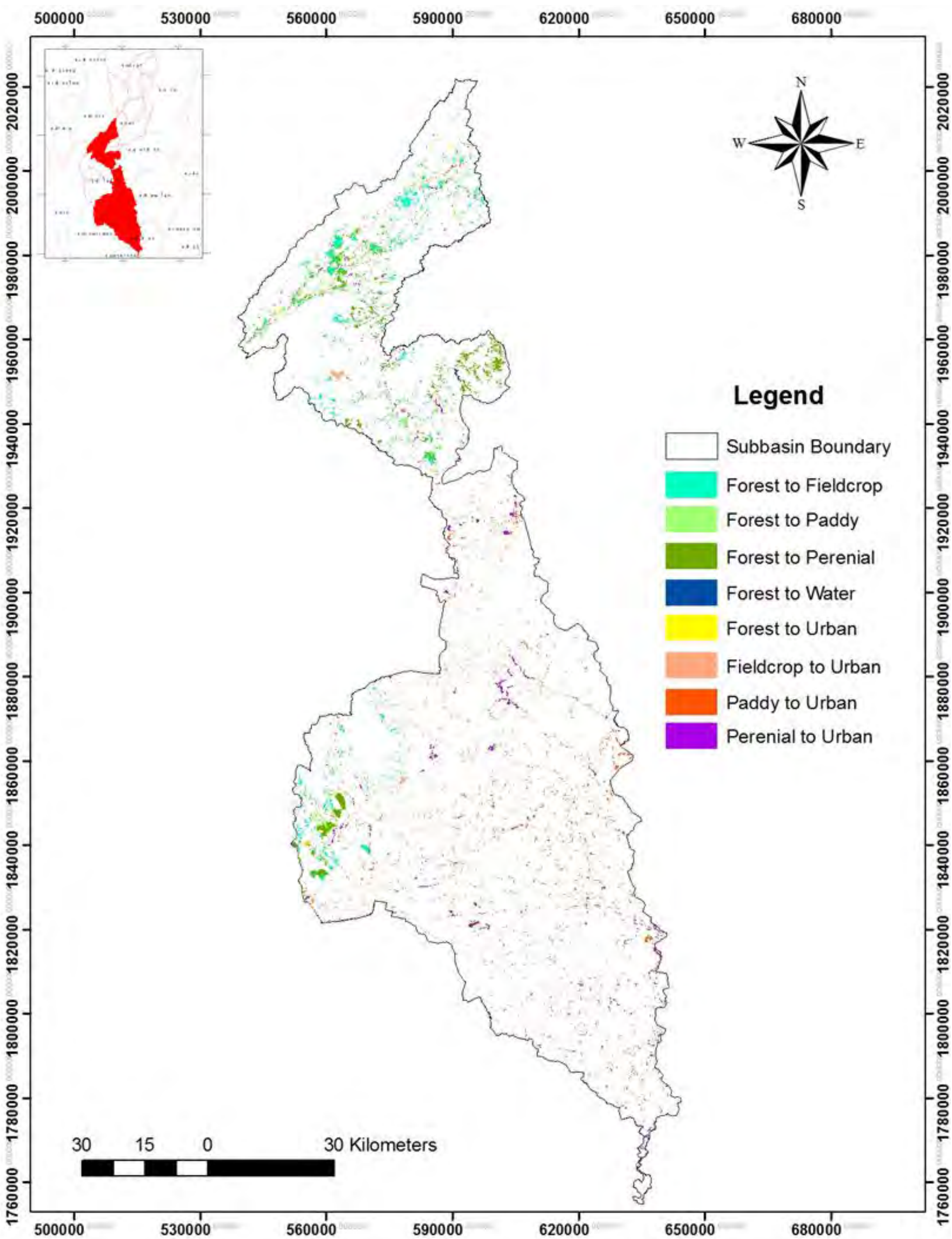


Figure 4-50 Change detection map of Lower Part of Yom Sub-basin from 2003 to 2009

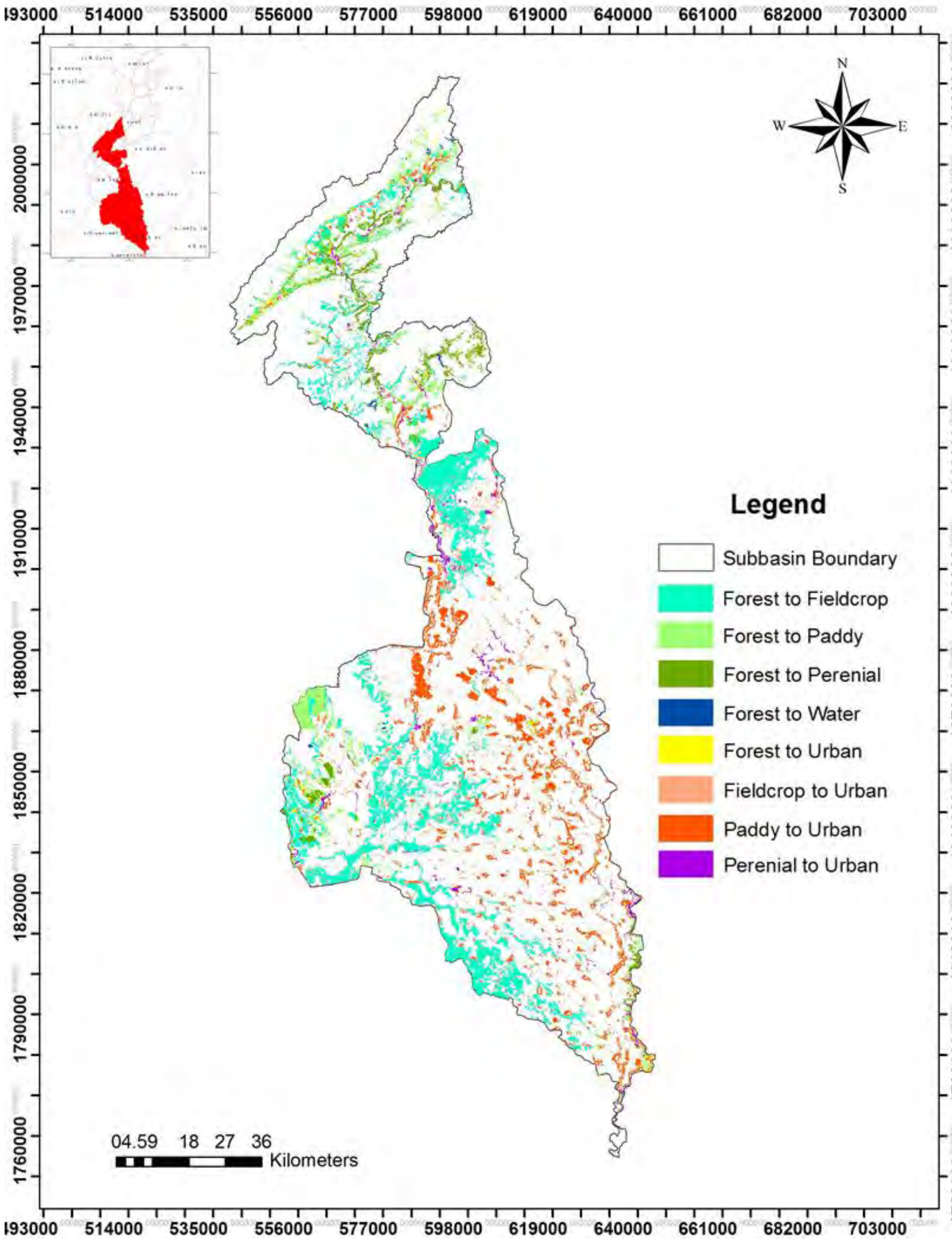


Figure 4-51 **Change detection map of** Lower Part of Yom Sub-basin **from 1988 to 2009**

4.3 Result of Runoff Simulation

To capture the potential effects of land use changes on runoff, the precipitation data were used for each model run to determine if changes in river runoff were indeed due to changes in land use. Differences in river runoff, and the associated changes in model parameters, were therefore associated with changes in land use.

The influences of the land use changes were quantified by comparing the SWAT output of the 8 scenario in the section 3.8.1. Figure 4-46 to 4-51 showed the simulated runoff from SWAT model for scenario 1-4 with input land use maps of year 1988, 1995, 2003 and 2009 at station Y20 and Y14.

To simulate the differences between river runoff before and after land use changes, the model parameters derived during the start of the study period were compared with those derived at the end of the study period to simulate runoff under the same precipitation regimes. The simulated runoff during the start period (year 1988–1989)and the end period (year 2008–2009), when land use map of 2009 was replaced by land use map of 1988, 1995 and 2003 at station Y14 and station Y20 were show in Figure 4-52 to 4-59

4.3.1 Scenario 1: 1988 land use and 1988-1989 climates

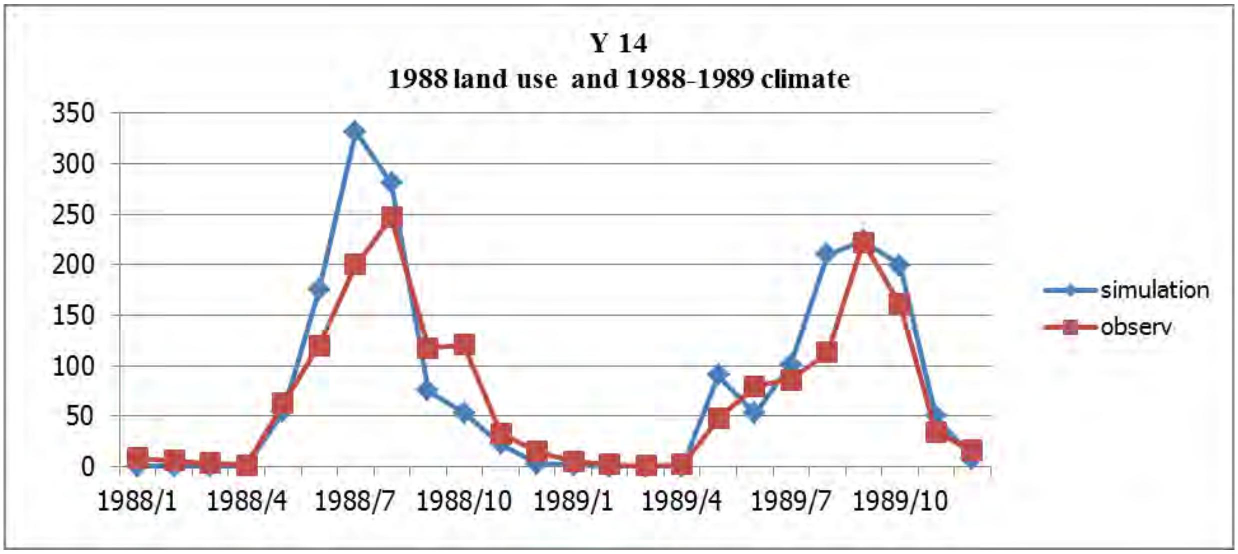


Figure 4-52 Observed and Simulated monthly runoff at station Y14 during 1988-1989

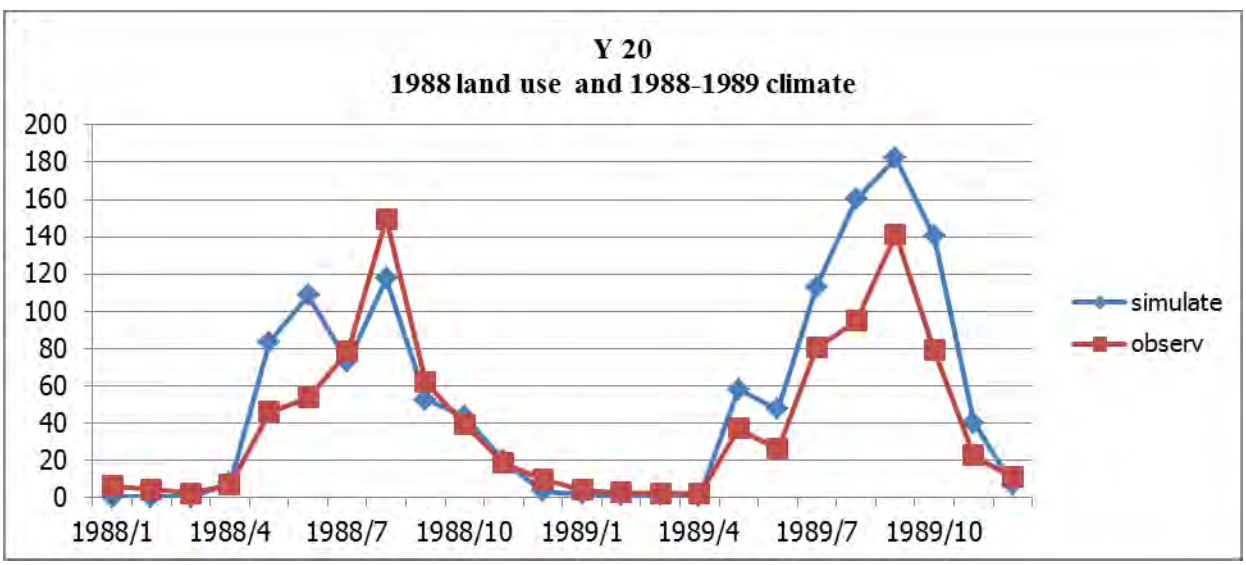


Figure 4-53 Observed and Simulated monthly runoff at station Y20 during 1988-1989

4.3.2 Scenario 2: 1995 land use and 1995-1996 climate

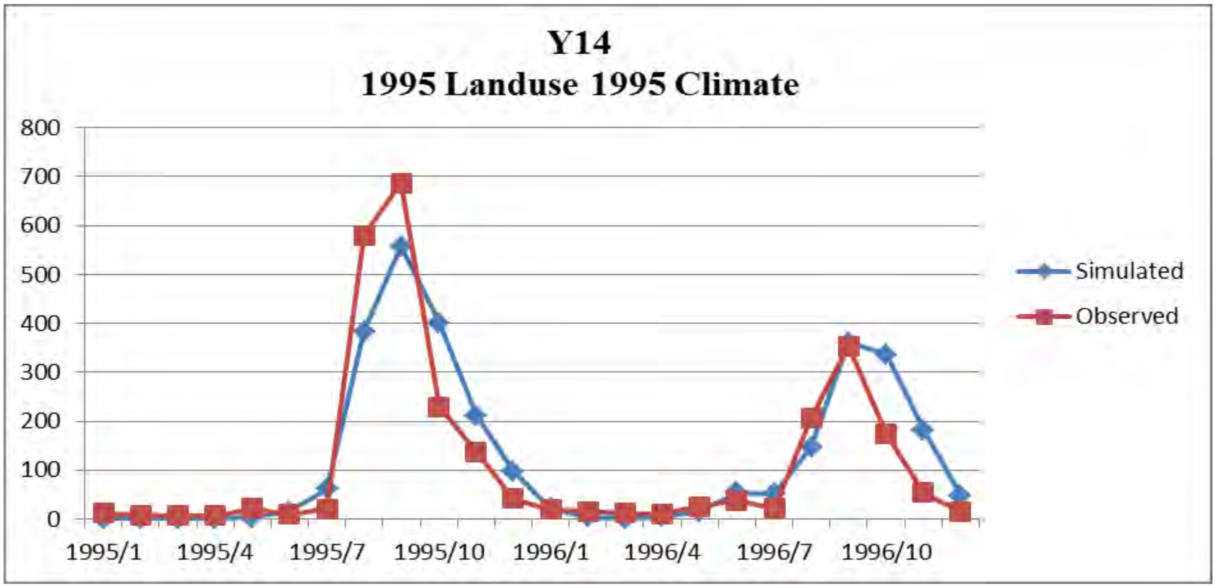


Figure 4-54 Observed and Simulated monthly runoff at station Y14 during 1995-1996

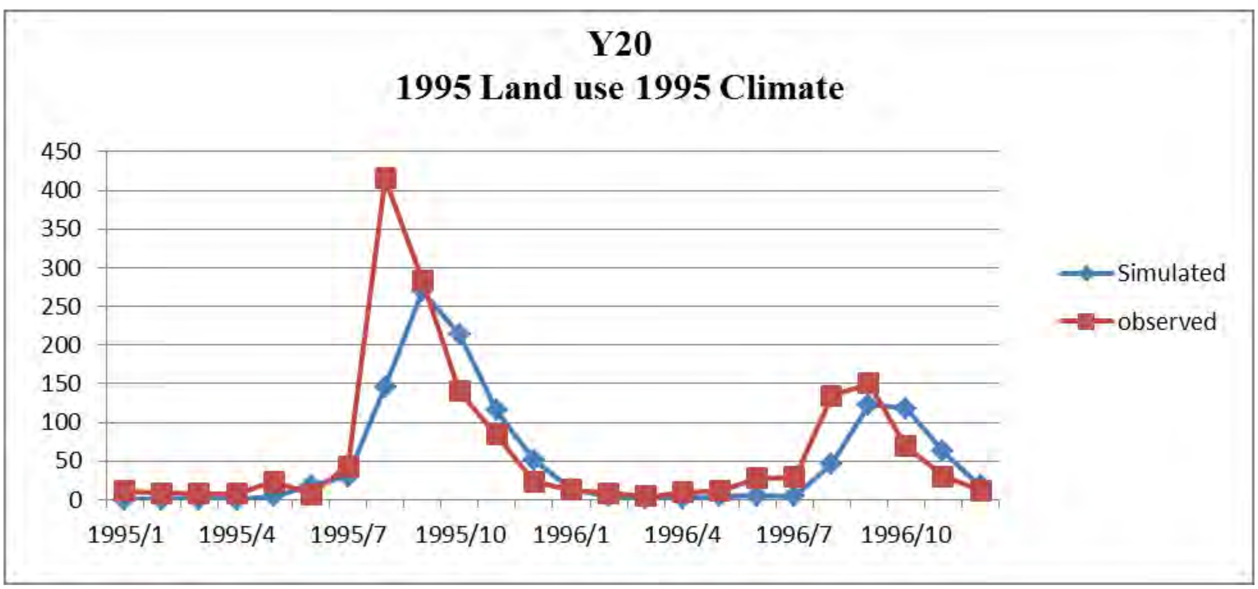


Figure 4-55 Observed and Simulated monthly runoff at station Y20 during 1995-1996

4.3.3 Scenario 3: 2003 land use and 2002-2003 climate

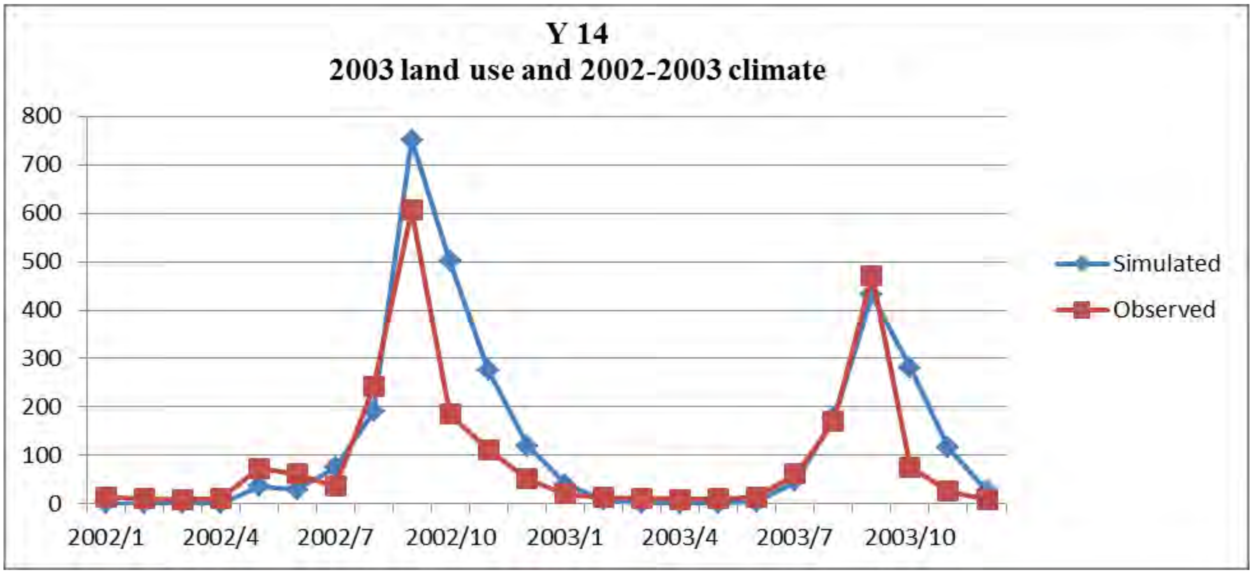


Figure 4-56 Observed and Simulated monthly runoff at station Y14 during 2002-2003

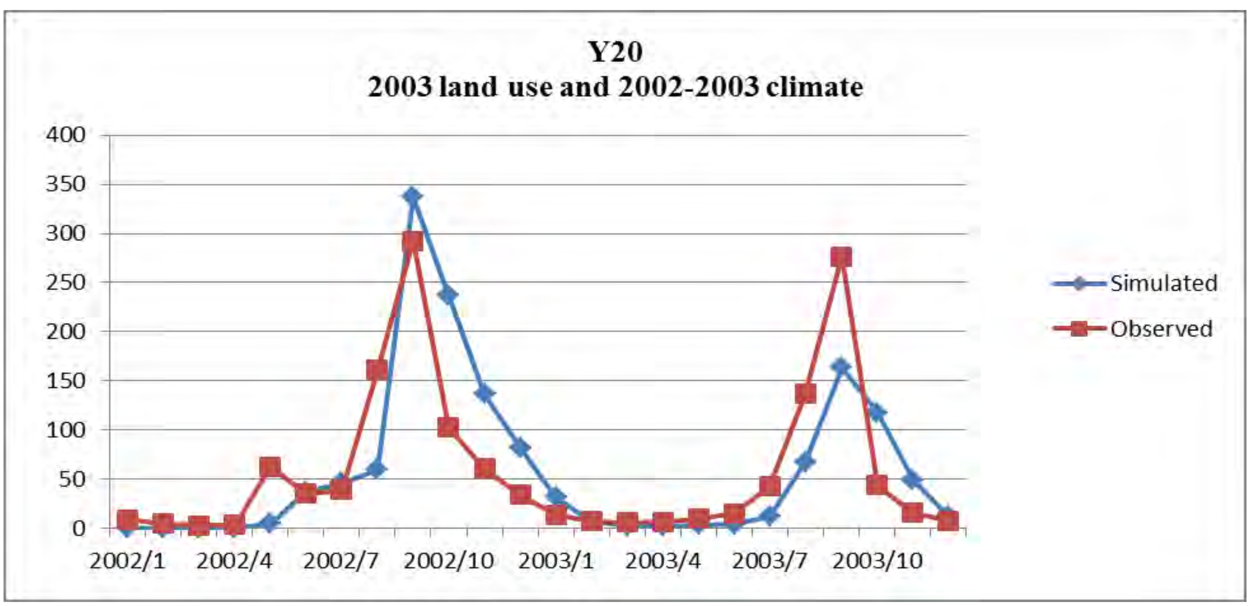


Figure 4-57 Observed and Simulated monthly runoff at station Y20 during 2002-2003

4.3.4 Scenario 4: 2009 land use and 2008-2009 climate

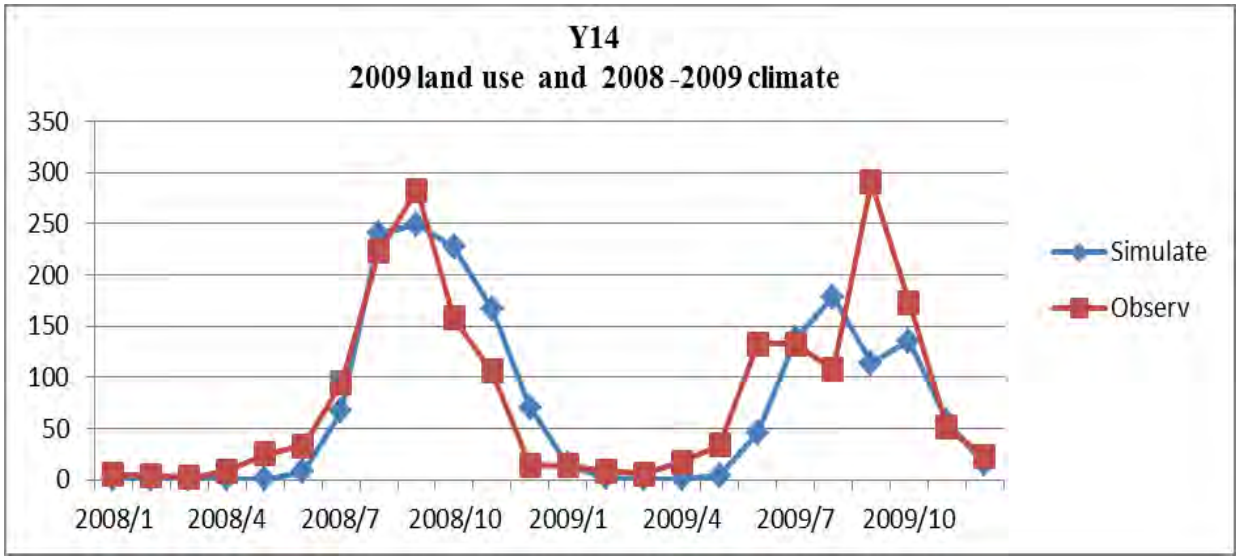


Figure 4-58 Observed and Simulated monthly runoff at station Y14 during 2008-2009

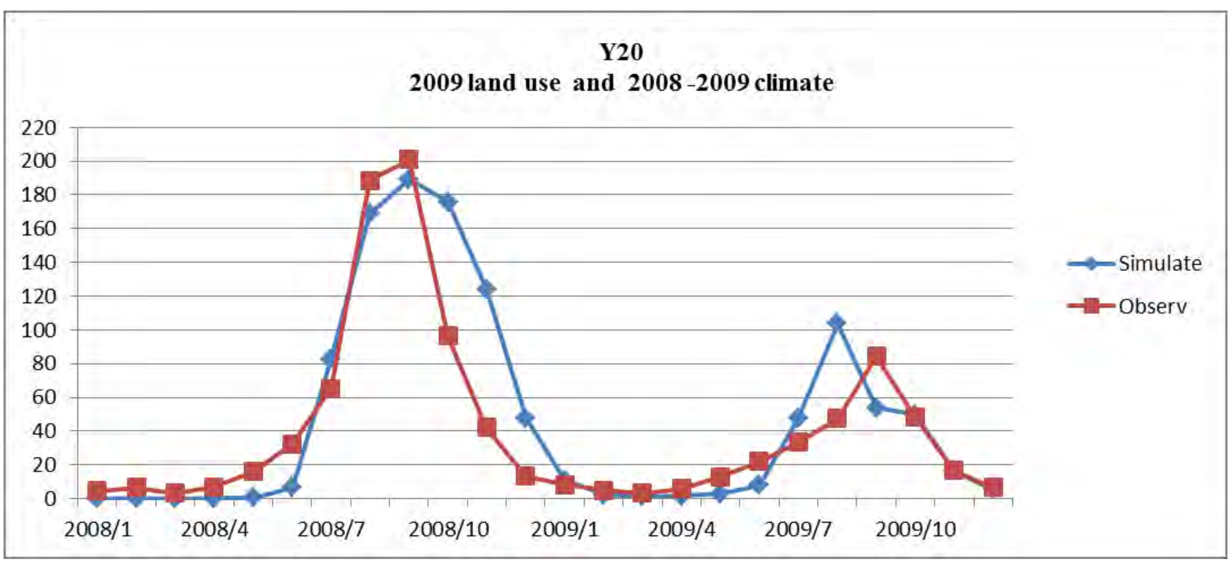


Figure 4-59 Observed and Simulated monthly runoff at station Y20 during 2008-2009

4.3.5 Scenario 5: 1988 land use and 2008-2009 climate

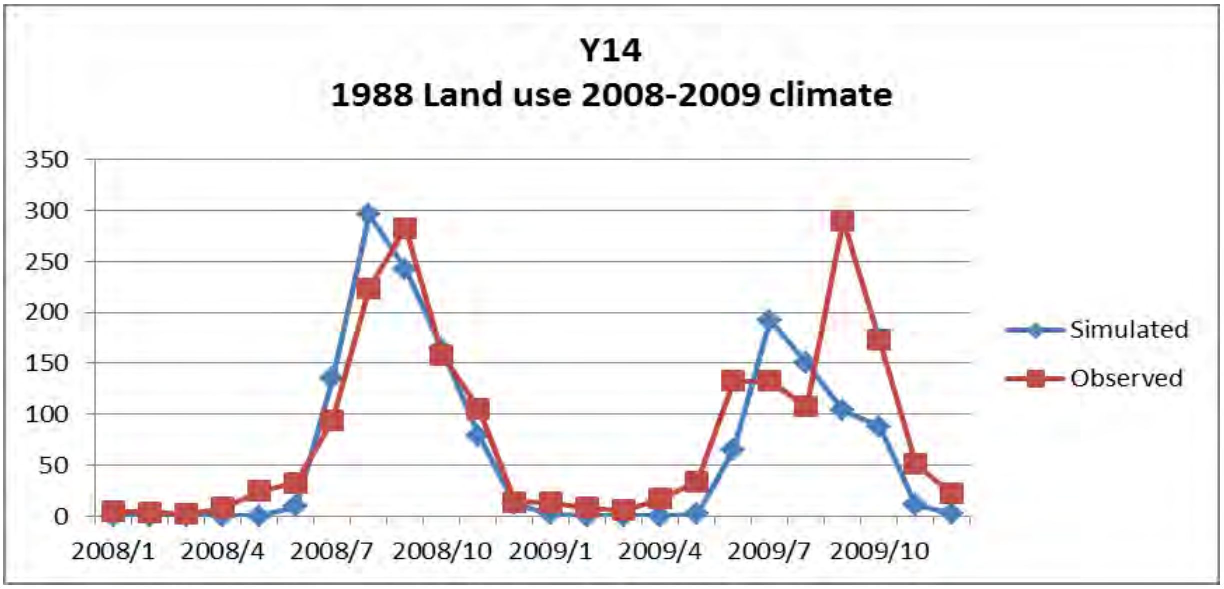


Figure 4-60 Observed and Simulated monthly runoff at station Y14

land use map 1988 and 2008-2009 climates

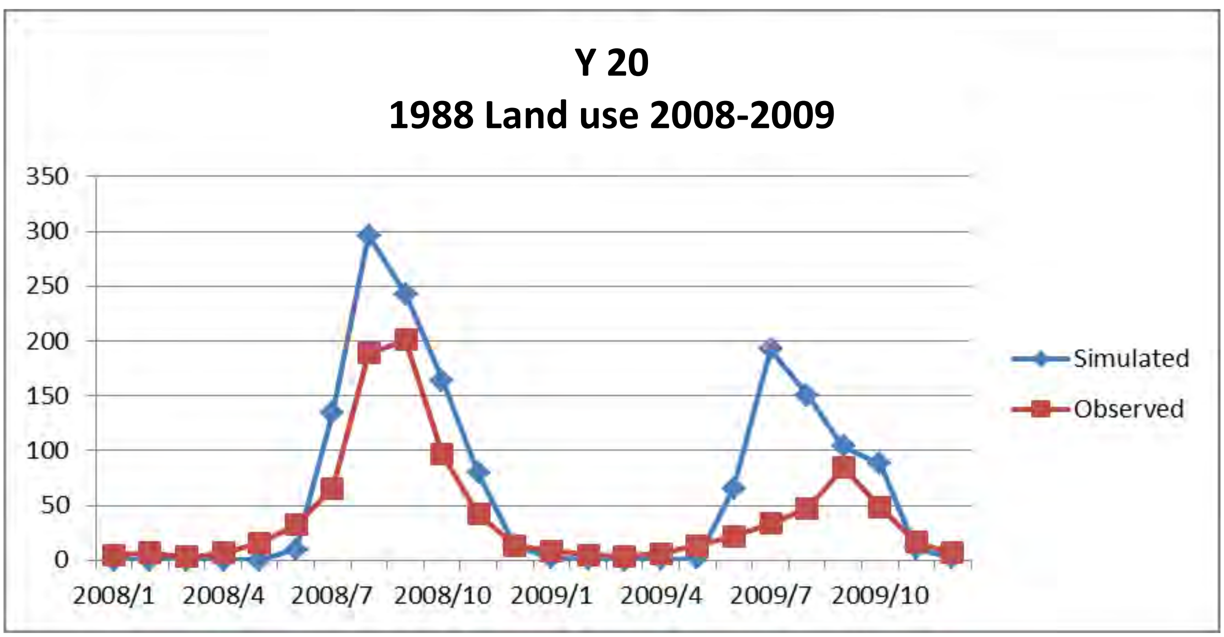


Figure 4-61 Observed and Simulated monthly runoff at station Y20

land use map 1988 and 2008-2009 climates

4.3.6 Scenario 6: 1995 land use and 2008-2009 climate

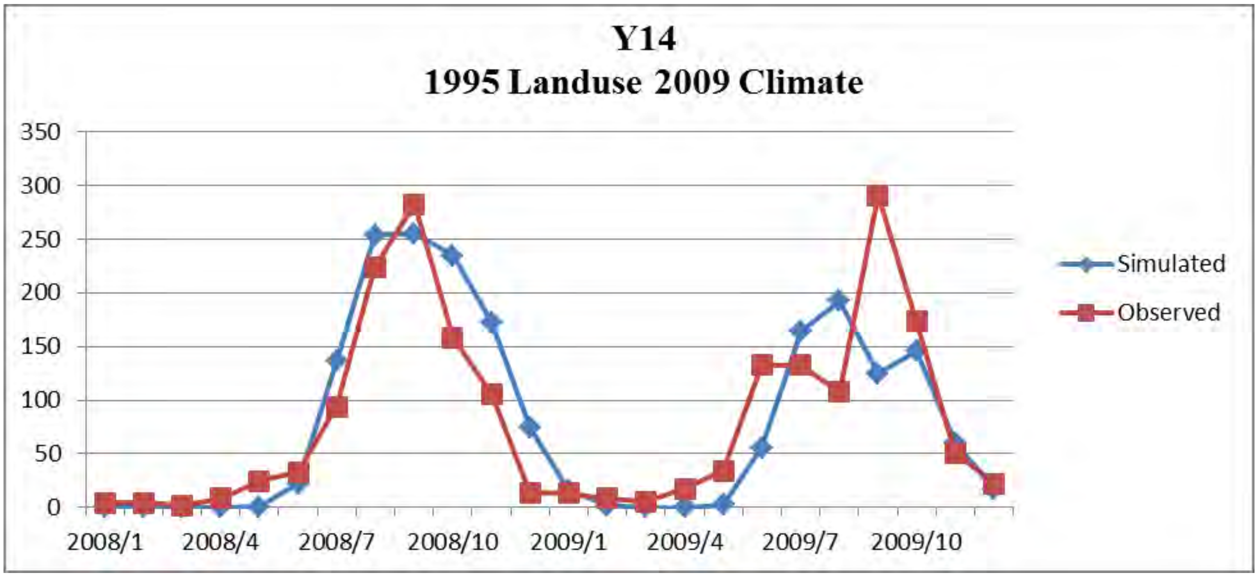


Figure 4-62 Observed and Simulated monthly runoff at station Y14

land use map 1995 and 2008-2009 climates

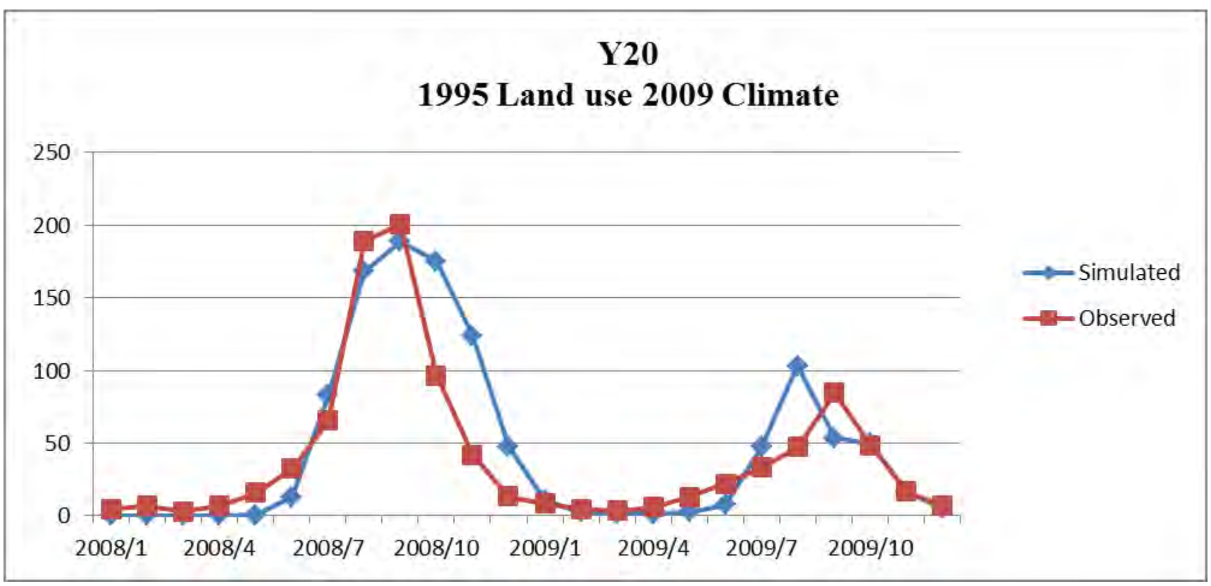


Figure 4-63 Observed and Simulated monthly runoff at station Y20

land use map 1995 and 2008-2009 climates

4.3.7 Scenario 7: 2003 land use and 2008-2009 climate

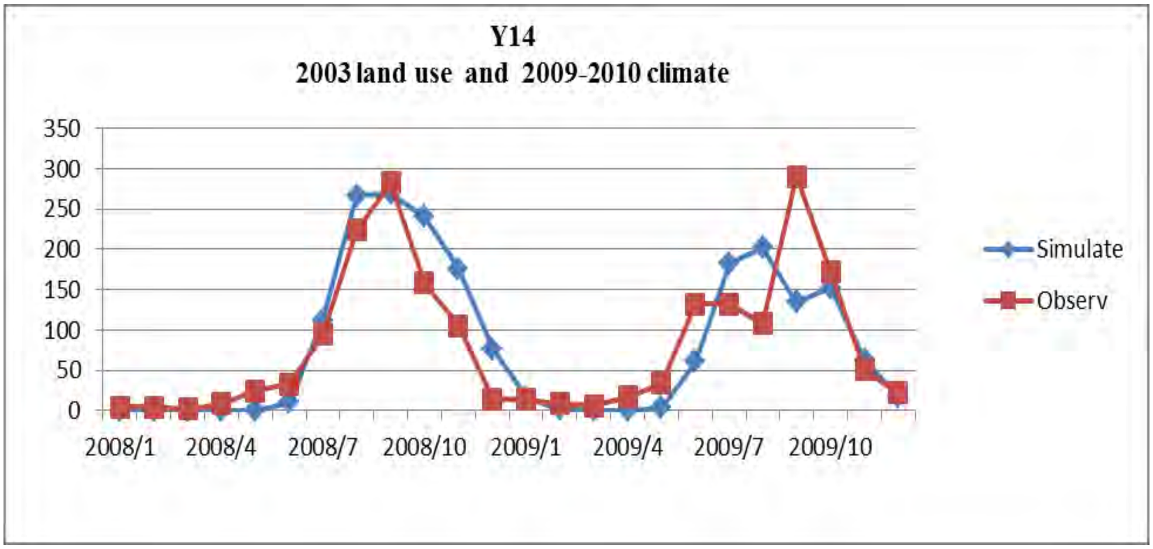


Figure 4-64 Observed and Simulated monthly runoff at station Y14

land use map 2003 and 2008-2009 climates

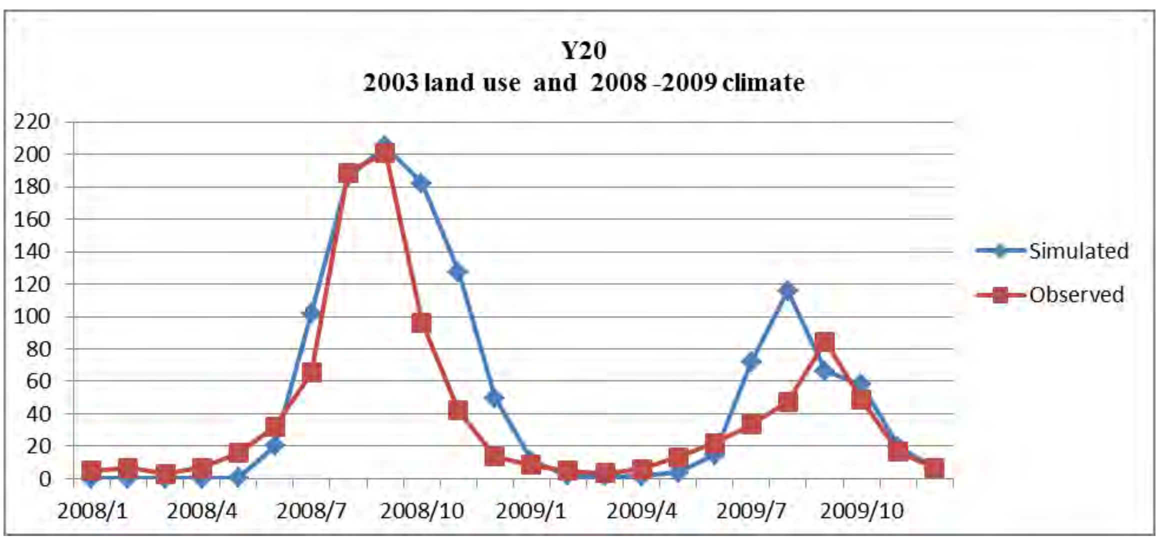


Figure 4-65 Observed and Simulated monthly runoff at station Y20

land use map 2003 and 2008-2009 climates

4.3.8 Scenario 8: 2009 land use and 1988-1989 climate

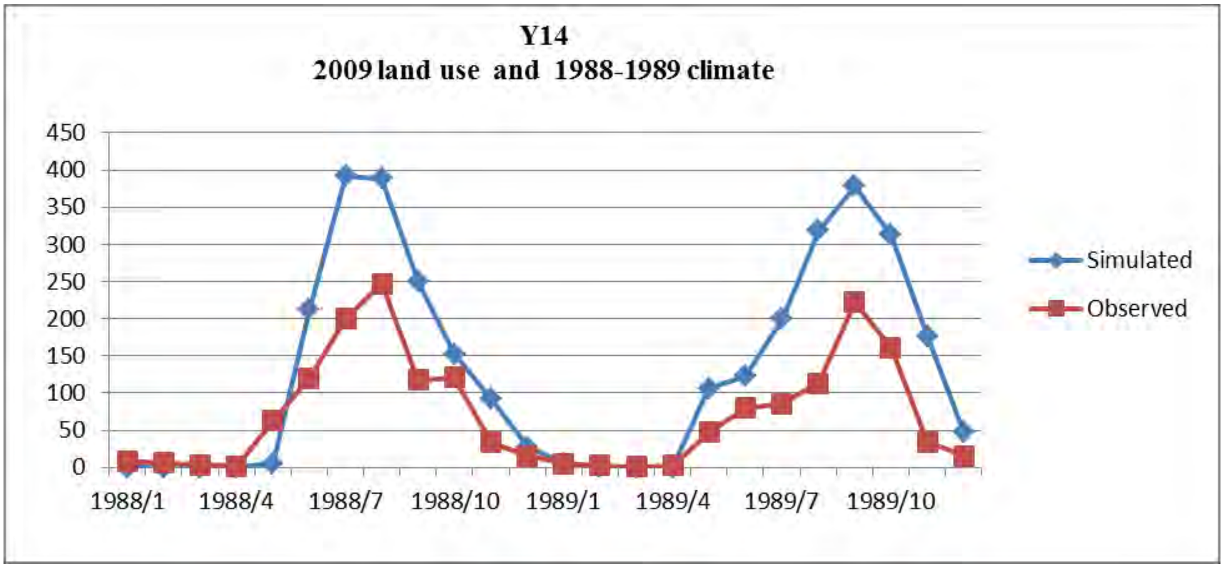


Figure 4-66 Observed and Simulated monthly runoff at station Y14

land use map 2009 and 1988-1989 climates

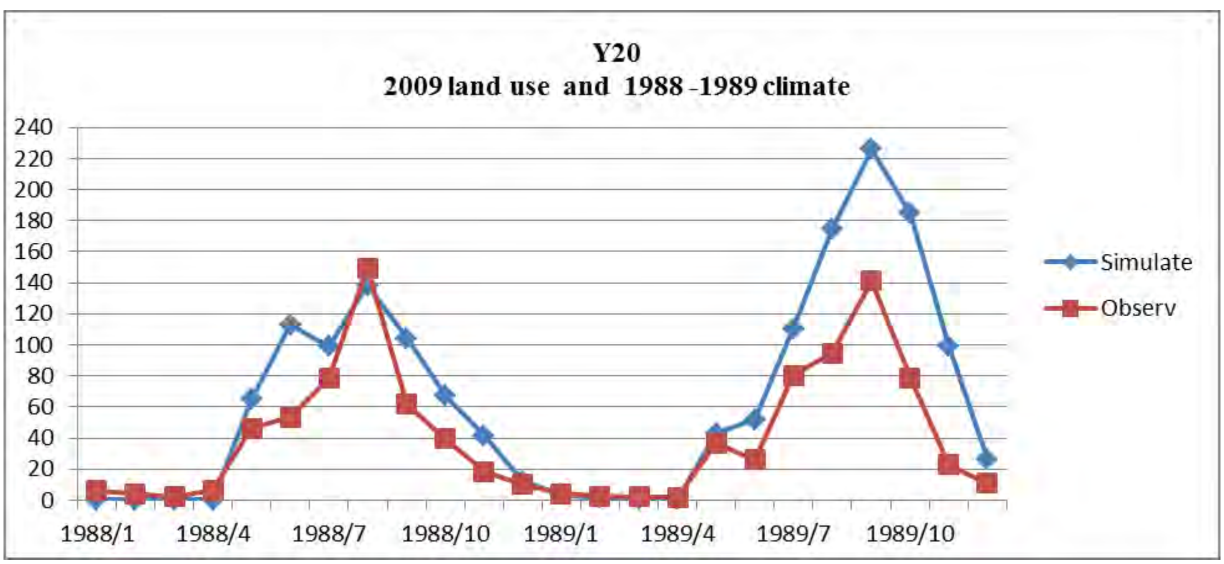


Figure 4-67 Observed and Simulated monthly runoff at station Y20

land use map 2009 and 1988-1989 climates

CHAPTER V

DISCUSSION AND CONCLUSION

5.1 Discussion

In this part, the results of the study methods as previously mentioned were discussed in two categories. Firstly, dynamic spatial patterns of land use changes processes results were proposed and discussed. Secondly, relationship between land use changes in the Yom River Basin and River runoff during 1988-2009. Finally, conclusion and recommendation in this research were summarized and proposed.

5.1.1 Dynamic spatial patterns of land use changes processes in the Yom River Basin during 1988-2009

In this research, the combination bands (R=5, G=4, B=3) of Landsat 5TM satellite imageries in the year 1988, 1995, 2003 and 2009 with supervised classification process were used for land use classification. The results revealed that land use categories in the Yom River Basin were classified as 6 land use categories, namely, paddy field, field crops, perennial , forest, urban and built-up land, and water bodies.

Change detections of land use in Yom River Basin during 1988 to 1995 were analyzed using overlay technique in ArcMap GIS version 9.3 The results revealed that the total change areas were 2460.315 km^2 (10.27% of total areas). The most proportion of change areas was forest land that was decreased 1979.67 km^2 or 80.46% of total change areas), whereas agricultural land, urban and built-up land, and water bodies were increasing from 1988 to 1995(Figure 5-1)

Change detections of land use in the Yom River Basin during 1995 to 2003 were analyzed using overlay technique. The results revealed that the total change areas were 1610.632 km^2 (6.73% of total areas). The most proportion of change areas was forest land that was decreased 1141.69 km^2 or 4.77% of total change areas), whereas agricultural land, urban and built-up land, and water bodies were increasing from 1995 to 2003(Figure 5-2)

Change detections of land use in the Yom River Basin during 2003 to 2009 were analyzed using overlay technique in. The results revealed that the total change areas were 1741.171 km^2 (7.27% of total areas). The most proportion of change areas was forest land that was decreased 1300.867 km^2 or 5.43 %of total change areas , whereas agricultural land, urban and built-up land, and water bodies were increasing from 2003 to 2009(Figure 5-3)

Change detections of land use in the Yom River Basin during 1988 to 2009 were analyzed using overlay technique. The results revealed that the total change areas were 1931.16 km^2 (8.06 % of total areas). The most proportion of change areas was forest land that was decreased 1466.50 km^2 or 6.12 % of total change areas, whereas agricultural land, urban and built-up land, and water bodies were increasing 1,359.09 km^2, 23.38 km^2 and 40.21 km^2 or 5.67%, 0.10% and 0.17%, respectively. (Figure 5-4)

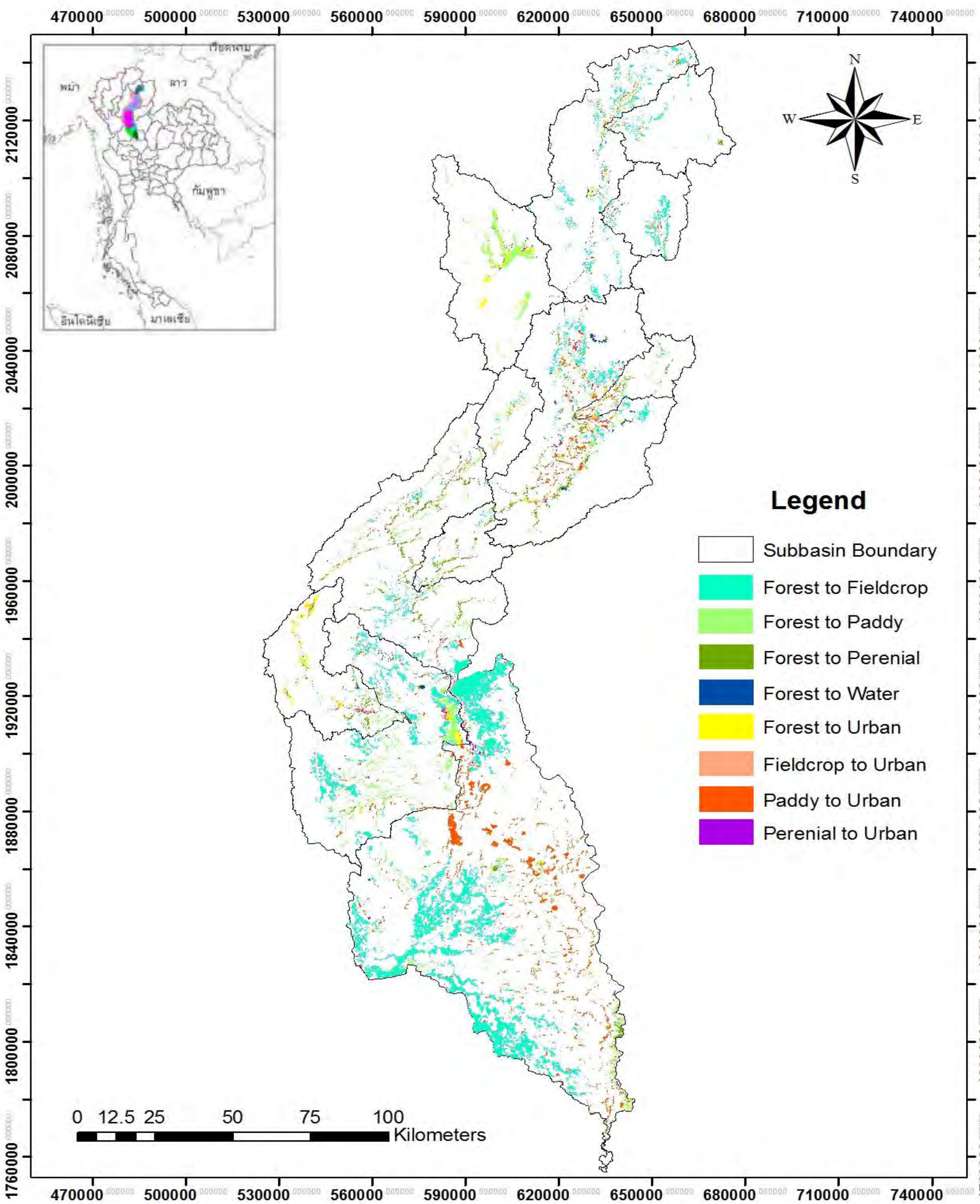


Figure 5-1 Changes detection in the Yom River Basin during 1988 - 1995

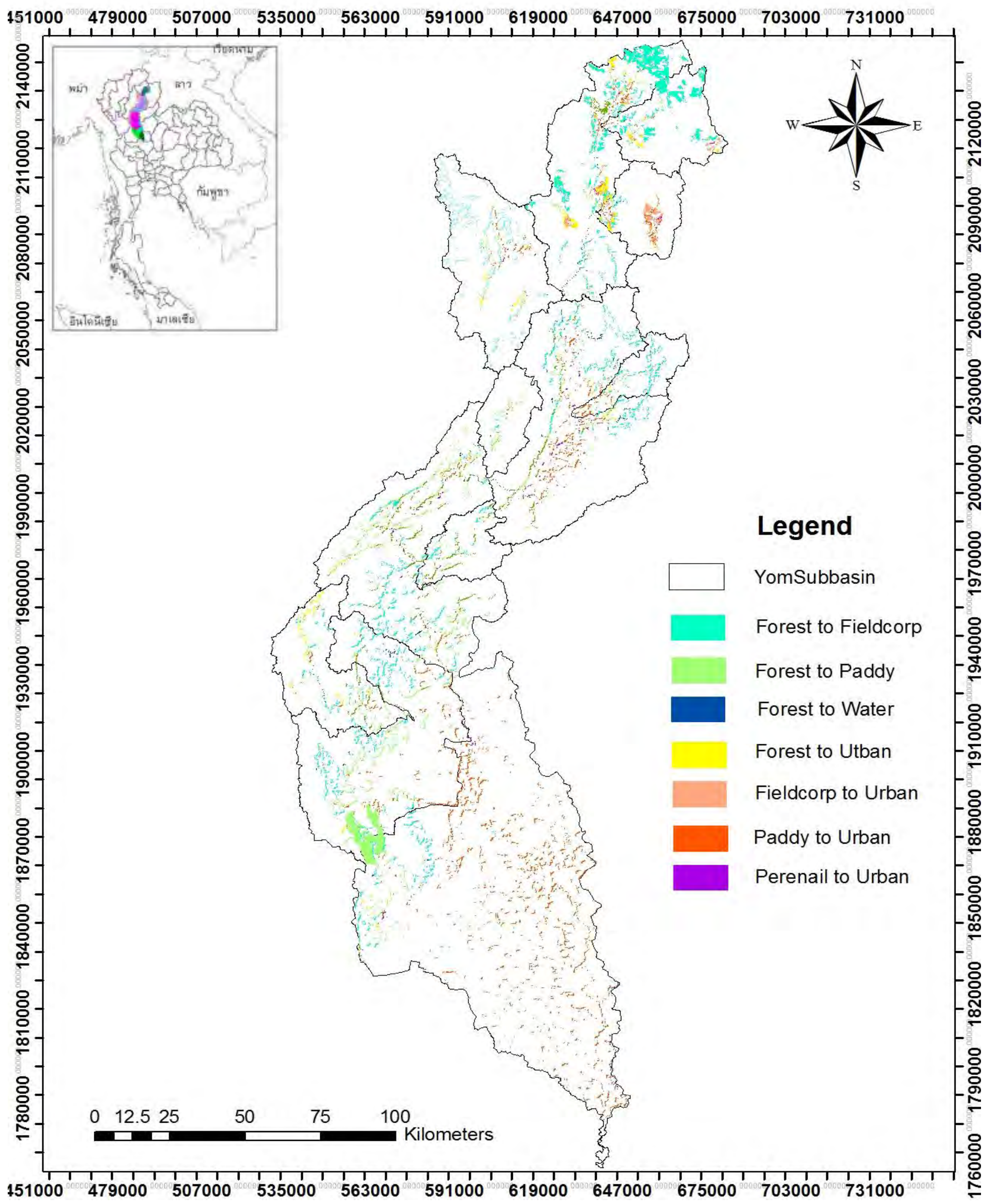


Figure 5-2 Changes detection in the Yom River Basin during 1995 - 2003

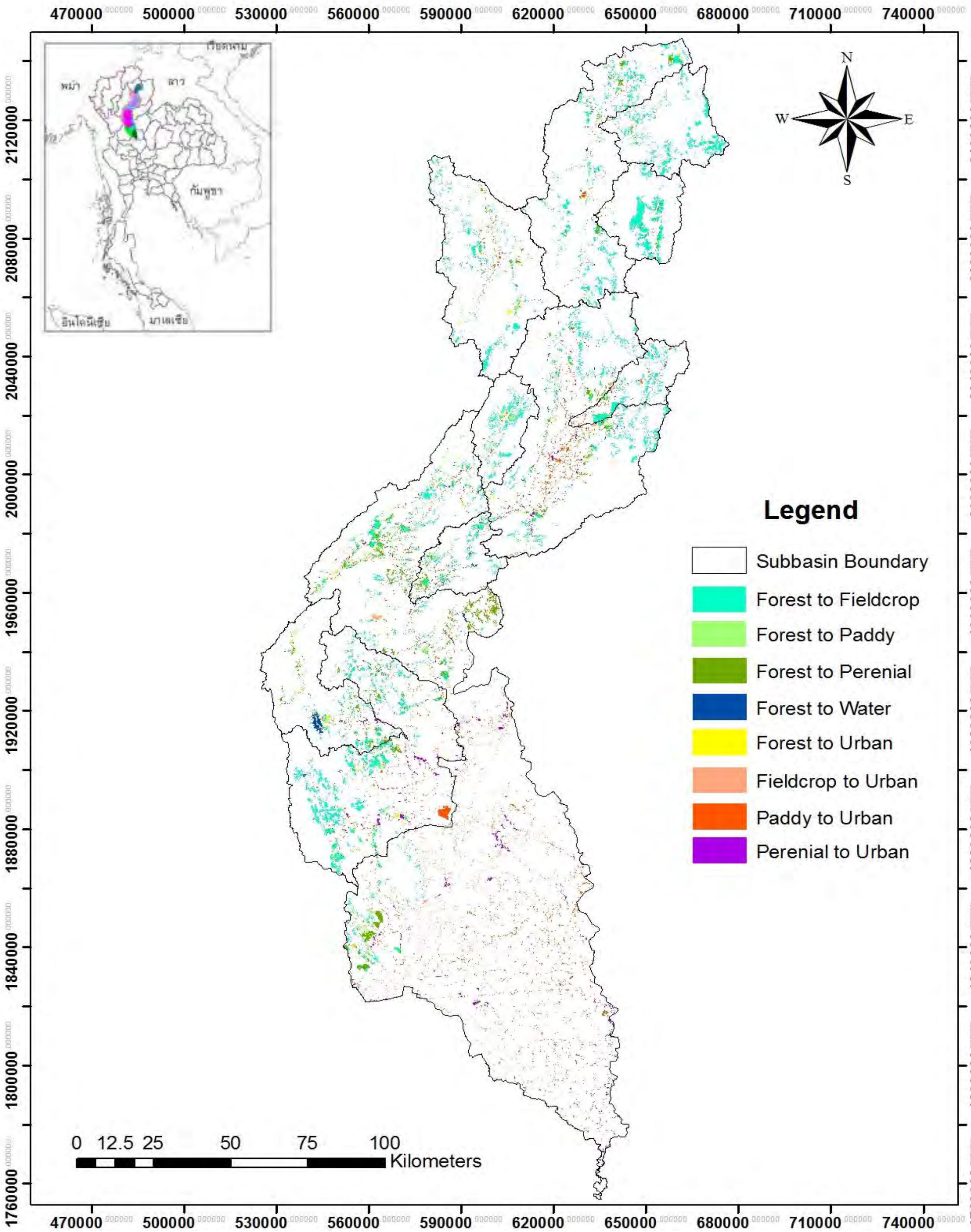


Figure 5-3 Changes detection in the Yom River Basin during 2003 - 2009

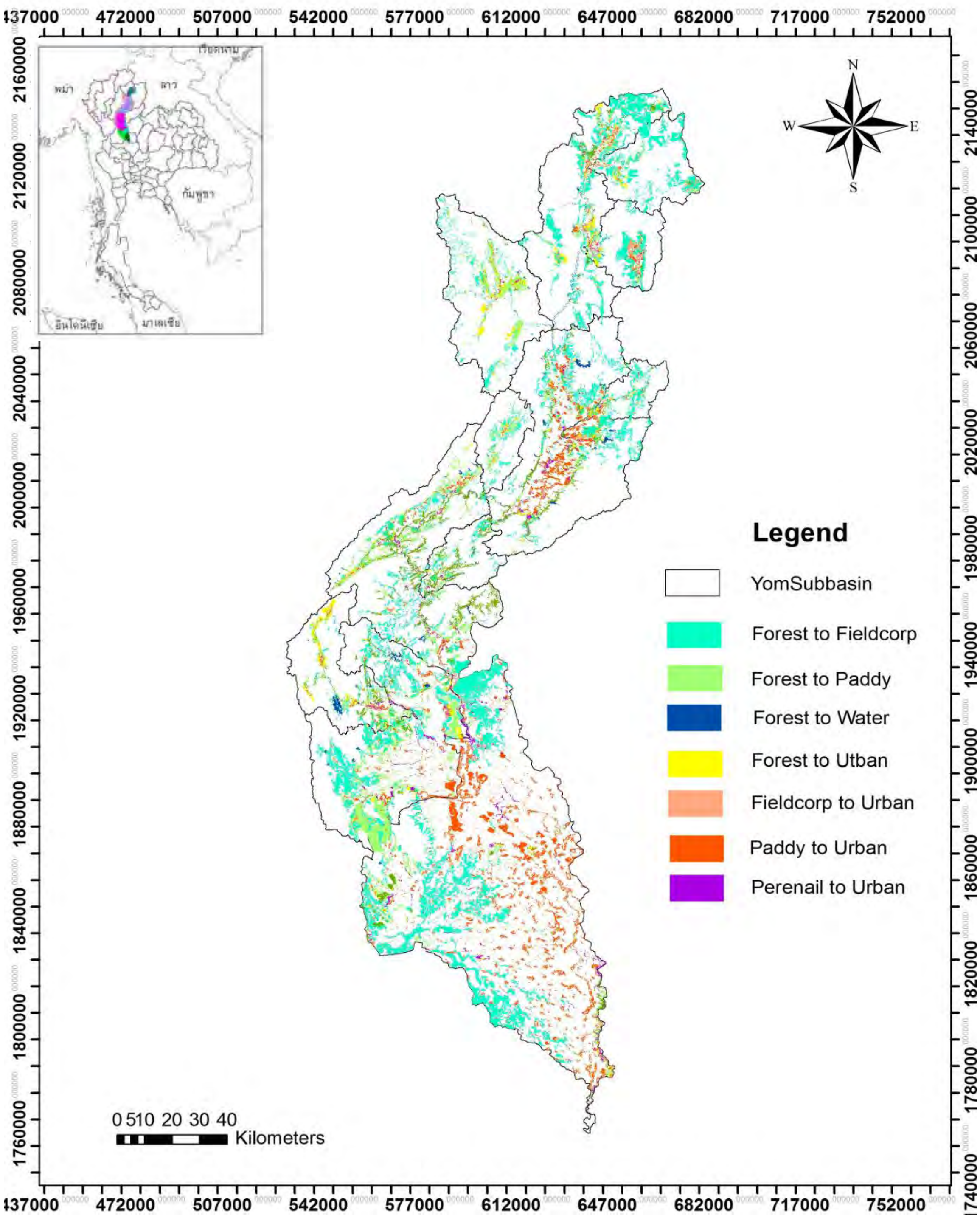


Figure 5-4 Changes detection in the Yom River Basin during 1988 - 2009

The largest land use changes over the study period in terms of actual area were decrease in forest cover, expanse of agriculture and increase in urban area, this was mainly due to commercial and industrial growth (Department of Environmental Quality Promotion (DEQP), 2007).

The land characteristics (soil texture, topography, and mean annual precipitation) effected the deforestation in the Yom River basin watershed during 1988 to 2009. The agricultural land was observed to be related with the decreasing forest land. It can be explained that agricultural because this terrain covered high fertility soils and area the rainfall of which increased. The study area was appeared agricultural land such as corn, sugarcane, cassava, rice, chili, soy, tobacco, para rubber and teak.

Land use changes in the Yom River Basin have largely featured agricultural transformations in different altitude zones. The highland pioneer shifting cultivation has been replaced by expanded permanent fields producing commercial horticultural crops. While some midland rotational agriculture fallow shifting cultivation systems remain, others have been replaced by rained permanent plots producing subsistence and commercial field crops. Irrigated paddy has expanded where terrain allows, and lowland agriculture has increased dry-season water use for irrigated rice, cash crops and fruit orchards.

5.1.2 Relationship between land use changes in the Yom River Basin and River runoff during 1988-2009

The results of the calibrated SWAT model at Y20 and Y14 during the start period (year 1988–1989) are shown the regression coefficient (R^2) was 0.85 and 0.84, respectively. For the calibrated results, these show that the model performance was good and in the acceptable limit. The results of the validated SWAT during the end period (year 2008–2009) model shows that the regression coefficient (R2) resulted 0.69 and 0.77, respectively . These results indicated that the model performance is very good and highly acceptable.

To simulate the differences between river runoff before and after land use changes, the model parameters derived during the start of the study period were compared with those derived at the end of the study period to simulate runoff under the same precipitation regimes. An increase and decrease in river runoff for the simulated years using the model parameters to reflect the change in LULC was apparent in Figure 5-5 to 5-8.

The Runoff during the start period (year 1988–1989), when land use map of 1988 was replaced by land use map of 2009, was increased with 131.57-169.61 MCM/Year or 22.53 - 25.86 % at station Y20 and 522.55-730.93 MCM/Year or 34.39 - 77.89 % at station Y14, respectively (Figure 5-5, 5-6). The simulated runoff during the end period (year 2008–2009)), when land use map of 1988 was replaced by land use map of 2009, was increased with 406-425 MCM/Year or 25- 98 % at station Y20 and 840-1170 MCM/Year or 47-154 % at station Y14, respectively (Figure 5-7, 5-8).

The simulated runoff during the end period (year 2008–2009), when land use map of 2009 was replaced by land use map of 1988, 1995 and 2003 at station Y14 were decreased 1668.7-2003.2, 1505.9-1791.4, 1451.6-1789.8 MCM/Year, respectively (Figure 5-9). At station Y 20, the simulated runoff were decreased 795.51 - 1556.98, 738.69 - 1441.858, 52.66 - 1286.18 MCM/Year, respectively (Figure 5-10).

The comparison runoff result of the 4 land use data (of year 1988, 1995, 2003 and 2009) and their respective observed discharge data has revealed that the land use changes in year 1988, 1995, 2003 and 2009 has caused a significant change in the simulated average monthly of the Yom River Basin. The lowest and the highest simulated runoff obtained from the land use data of 1988, 2009, respectively, indicated that the change in the land use impacted on the amount of runoff of the area in these 2 periods.

The results (Figure 5-5 to 5-10) have clearly shown that the difference in the quantity of the runoff in the 2 periods was resulted from the difference in the land use of the area. The main differences were observed in the amount of forest land, agricultural land and urban and build-up land. The total extents of forest land, agricultural land and urban and build-up land in the land use data of year 1988 were 54.84%, 41.43% and 2.93%, respectively. The forest land in the land use data of year 2009 reduced to 48.9% whereas agricultural land and urban land grown to 45.76% and 4.17%, respectively.

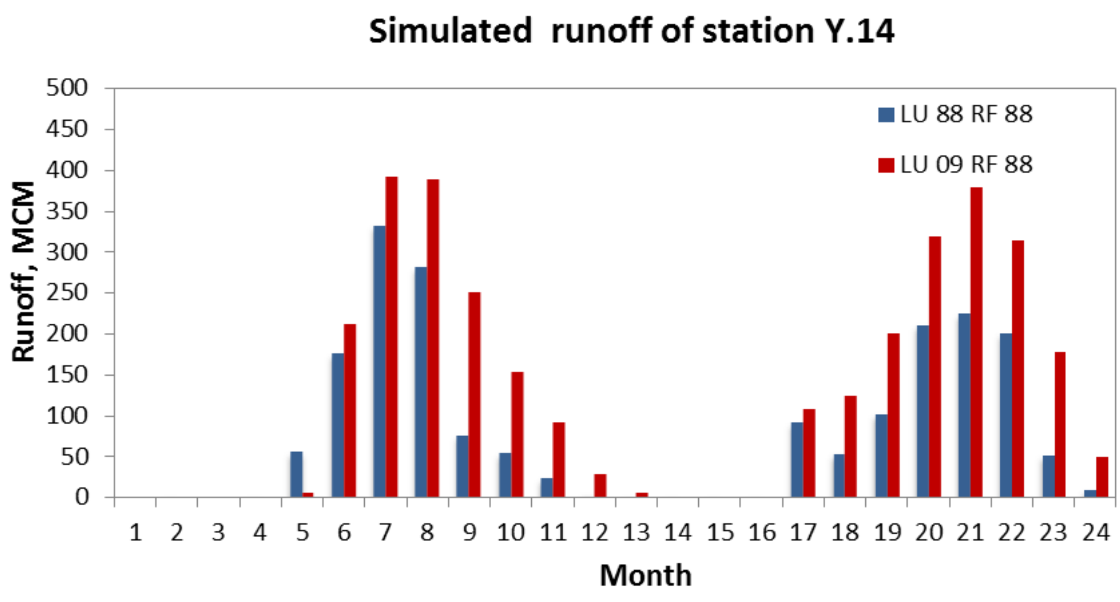


Figure 5-5 comparison simulated runoff between different land use 1988, 2009 under the same precipitation period 2008-2009 at station Y14

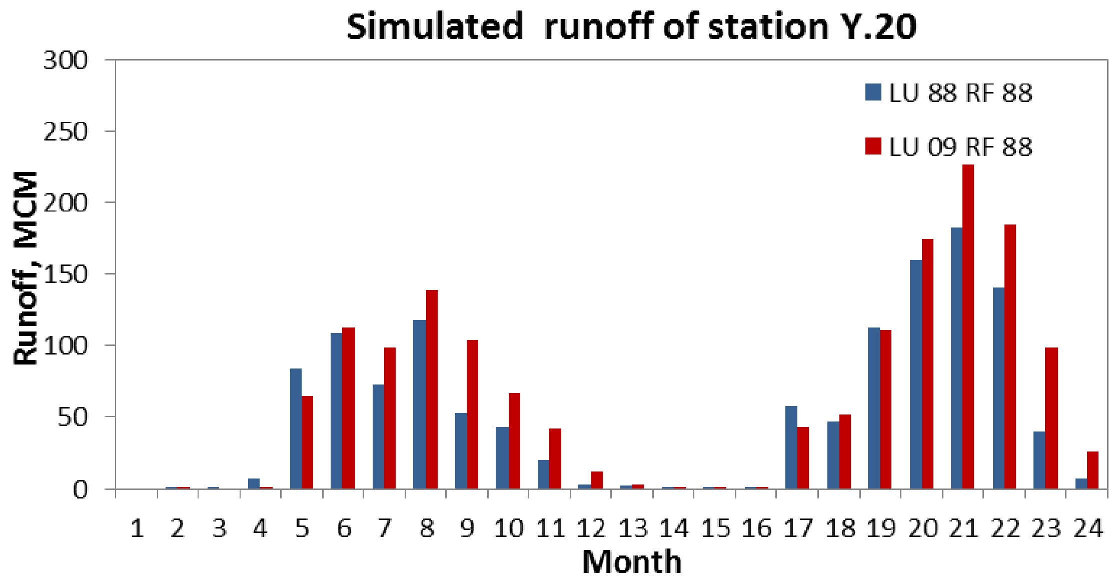
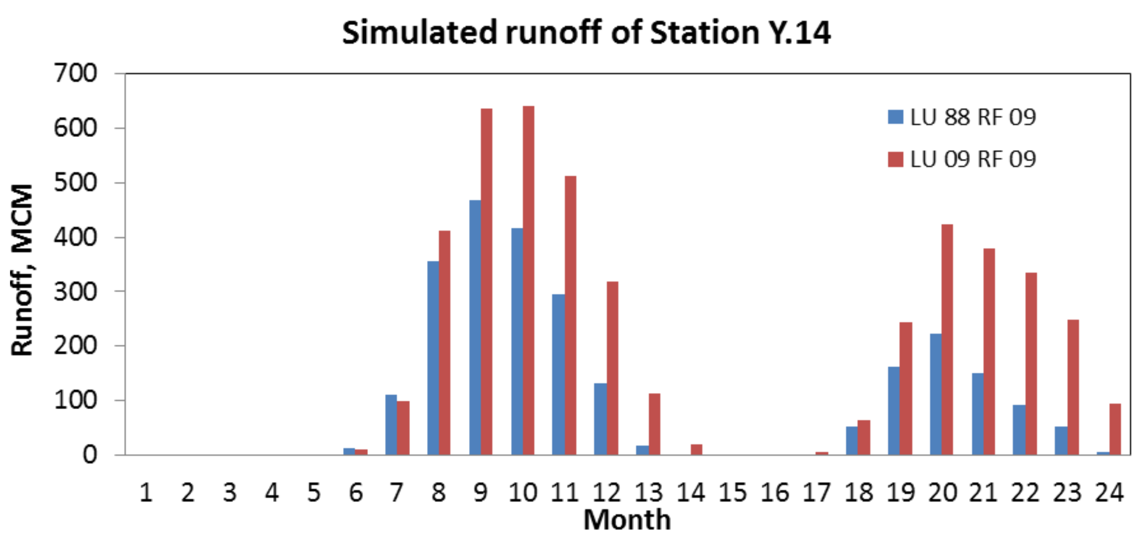


Figure 5-6 comparison simulated runoff between different land use 1988, 2009

under the same precipitation period 2008-2009 at station Y20



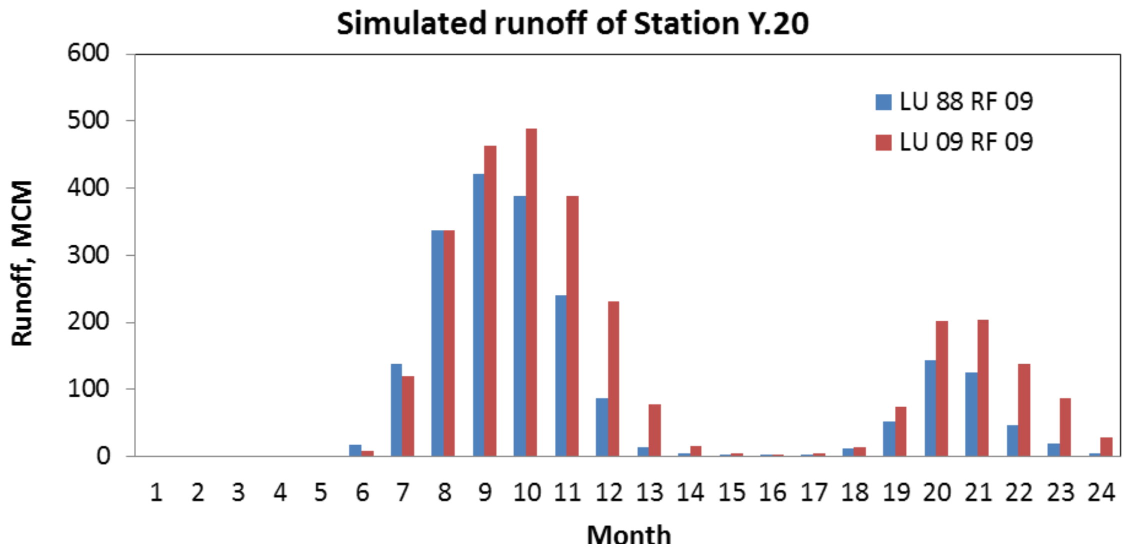


Figure 5-8 comparison simulated runoff between different land use 1988, 2009

under the same precipitation period 2008-2009 at station Y20

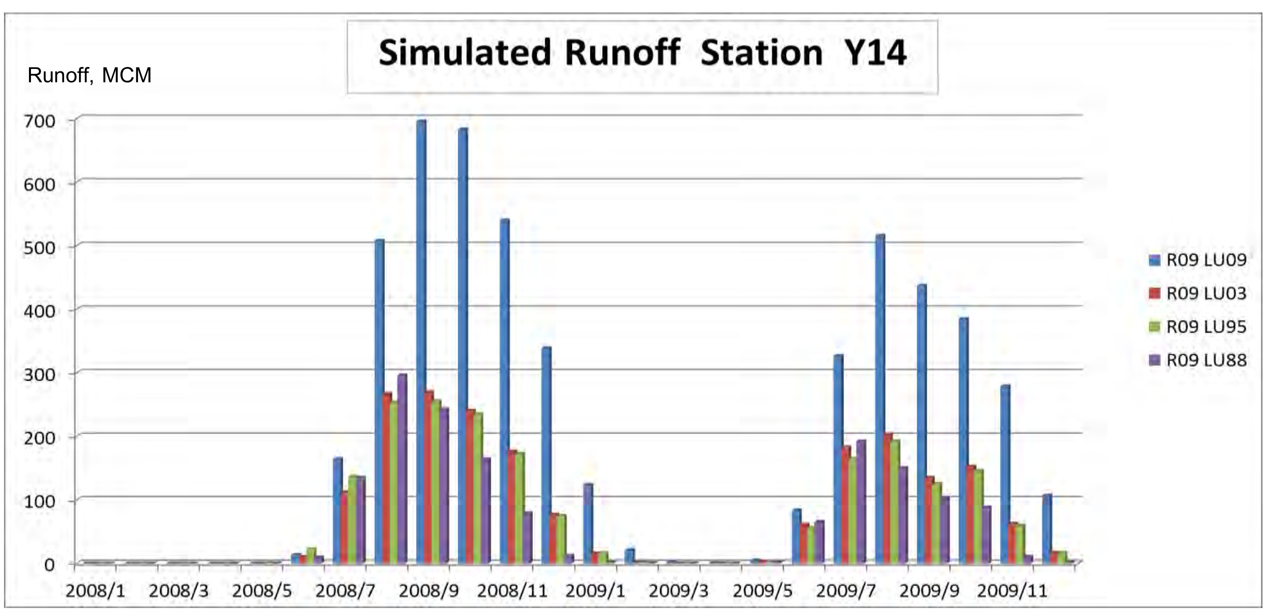


Figure 5-9 comparison simulated runoff between different land use 1988, 1995, 2003 and 2009

under the same precipitation period 2008-2009 at station Y14

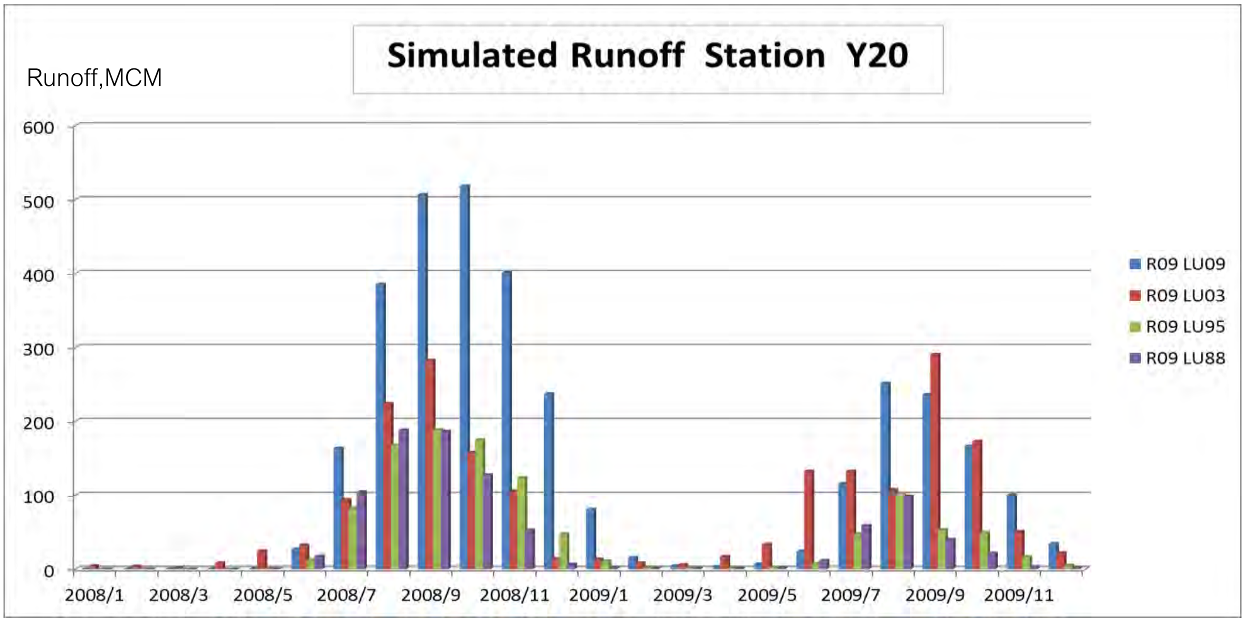


Figure 5-10 comparison simulated runoff between different land use 1988, 1995, 2003 and 2009 under the same precipitation period 2008-2009 at station Y20

When considering only the drainage area of station Y14 and Y20 (Figure 5-11 to 5 - 12), this indicated that the three land use classes were the main reasons to the decrease and the increase of the amount of simulated runoff. In general, a decrease in forest land of an area causes an increase in runoff of the area due to a decrease in evapotranspiration. On the other hand an increase in bare land causes an increase in discharge due to high surface runoff.

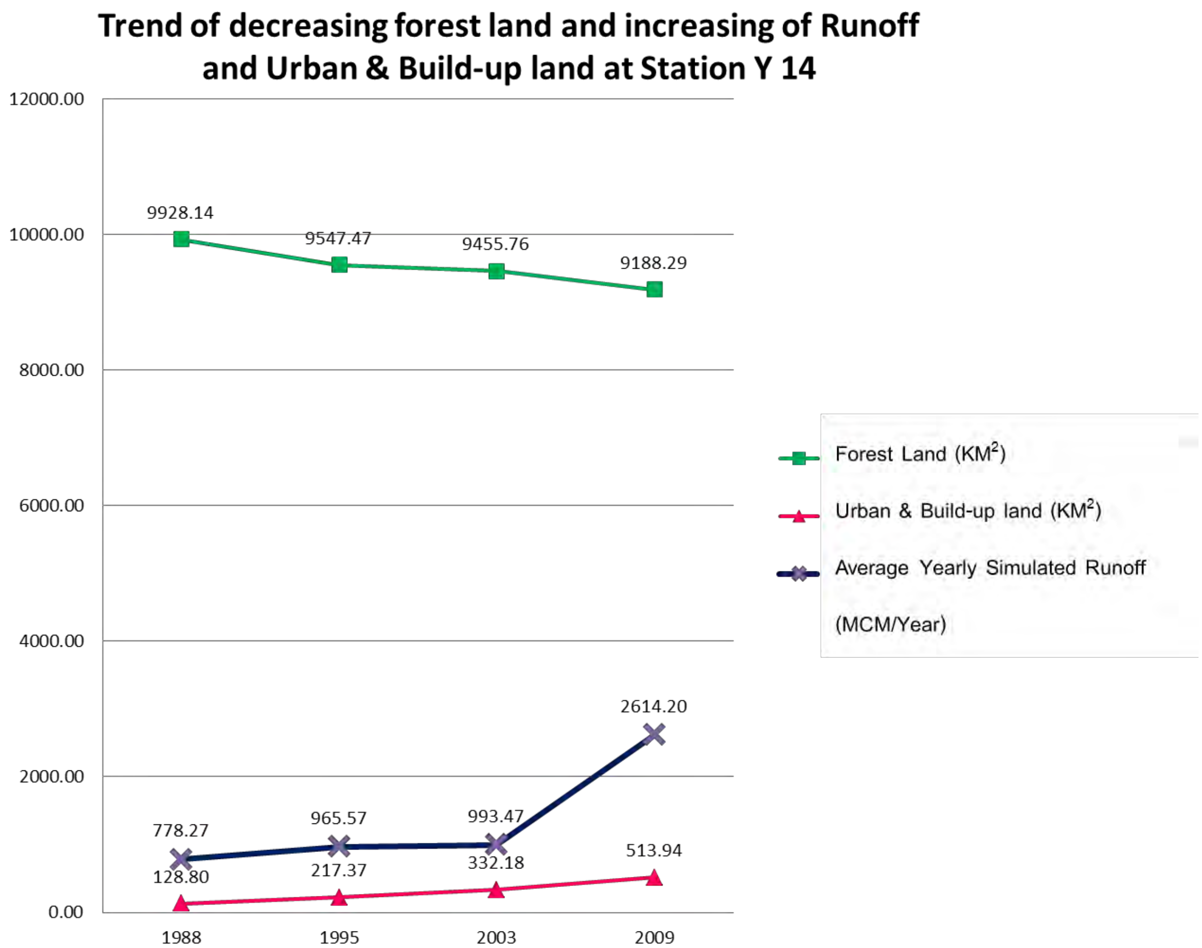


Figure 5-11 The relationship between simulated runoff and decreasing of forest land and increasing urban& build-up land at station Y14

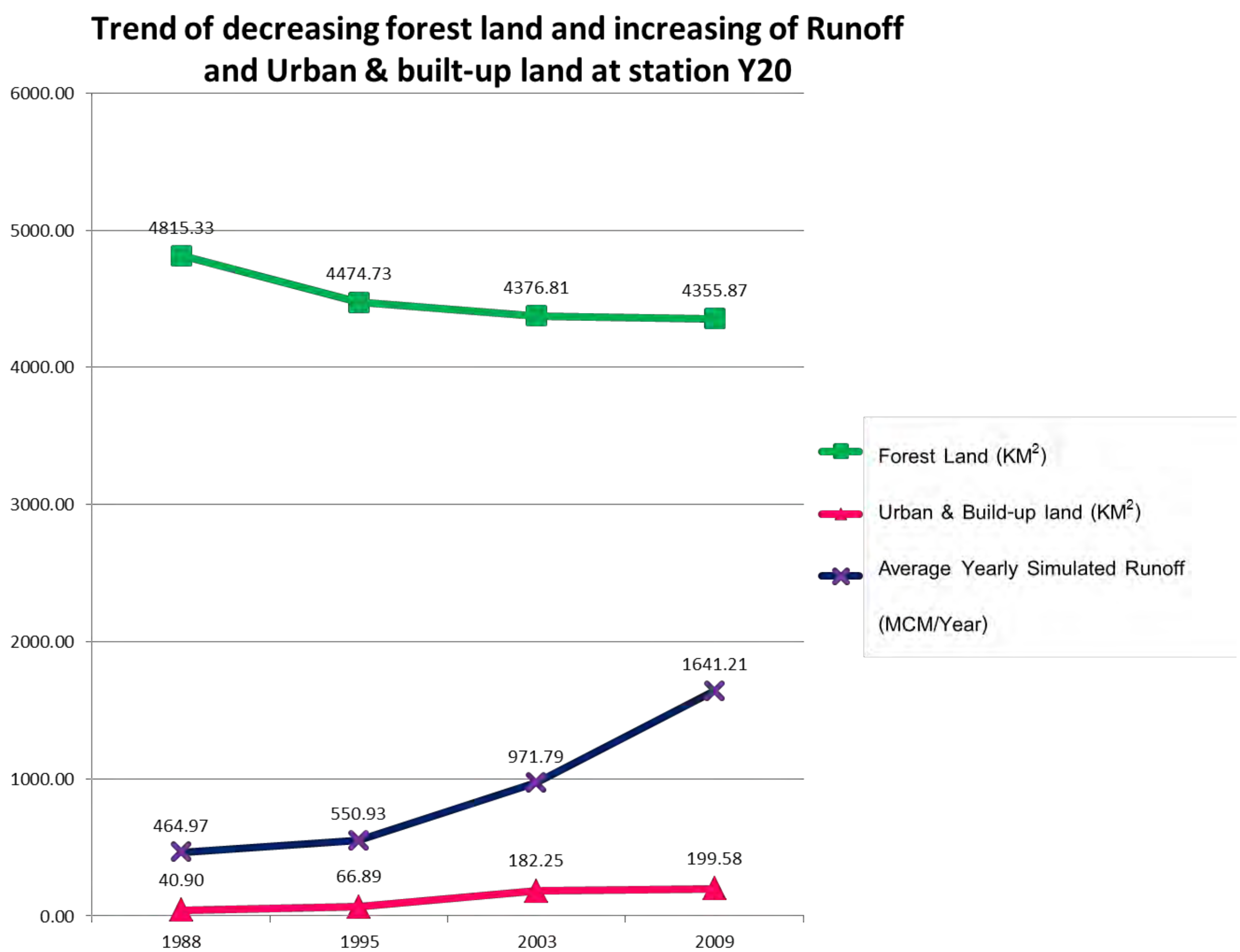


Figure 5-12 The relationship between simulated runoff and decreasing of forest land and increasing urban& build-up land at station Y20

On the basis of the results presented in this study, increasing of the river runoff exhibited relation to the decrease of forest land. Land use changes can affect river runoff, implying changes in the hydrological characteristics of the watershed. Several others have reported changes in watershed characteristics (e.g. discharge) associated with changes in Land use. For example, Pikounis M. *et al*. (2003) also found that the deforestation scenario was the one that resulted in the greatest modification of total monthly runoff by investigates the hydrological effects of specific land use changes in a catchment of the river Pinios in Thessaly on monthly time step. Olan V. (2005) studied the effect of land use changes on surface runoff in the Upper Nan River Basin, Thailand. Three scenarios postulating changes in land use, reforestation, agricultural and the urban expansion are modeled and then used to assess the consequences on surface runoff. The results demonstrated that impacts on runoff can be clearly detected. These results support the idea that the increasing runoff was directly related to the decrease of forest land in the watershed.

5.2 Conclusion

In this research, three data input, which were thematic (GIS and remote sensing) data preparation, field investigation, and laboratory analysis were carried out to investigate dynamic spatial patterns of land use changes and to identify the impact of land use and land cover changes on river run off in the Yom river basin.

This research used the temporal Landsat-5 TM imageries covered the Yom River Basin, acquired during 1988-2009, and were chosen to create the false color composite (Bands R=5, G=4, B=3) for the land use classification system with supervised classification process. According to the study, that Yom River Basin were 6 land use categories that was identified as paddy field, field crops, perennial, forest, urban and built-up land and water bodies. Field investigations were used to test for accuracy against the land use interpretation. The total overall accuracy assessments of land use classifications in 1988, 1995, 2003 and 2009 were 76.60%, 72.98%, 86.08 and 82.11%, respectively.

Change detection of land use in the Yom River Basin during 1988-2009 was analyzed using overlay technique in ArcMap GIS version 9.3. The results revealed that the total change area was 1931.16 km^2 (8.06 % of total areas). The most proportion of change area was forest land (decrease 1422.6 km^2 or 5.94% % of total change area) whereas agricultural land, urban and built-up land and water bodies were increasing over time.

To simulate the differences between river runoff before and after land use changes, the model parameters derived during the start of the study period were compared with those derived at the end of the study period to simulate runoff under the same precipitation regimes.

The Runoff during the start period (year 1988–1989), when land use map of 1988 was replaced by land use map of 2009, was increased with 131.57-169.61 MCM/Year or 22.53 - 25.86 % at station Y20 and 522.55-730.93 MCM/Year or 34.39 - 77.89 % at station Y14, respectively The discharge during the end period (year 2008–2009), when land use map of 1988 was replaced by land use map of 2009, was increased with 406-425 MCM/Year or 25- 98 % at station Y20 and 840-1170 MCM/Year or 47-154 % at station Y14, respectively.

A slight increase occurred concurrently in the long-term discharge with changes in land use, especially a decrease in forest land and an increase in urban areas. The relatively small increase in the areal coverage of urban areas may have had a disproportionally large impact on discharged behavior (mean and extreme flows) due to the location of these land use changes adjacent to the banks of the Yom River.

The Lower Yom River Basin is underlain by alluvial fan and floodplain deposits. The contributions of land use changes on hydrological components, increased runoff occurred in the long term discharge, especially in the upper part of the basin, which may cause more floods in the lower part of the basin.

The Yom River Basin has been characterized by urbanization along the river over the last decade and may continue to experience extensive landscape change in the future, the potential for increased discharge and urban flooding is probable. The approach applied in this study could be applied to other watersheds, which have been highly changed and would essential for sustainable water resources management.

Satellite remote sensing is useful in classifying, studying land use changes and detection of change in the Yom River basin. The area was subjected to urbanization and this was mainly at the expense of agricultural area. Higher resolution satellite imagery would be helpful in identifying subclasses on land use/land cover, especially in urban areas.

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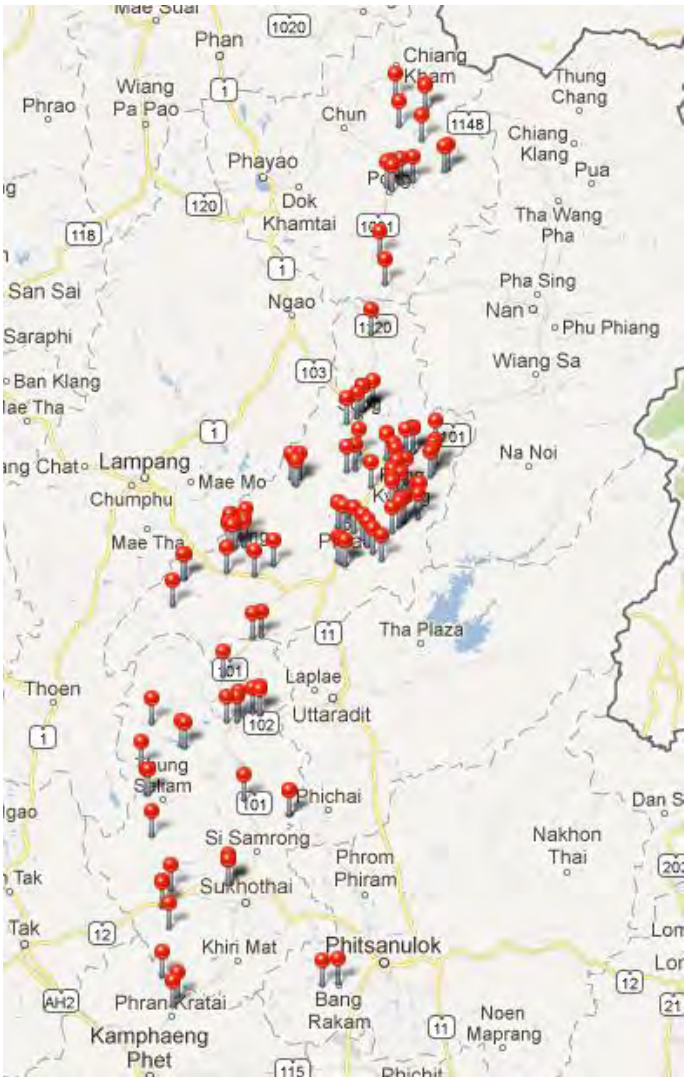
APPENDIX

FIELD INVESTIGATION

Field investigation was an essential part of verify the image interpretation process, as it was important to be confident of the validity of the desk-based assessment. The aim of field investigation was to confirm as many of the land use patterns as possible in the Yom River Basin.

Most of the field investigation was done by travelling in a vehicle for this reason a set of intensive 400 + 1200 ground truth point was organized to localize different land cover and land use categories in order to refine the aforementioned classification. These is some example photography from field investigation. The picture below showed the location of photography.



Lat 15°52'38"

Long 100°15'11"

Lat 15°53'41"

Long 15°52'38"

Lat 16°45'06"

Long 100°04'19"

Lat 16°41'18"

Long 99°36'03"

Lat 16°46'48"

Long 99°34'14"

Lat 16°55'30"

Long 99°35'20"

Lat 17°12'10"

Long 99°32'13"

Lat 17°24'54"

Long 99°30'17"

Lat 17°32'47"

Long 99°32'06"

Lat 17°28'39"

Long 99°37'36"

Lat 17°41'17"

Long 99°45'32"

Lat 18°00'02"

Long 99°46'18"

Lat 17°58'43"

Long 99°38'20"

Lat 17°58'35"

Long 99°38'12"

Lat 18°08'01"

Long 100°07'26"

Lat 18°04'48"

Long 100°12'55"

Lat 18°03'32"

Long 100°13'55"

Lat 18°04'53"

Long 100°12'57"

Lat 18°07'12"

Long 100°17'46"

Lat 18°07'58"

Long 100°19'05"

Lat 18°08'47"

Long 100°19'24"

Lat 18°08'53"

Long 100°19'32"

Lat 18°09'07"

Long 100°20'05"

Lat 18°09'45"

Long 100°22'30"

Lat 18°11'29"

Long 100°22'49"

Lat 18°11'40"

Long 100°22'21"

Lat 18°12'01"

Long 100°17'37"

Lat 18°13'17"

Long 100°19'11"

Lat 18°14'19"

Long 100°17'37"

Lat 19°20'20"

Long 100°18'55"

Lat 19°22'57"

Long 100°23'54"

Lat 19°10'00"

Long 100°19'09"

Lat 19°09'25"

Long 100°16'50"

Lat 19°09'29"

Long 100°17'22"

Lat 19°09'22"

Long 100°16'48"

Lat 18°42'46"

Long 100°13'46"

Lat 18°18'46"

Long 100°25'33"

Lat 18°19'15"

Long 100°25'57"

Lat 18°01'09"

Long 100°08'42"

Lat 17°48'27"

Long 99°53'00"

Lat 17°33'04"

Long 99°46'16"

Lat 17°34'52"

Long 99°52'35"

Lat 17°34'35"

Long 99°51'22"

Lat 17°33'47"

Long 99°48'47"

Lat 17°18'47"

Long 99°49'35"

Lat 17°03'26"

Long 99°46'32"

Lat 18°04'27"

Long 99°46'48"

Lat 18°05'59"

Long 99°46'59"

Lat 18°21'39"

Long 100°21'41"

Lat 18°21'18"

Long 100°20'13"

Lat 15°52'11"

Long 100°15'49"

The Example of index table form field investigation

FileName	Latitude	Longitude
I:\3_3_2555\20120302_101205.jpg	18.13267	100.1201
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I:\3_3_2555\20120302_103042.jpg	18.21347	100.2016
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I:\3_3_2555\20120302_110522.jpg	18.16756	100.2495
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I:\3_3_2555\20120302_114429.jpg	18.22338	100.2393
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I:\3_3_2555\20120302_114516.jpg	18.22294	100.2398
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I:\3_3_2555\20120302_123206.jpg	18.14131	100.1257
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I:\3_3_2555\20120302_123428.jpg	18.12965	100.1153
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FileName	Latitude	Longitude
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FileName	Latitude	Longitude
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I:\3_3_2555\20120302_173112.jpg	17.18472	99.48878
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I:\3_3_2555\20120303_100345.jpg	17.16409	99.50424
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I:\3_3_2555\20120303_100440.jpg	17.15936	99.50249
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I:\3_3_2555\20120303_102709.jpg	17.08452	99.52287
I:\3_3_2555\20120303_102752.jpg	17.07805	99.52352
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I:\3_3_2555\20120303_102851.jpg	17.08063	99.52581
I:\3_3_2555\20120303_102906.jpg	17.07581	99.53024
I:\3_3_2555\20120303_102910.jpg	17.07581	99.53024
I:\3_3_2555\20120303_103028.jpg	17.06979	99.53205
I:\3_3_2555\20120303_103134.jpg	17.0646	99.52933
I:\3_3_2555\20120303_103329.jpg	17.0541	99.53017
I:\3_3_2555\20120303_103530.jpg	17.04486	99.5301
I:\3_3_2555\20120303_104909.jpg	17.04093	99.53125
I:\3_3_2555\20120303_105102.jpg	17.03477	99.53363
I:\3_3_2555\20120303_105710.jpg	17.01153	99.55185
I:\3_3_2555\20120303_105800.jpg	16.99939	99.54941
I:\3_3_2555\20120303_111519.jpg	16.5479	99.56905
I:\3_3_2555\20120303_111737.jpg	16.54561	99.57163
I:\3_3_2555\20120303_112620.jpg	16.50956	99.56884
I:\3_3_2555\20120303_112745.jpg	16.49724	99.57531
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FileName	Latitude	Longitude
I:\3_3_2555\20120303_113558.jpg	16.48444	100.0014
I:\3_3_2555\20120303_120201.jpg	16.45284	100.0687

BIOGRAPHY

Ms. Supattra Kitichuchairit was born in Saraburi, Thailand on September 2, 1985. In 2007 she received a Bachelor degree of Science in Geo-informatics Technology from Department of Geology, Faculty of humanities and social science, Burapha University. After then she entered the Earth Sciences program, Department of Geology, Faculty of Science, Chulalongkorn University for a Master of Science degree study.