การเปลี่ยนแปลงการใช้ประโยชน์ที่ดินและสิ่งปกคลุมดินในพื้นที่ลุ่มน้ำจันทบุรี
หลังการเกิดน้ำท่วม พ.ศ. 2542, 2549 และ 2556

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วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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LAND USE AND LAND COVER CHANGE OF CHANTHABURI WATERSHED

FOLLOWING 1999, 2006 AND 2013 FLOODS

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A Thesis Submitted in Partial Fulfillment of the Requirements

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จุติ เจตวุฒิประภา : การเปลี่ยนแปลงการใช้ประโยชน์ที่ดินและสิ่งปกคลุมดินในพื้นที่ลุ่มน้ำจันทบุรีหลังการเกิดน้ำท่วม พ.ศ. 2542, 2549 และ 2556 (LAND USE AND LAND COVER CHANGE OF CHANTHABURI WATERSHED FOLLOWING 1999, 2006 AND 2013 FLOODS) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: รศ. ดร. ศรีเลิศ โชติพันธรัตน์, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: ผศ. ดร. สมบัติ อยู่เมือง, หน้า.

เทคโนโลยีการสำรวจระยะไกล และระบบสารสนเทศทางภูมิศาสตร์ เป็นเครื่องมือที่มีประสิทธิภาพอย่างยิ่งในการศึกษาสภาพแวดล้อมบนพื้นผิวโลก ในการศึกษาครั้งนี้ได้นำภาพถ่ายดาวเทียม LANDSAT 5 TM, 7 ETM+ และ 8 OLI ช่วงเวลาก่อนและหลังเกิดน้ำท่วม 3 ปี ได้แก่ 2542 2549 และ 2556 รวมทั้งหมดจำนวน 6 ภาพ เข้าสู่ขั้นตอนการจำแนกด้วยวิธีการจำแนกแบบกำกับดูแล ได้ผลการจำแนกทั้งหมด 9 ประเภท ได้แก่ พื้นที่นาข้าว พื้นที่พืชไร่ พื้นที่เพาะปลูกยางพารา พื้นที่เพาะปลูกไม้ผล พื้นที่เพาะเลี้ยงสัตวน้ำ พื้นที่ป่าไม้ พื้นที่ป่าชายเลน พื้นที่เมืองและสิ่งปลูกสร้าง และพื้นที่แหล่งน้ำ โดยจากผลการจำแนกพบว่าการใช้ประโยชน์ที่ดิน และสิ่งปกคลุมดินประเภทหลักภายในลุ่มน้ำ ได้แก่ พื้นที่ป่าไม้ และพื้นที่เพาะปลูกไม้ผล หลังจากนั้นได้ทำการรวมชั้นข้อมูลให้เป็นข้อมูลการใช้ประโยชน์ที่ดิน และสิ่งปกคลุมหลักๆ 4 ประเภท ได้แก่ พื้นที่เกษตรกรรม พื้นที่ป่าไม้ พื้นที่เมืองและสิ่งปลูกสร้าง และพื้นที่แหล่งน้ำ แล้วนำมาวิเคราะห์การเปลี่ยนแปลง โดยผลปรากฏว่าพื้นที่เปลี่ยนแปลงส่วนใหญ่เป็นพื้นที่เกษตรกรรม ได้เปลี่ยนไปเป็นพื้นที่เมือง และสิ่งปลูกสร้าง ในช่วงเวลาหลังเกิดน้ำท่วม ปี 2542 2549 และ 2556 นอกจากนี้ ข้อมูลเชิงพื้นที่หลายประเภท ได้แก่ ข้อมูลแบบจำลองความสูงเชิงเลข ภูมิประเทศ การใช้ประโยชน์ที่ดิน และพื้นที่น้ำท่วม ได้ถูกนำมาวิเคราห์พื้นที่ที่มีความอ่อนไหวต่อการเกิดน้ำท่วม โดยเมื่อศึกษาผลการวิเคราห์ที่แสดงในรูปแบบของแผนที่จะพบว่า พื้นที่ที่มีความอ่อนไหวสูง คิดเป็นร้อนละ 3.71 ของพื้นที่ลุ่มน้ำ ส่วนใหญ่ครอบคลุมพื้นที่เกษตรกรรม และพื้นที่เมือง ผลจากการศึกษาในครั้งนี้จะเห็นได้ว่า น้ำท่วมไม่ได้เป็นสาเหตุที่สำคัญต่อการเปลี่ยนแปลงการใช้ประโยชน์ที่ดิน แต่ปัจจัยหลักคือด้านเศรษฐกิจและสังคม ที่ส่งผลให้เกิดการเปลี่ยนแปลงขึ้นภายในลุ่มน้ำ จากการศึกษาทั้งหมดได้ให้องค์ความรู้ใหม่ที่มีประโยชน์ต่อการตัดสินใจ การวางแผน และการจัดการการใช้ประโยชน์ที่ดิน และสิ่งปกคลุมดินภายในระดับลุ่มน้ำ

ภาควิชา ธรณีวิทยา	ลายมือชื่อนิสิต ....
สาขาวิชา โลกศาสตร์	ลายมือชื่อ อ.ที่ปรึกษาหลัก ....
ปีการศึกษา 2560	ลายมือชื่อ อ.ที่ปรึกษาร่วม ....

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CHUTI CHATEWUTTHIPRAPA: LAND USE AND LAND COVER CHANGE OF CHANTHABURI WATERSHED FOLLOWING 1999, 2006 AND 2013 FLOODS. ADVISOR: ASSOC. PROF. SRILERT CHOTPANTARAT, Ph.D., CO-ADVISOR: ASST. PROF. SOMBAT YUMUANG, Ph.D., pp.

The application of remote sensing (RS) and Geographic Information System (GIS) has become an effective tool and widely used in monitoring the environment on the earth surface. In this study, Landsat imageries were used as a data to deal with the assessment of land use and land cover changes (LULC) before and after the 3-year floods in 1999, 2006 and 2013. The images were classified by supervised classification process and it can be identified as 9 classes consisting of paddy field, field crop, para rubber, orchard, aquacultural land, forest land, mangrove forest, urban and built-up area, and water bodies. The result revealed that the main classes are forest and orchard. After that, LULC were then reclassified into 4 main classes for change detection, comprising of agricultural land, forest land, urban and built-up area, and water bodies land. The results showed that LULC change occurs among agricultural land into the urban built-up area. The flood vulnerability map was generated by various thematic data, namely, Digital Elevation Model (DEM), landform, LULC, and the flood inundation area. These data were calculated with a scoring method to classify flood vulnerability areas consisting of high, low and non-flood vulnerability. The result of analysis revealed that approximately 3.71% of the watershed area is categorized as a high vulnerability area, mainly in agricultural land and urban and built-up area. Furthermore, the finding in this study presented that the socioeconomics factor plays an important role in LULC in Chanthaburi watershed. The results of this study can be used as a data for a decision making and planning land use and land cover management.

Department:	Geology	Student's Signature	....
Field of Study:	Earth Sciences	Advisor's Signature	....
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Above all, I would like to thank my family for their support. The merit of this thesis, I dedicate to my father, my mother and my family, all former teachers and everyone who has taught me.

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LIST OF ABBREVATION

DEM:	Digital Elevation Model
GIS:	Geographic Information System
GPS:	Geographical Positional System
RS:	Remote Sensing

CHAPTER I
INTRODUCTION

1.1 Rationale

Watershed is an area which catches the water from precipitation and then drained by a river and its tributaries. It is a resource area where the ecosystem is closely interconnected around an elementary resource – water. The watershed or river basin is an ideal management unit, it is the places, where we live and where we play. Everyone relies on water and other natural resources to exist. Everything you and others do on the land impacts the quality and quantity of water and other natural resources (Ma, 2004). So the watershed is the logical unit for coordinated land-use planning and management and effective and sustainable resource and environmental management (UN Economic Commission for Asia and the Pacific -Bangkok, 1997).

Chanthaburi Province is in the eastern part of Thailand. There are many watersheds locate in this area. One of them is Chanthaburi watershed, where located in East-coast gulf watershed of Thailand and has a Chanthaburi River as a mainstream. They flow from the mountain area in the upper part of the watershed to the plain and floodplain in the lower part, then they drain into the Gulf of Thailand. This area is influenced by Northeast Monsoon, especially Southwest Monsoon, which blows for 5 months from May to October (Climatological Center - Thai Meteorological Department, 2014), increases the humidity above watershed in the rainy season and it is the important role for rainfall distribution over this watershed.

The important issues of this watershed are the extremely rainfall will cause by a flash flood and riverine flood. It usually happens in every year, and damages to property, human settlement, agricultural area and transport routes.

For the last 15 years, there are 3 years in 1999, which flood occurrence was on 31 July to 6 August 1999, 2006, which flood event happened on 6 to 10 October 2006 and 2013, which flood occurrence was on 23 to 26 July 2013, those 3 flood years affects more than other years (Royal Irrigation Department, 2012) and Chanthaburi watershed has been a lot of land use and land cover (LULC) change (Soytong et al., 2016), the flood may be a cause of LULC change, especially in the lower area, which usually affects in every year. The study of LULC change after flooding might reveal its pattern and lead to land use planning in the future.

The Geo-Informatics, which consist of remote sensing (RS) and Geographic Information System (GIS), techniques are art and science to obtain the reliable information about physical object on the earth surface through the process of recording, measuring and interpreting imagery and digital representations of energy pattern which can retrieve by non-contact sensor system (Jensen, 2009), were applied to investigate and detected a LULC change over Chanthaburi basin after the flooding events in the past 15 years.

RS and GIS are recently the important tool in LULC study. So, we can produce the flood vulnerability map for planning LULC and reducing the impact of flooding in the future.

1.2 Objectives

- To analyze land use and land cover following 1999, 2006 and 2013 floods in Chanthaburi watershed.
- To compare land use and land cover change following floods 1999, 2006 and 2013.
- To generate a flood vulnerability map.

1.3 **Scope and limitation**

This research aims for determining LULC change after the flooding in 1999, 2006 and 2013. So, the satellite image data is a very important to study and understand the past. Landsat satellite image is an easy access data and widely used. There are 6 satellite images from 3 Landsat satellite systems were used in this study, namely Landsat 5 Thematic Mapper (TM) (30 meters resolution RGB band) Landsat 7 Enhanced Thematic Mapper Plus (ETM+) and Landsat 8 Operational Land Imager (OLI) (30 meters resolution RGB band, the 15-meter panchromatic band).

1.4 Location of study area

This research was conducted in the Chanthaburi watershed which situates in Chanthaburi province, cover 5 districts area, namely Muang Chanthaburi, Khao Khitchakut, Makham, Tha Mai and Laem Sing, it drains an area of 1593.33 km^2. The extent of the coordinates of the study area are approximately defined as 820000 E, 1380000 N in the northwestern edge and 860000 E, 1455000 N in the southeastern edge in 48 North zones of Universal Transverse Mercator projection (UTM) with WGS 1984 ellipsoid. This study area covering path 128 row 51 of Landsat 5-TM and Landsat 8-OLI. The hinterland of the watershed is mountainous, with the Chanthaburi mountain ranges. Its elevation ranges from 0 to 1675 meters above average mean sea level.

Figure 1 The location of study area with water stream in watershed.

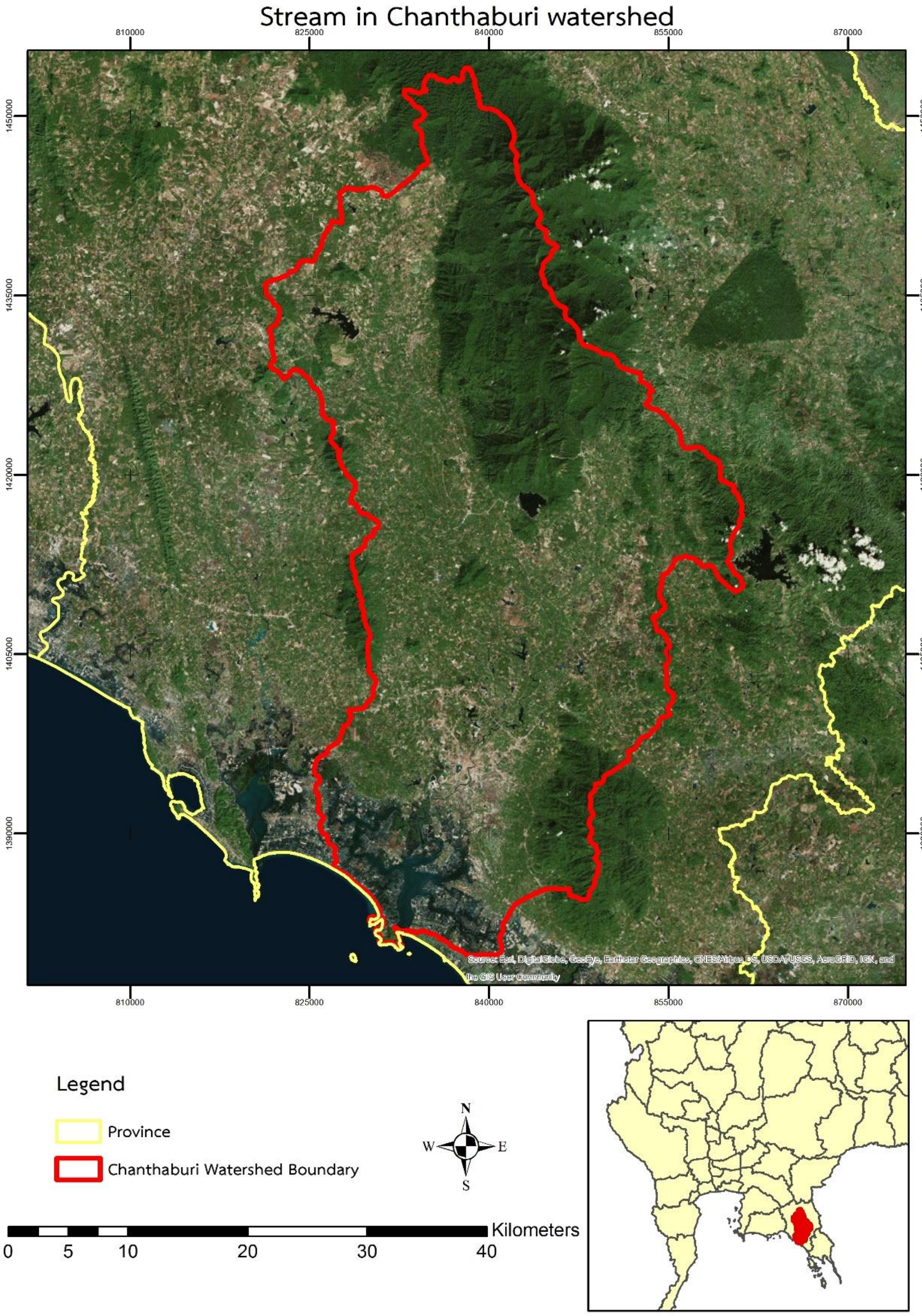

Figure 2 Geographic setting of the study area.

1.5 Benefit of the Study

The benefit of this thesis consists of:

1. Map of land use and land cover following floods 1999, 2006 and 2013 in Chanthaburi Watershed.

2. Map of land use and land cover changes following floods 1999, 2006 and 2013 in Chanthaburi Watershed.

3. Map of flood vulnerability in Chanthaburi Watershed.

1.6 Research Methodology

To accomplish the aims of this thesis, three sequential steps are designed described as follow:

1.6.1 Preparation

This step includes:

• Study and researching the data which related to the LULC and flooding that can be anything about research in the Chanthaburi watershed area or outside, for the purpose of the method adaptation and principle to accomplish the research objective.

• Study and acquisition of background information of study area and basic data acquisition, e.g. satellite images in 30 meters resolution (Landsat 5 TM and Landsat 8 OLI), LULC map, topographic map.

1.6.2 Field Investigation

• The field investigation was done in study in order to validate LULC interpretation, the classified map of land use was compared to the reference data from the field investigation in order to achieve the accuracy assessment by the error matrix and Kappa index, which used a random sample points distributed across the research area and a collected LULC types data to generate an accuracy of LULC cover classification.

1.6.3 Laboratorial Study

• To classification LULC for year 1999, 2006 and 2013, the composite satellite images were classified by digital classification method (Supervised classification: Maximum Likelihood algorithm)

• To achieve the change detection of LULC, all of the interpreted LULC map for each year were compared with GIS software analysis to get a changes area.

• To achieve the flood vulnerability area, GIS data was used collected and generated to flood vulnerability map.

1.6.4 Discussion and Conclusions

• Conclusion and discussion LULC change after the flooding in Chanthaburi watershed accomplish the objectives.

In order to achieve the objectives of this research, the schematic diagram of methodology system was designed as shown in Figure 3.

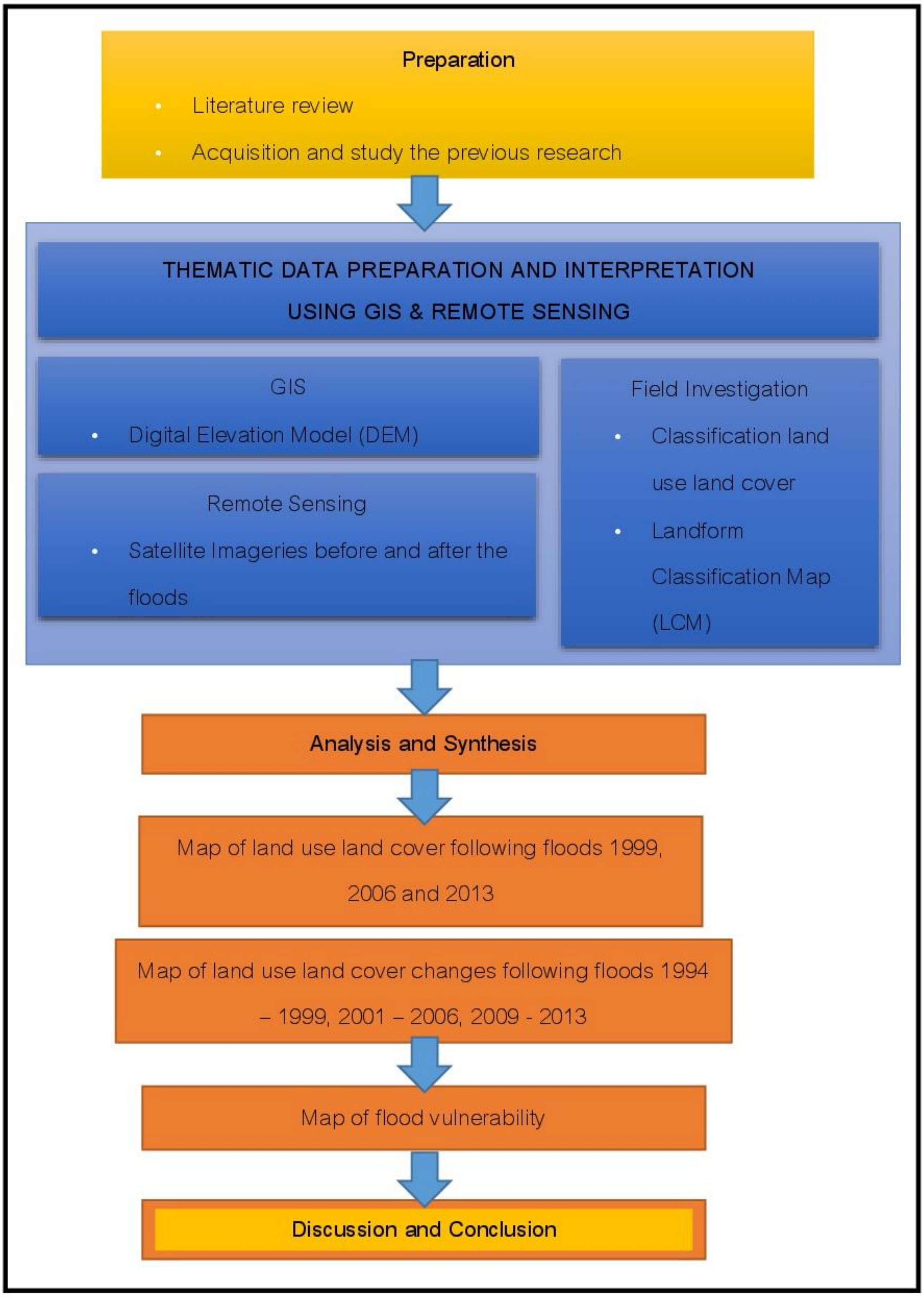

Figure 3 Schematic diagrams illustrating the research methodology system.

1.7 Components of the thesis

Chapter 1 Introduction

This chapter provides the summary about this study include the background of this study, the research problem and question, the objectives, the research output and benefit, the limitation of the research, and the thesis structure

Chapter 2 Literature review

This chapter provides the definition and terminology of LULC, cause of LULC change and reviewed a principle of Geo-informatics include GIS, RS and GPS and its application on detection a LULC change. Moreover, a flood and vulnerability are briefly described following the previous investigation from the related technical literature.

Chapter 3 Data preparation and Methodology

This chapter present data preparation and methodology. The data interpretation and preparation are presented in term of types and sources of input data and data production stage. The data input from data pre-processed with the application of GIS and RS techniques are produced and interpreted.

Chapter 4 Result and Analysis

This chapter shows a result of the LULC classification, which consist of several satellite imageries during 1999, 2006 and 2013 floods. The result of the LULC pattern and LULC change were shown as a map and the vulnerability map which is generated by GIS data will be revealed in this chapter.

Chapter 5 Discussion and Conclusion

This chapter is the last section of this thesis, the result from chapter 4 will be discussed in this chapter, the title of discussion includes LULC pattern, LULC change and flood vulnerability in Chanthaburi watershed. Then, followed by conclusion and recommendation.

CHAPTER II
LITERATURE REVIEW

2.1 Definition and terminology

The earth has changed in every day, the air has polluted, the water has contaminated and the land has changed by human into the difference land cover. All of these alterations are from human activities, it has been causing many problems – flooding caused by the extreme rainfall, heat wave caused by warmer earth temperature.

For the over the more than past a half of century, the results of human activities, affect the changes of vegetation on earth's terrestrial surface and affect weather and climate through changes in LULC (Melillo et al., 2014).

There are many definitions of LULC, almost all of them have a quite same meaning, but different in their way to clarify the term of LULC, which depends on researching and understanding of the authors.

Land cover refers to the covering of biological and physical feature on land surface such as water, vegetation, bare soil and artificial structures (Liang et al., 2012). It is described as the vegetation (natural or planted) or manmade constructions which occur on the earth surface (Coffey, 2013)

Land use refers to land cover but difference in term of its purpose and intentional use. It is categorized by the activities, arrangements, and inputs people undertake in a land cover type to produce, change or maintain it, area for residential, agricultural or industrial purpose. Land use contrasts with land cover due to the intentional role of people to adapt the natural land cover to their advantage: turn natural land resources in to beneficial output. (FAO, 1993)

2.2 The cause of land use and land cover change

Land use and land cover change has appeared for more than 300 years and land cover was not changed to another land use type as much as today. However, agricultural, which is the important driving factor affect to land cover, spreaded through the natural forest area for a long time, specifically in Europe, South Asia, East Asia and Africa, but the rate of agricultural expansion area has increased since 18^{th} century.

According to the BIOME 300 Project, their result shows that agricultural area or cropland area increased by 5 times from 3-4 million km^2 to 15-18 million km^2 between 1700 and 1800, most of land cover type that have been affected by expansion of cropland area is forest area (Lambin and Geist, 2008).

In generally, affecting factor of LULC change in many researches classify as two main factors include Socioeconomics (social, economic, political, demographic) and Physical (Biological) driving factor (weather and climate, soil types, topography, disaster). However, the initial study of LULC change, mostly focused on socioeconomics factor, because in 20^{th} century, the land used to be plentiful resources, turn out to be shortage resources, and these situations was in a trouble due to a population growth.

The understanding of LULC change will not happen, if proximate and underlying causes were not to be clear by definition.

Proximate causes (direct driver) are a physical or human action affect to land cover, recognized as endogenous forces which consist of various factor such as urban expansion, development of infrastructure and agricultural area expansion (Müller et al., 2012), the effect occur in local scale for instance, village and farm in local level (Lambin and Geist, 2008).

Underlying causes (indirect driver) are elemental pressure which have an effect on getting more intense of proximate causes. Many complexes driving factors such as social, economic, political, demographic, technology and biological (Blaikie and Brookfield, 2015; Brookfield, 1999) all of these factors are recognized as exogenous forces that affect the conversion of land cover (Lambin and Geist, 2008).

2.3 Geo-informatics

The Geo-informatics refers two words is consist of 3 significance elements, which each one has difference processes, method and data acquisition, include RS, GIS and GPS. Each element has specific properties that can generate physical environment and human interaction with earth’s surface on map and research. So, using these tools, understanding in meaning and processing is very helpful to achieve a goal (Ayanlade et al., 2015).

2.3.1 Remote Sensing

Definition

Remote Sensing is recognized as a tool, technique and technology for collecting and observing the earth's surface data. It has become one of the most widely tool in environmental study since the last four decades, due to up-to-date and cost-effective (Lein, 2011). There are a couple of RS definition in various resources that depend on researching and understanding of many researcher's aspect.

Remote Sensing defined as the obtaining and measurement of information about object's properties by device without a physical contact to the features. It has a wide definition which covers in various context for instance, medical technologies such as X-rays and magnetic resonance imaging (MRI). In term of environmental, RS refers to a measuring and recording technology using electromagnetic energy which derives from the objects on the Earth's surface, oceans, or atmosphere. Essentially, the properties of these objects, in terms of their associated levels of electromagnetic energy, provide a way to detect, describe, and differentiate between them. Because the electromagnetic properties of these features are commonly collected by instruments mounted on aircraft or Earth-orbiting spacecraft, RS is an effective tool to collect and acquire a large spatial information of the earth's with a single observation, or scene. (Khorram et al., 2012)

RS can be defined as art, science and technology of collecting information about object on earth's surface without being to contact with an object. The detection of wavelengths reflected from object and material is a main proposes of RS to categorize object types.

Remote Sensing Component and Processing

The main components of RS are shown in the figure 4 (Lein, 2011)

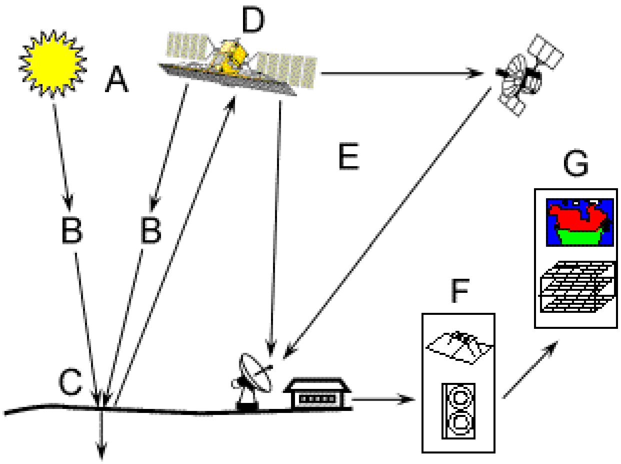

Figure 4 Components of RS Processing. (Natural Resources Canada, 2016)

(A) Energy source is a significant elements of RS, because of providing electromagnetic energy to the target.

(B) The energy travel from source to the target on surface through the atmosphere and it reflected back from the target to the sensor.

(C) The energy interacts with the target depending on the properties of the target and the radiation.

(B) The radiation scattered or emitted by the target, the sensor collect and record the data.

(E) The energy that recorded as a digital form will be transfer from the sensor on satellite to the ground station, where the data are processed into an satellite image.

(F) Satellite image is a product of processed image, then it will be interpreted to extract object's information.

(G) Applying data to research or reveal new knowledge about earth surface is a final component of RS processing

The main element of satellite that involves RS detection is sensor, which there are two system sensors include Passive Sensor and Active Sensor, each them have a different recording and measurement. Passive sensor uses energy of the sun as a significant source and usable only in daylight. On the other hand, active sensor has their own energy source which will be sent by sensor to object no need to rely on the sun radiation.

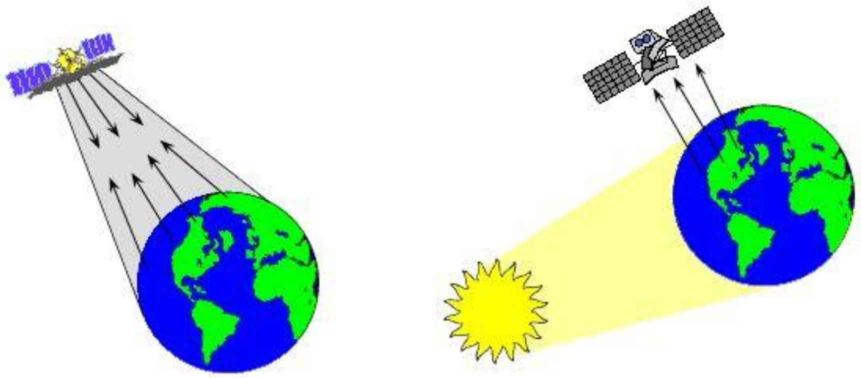

Figure 5 Active and Passive sensors. (Lein, 2011)

The Electromagnetic Spectrum

The energy illuminates from the sun to the target, in form of electromagnetic radiation. It consists of a number of electromagnetic wave categories depend on its wavelength, we referred each wavelength as electromagnetic spectrum. They range from highest frequency and shortest wavelength to lowest frequency and longest wavelength, the electromagnetic spectrum does not have a clear boundary, because of their continuous.

The electromagnetic spectrum has seven regions each has properties that can be apply for any aim in field of RS (Sanderson, 2010). Although RS includes many regions of energy in electromagnetic spectrum, only some region is useful for RS such as visible light, infrared and microwave (Lein, 2011).

Visible spectrum is a wavelength region which the human can detect, recognized as visible light or red, blue and green spectrum, other regions is an invisible light, cannot be detected by our eyes, but can detect by RS. The visible region covers a range from 0.4 to 0.7 micrometers, with violet is shortest and red is longest.

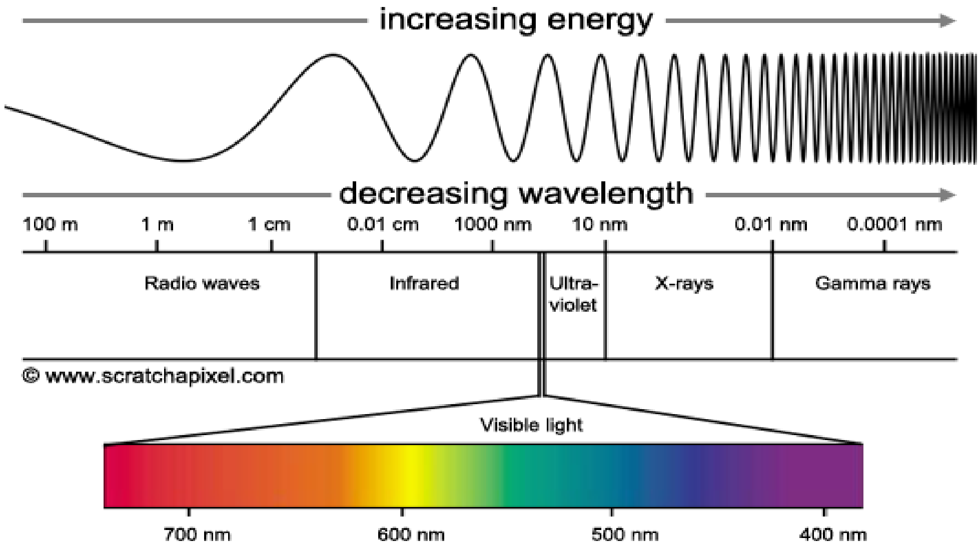

Figure 6 The electromagnetic spectrum. (Lein, 2011)

The further radiation in the spectrum which has a longer wavelength than visible light is infrared radiation (IR) region, it covers the wavelength wider than visible light for 100 times from 0.7 to 100 micrometers (Natural Resources Canada, 2016). We can identify different type of vegetation by using near-infrared and mid-infrared radiation – one part of IR region. The thermal infrared radiation (TIR) or emitted IR covers wavelength from 3.0 to 100 micrometers, this region is different from visible and Near-infrared (NIR) because the source of its energy is an object which the radiation is emitted from the earth surface.

The radiation beyond TIR toward larger wavelengths in the electromagnetic spectrum is recognized as microwave region, from about 1 millimeters to 1 meters. Its properties are quite similar to thermal infrared radiation, so this region is important for an active RS which can use at a night time and detect the target under the cloud cover condition (Eastman, 1999).

Radiation target interaction

When the solar radiation strikes a target surface, it can take place tree form of interaction such as reflection, scattering and emission. Different target has a different surface which makes them have unique in reflectance and absorption, so the various reflectance of each material surface is recognized as spectral reflectance signature of the material (Sanderson, 2010).

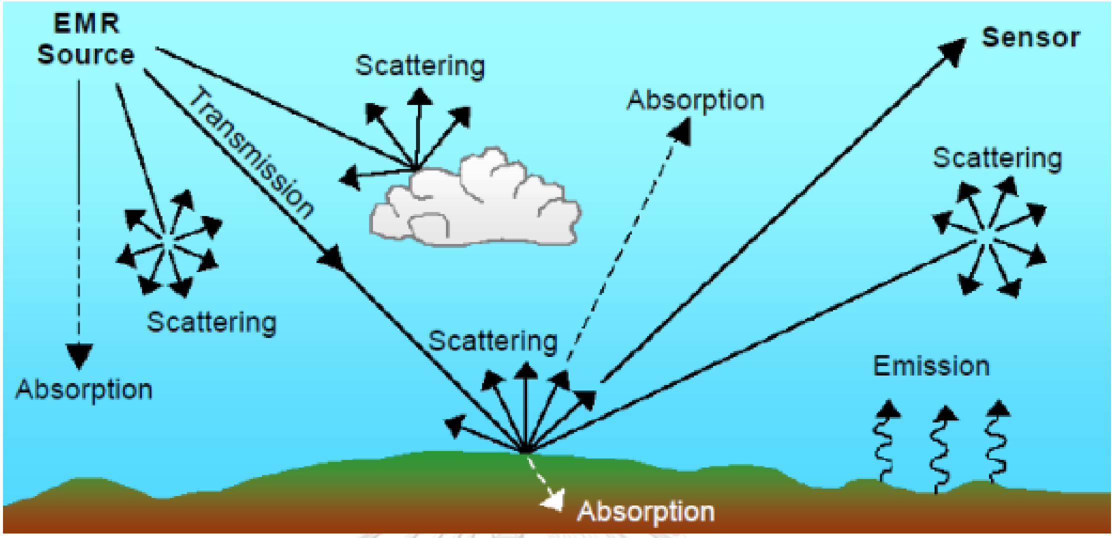

Figure 7 Energy interactions in the atmosphere and at the earth surface. (Sanderson, 2010)

Spectral reflectance signature (Figure 8) refers to the relationship between electromagnetic radiation and the reflectance of the target on the earth's surface, which each object has its unique signature, it is affected by material and structure of the object. The following figure shows the spectral reflectance signature of water (clear), vegetation (green) and dry bare soil (gray-brown)

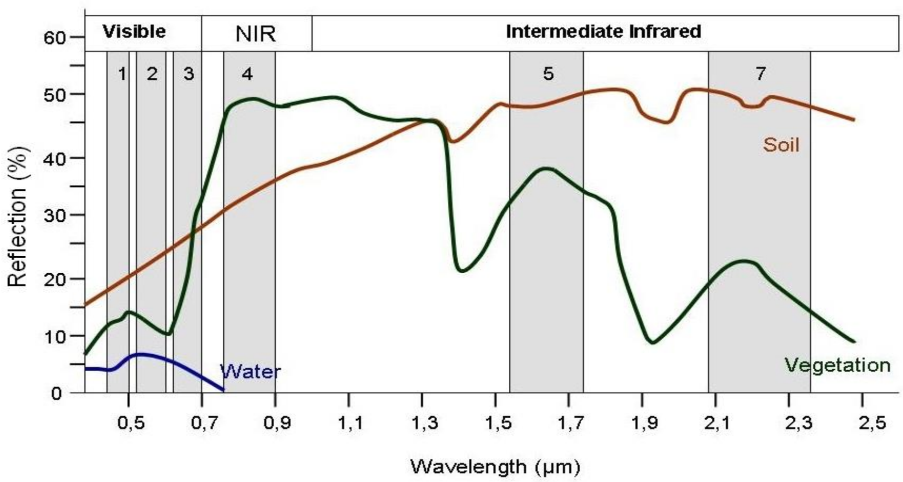

Figure 8 Spectral signatures of soil, vegetation and water, and spectral bands of Landsat 7. (U.S. Geological Survey, 2016)

Vegetation (green): The red and blue region of electromagnetic spectrum are absorbed by Chlorophyll in the leaves, but the green wavelengths will be reflected that why we can see a leave as a green color. The reflectance is peak again at near-infrared (NIR) region and higher than green region, because of structure in the leaves.

Water (clear water): The clear water has a low reflectance in the visible region, but the blue region is most reflectance.

Bare Soil (dry soil): There are many factors cause of a various curve of bare soil reflectance curve, because of a main soil's components such as color, moisture, carbonate and iron oxide. However, most of soil reflectance curve will be as same as a figure 8 that high reflectance appeared in visible light, near-infrared (VNIR).

Remote Sensing Resolution

Spatial resolution: The pixel size that is recorded in a raster image in typically pixels may correspond to square areas ranging inside length from 1 to 1,000 meters (3.3 – 3,000 feet)

Spectral resolution: The wavelength width of the different frequency bands recorded by the platform.

Radiometric resolution: The number of different intensities of radiation the sensor is able to distinguish. In the other word, it specifies how well the differences in brightness in an image can be perceived (The European Association of Remote Sensing Laboratories, 2015). Typically, this ranges from 8 to 14 bits, corresponding to 256 levels of the grayscale. If the Landsat 5 sensor used bits to record the data, there will be 256 digital values (Kumar, 2014).

Temporal resolution: It is the ability to collect the image at the same area same imagery scene, but different at the period of time (Eastman, 1999). For Landsat, its temporal resolution is 16 days, however, the temporal resolution relies on a sensor, swath overlap, and latitude (U.S. Geological Survey, 2016).

2.3.2 Geographic Information System (GIS)

Definition

GIS is a powerful and important tool for acquiring the geospatial data, solving and analyzing the spatial problem, and to make decisions. There is various definition of GIS for example, Greenberg et al. (2002) defined GIS as - An important tool for viewing broad scale pattern of spatial data, organizing and interesting information about an area, and analyzing that data answer the question, while Worboys and Duckham (2004) defined GIS as a computer-based data system which able to capture, modelling, management, retrieval, synthesis and performance of geographically referenced data. Moreover, Bajjali (2017) provided the definition with different explanation from the others by using the letters G, I, and S to classified meaning in his own way.

GIS refers to three combined parts:

1. Geographic: The geographical location of the real world (using coordinate system)
2. Information: The database
3. Systems: The hardware and software

GIS Data

The most important elements in using GIS is data, which is divided into 2 types include spatial data and attribute data (Kolios et al., 2017).

Spatial Data

This type of data is an important component in GIS processes, because each feature data represents the object and phenomenon on real earth’s surface. These data can be also divided into 2 types, such as vector and raster data structures, which used to represent real world features (Bajjali, 2017).

Vector data

Vector data, which store data in digital format, can be divided into 3 types: point, polyline, and polygons, each of them have a boundary, dimension, and location, its information will link to the attribute data (Greenberg et al., 2002; Kolios et al., 2017).

- **Point** contains a coordination, so the properties of point is to identify the location.
- **Line or Polylines** is one dimensional features, it comprises multiple connected points. Its properties are to measures the length of each features.
- **Polygons** is two dimensional features, it is comprised of multiple connected lines and these features can be indicated an area under a closed feature.

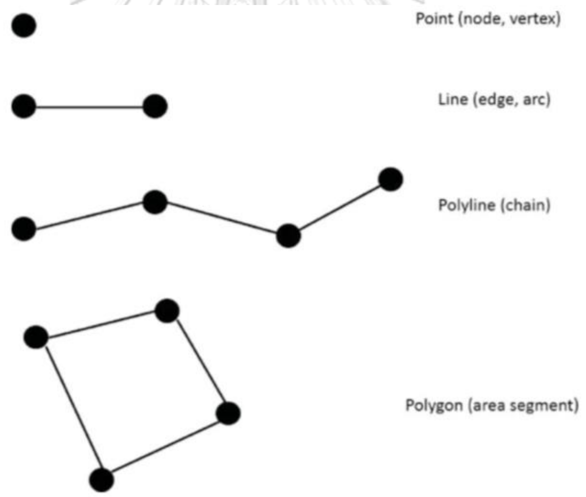

Figure 9 Types of objects represented using the vector data type. (Kolios et al., 2017)

Raster data

Raster data is a data in a grid cell format a tiny square pixel. Each pixel has its value, which can be useful for storing data. For example, each pixel in a satellite image has its value that vary from object to object, depend on reflectance characteristics of each object (Gisgeography, 2017).

Data overlay is a characteristic of GIS that it process can analyze and generate to display a result on a format of thematic digital map that could accomplish the goal and to satisfy a user.

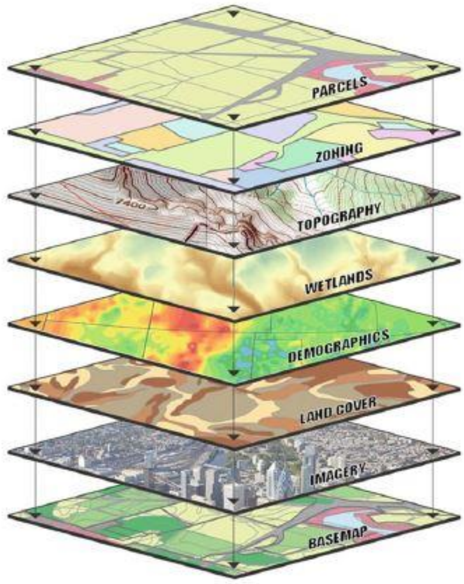

Figure 10 Different layers of data can be combined through a GIS to represent realistic and integrated digital maps of the Earth's surface. (Kolios et al., 2017)

Attribute Data

Attribute data is defined as the tabulated data which describe a spatial data. In other words, each spatial data contains attribute data in tabular format, which can show information about a geographic feature on the earth's surface.

2.3.3 Geographic Positional System (GPS)

ESRI (2012) provided a definition of GPS - A system of radio-emitting and receiving satellites applied for defining places on the earth. The signal that transmit from orbiting satellites will be received by GPS on earth, the location will be defined by calculating through trilateration. The U.S. Department of Defense developed and operated this system, it is necessary for mapping, surveying, navigation and other applications which accurate positioning is required.

GPS is a major tool in research because it is important components of Geo-informatics which is consists of RS, GIS and also GPS and every researcher can access any area on the earth by using GPS and integrate it in various subject areas (Department of Economics and Social Affairs Statistic Division, 2000).

GPS consists of 24 satellites – only 21 satellites is activated. Each satellite is a receiver to collect the signal that reflect from the earth's ground. They are circle around the earth at 20,000 km. above from the ground to completely coverage the whole earth's surface. All satellites broadcast signal in region of microwave, their design is suitable for any diverse condition under the procession.

The location of point is determined by the distance from GPS user at the ground to 3 satellites in the space which these satellites detect the latitude, longitude and altitude. The GPS receiver will calculate and measured the distance of satellites, its distances will intersect at the same point that is the exact location of GPS on earth's surface. The number of satellite affect the accuracy of GPS location, more satellite will provide more accuracy of point location (Institute of Physics, 2012).

2.4 Change detection of Land use and land cover

Change detection is recognized as a different in a state of something such as an object's changes on the earth's surface in two or more time periods. It uses for accessing LULC change, natural disasters impact, cultivation and urban growth (Theau, 2011).

The Geo-informatics is become the influence tool to apply the spatial information to carry out the goal in any issues, whether it be LULC, change detection, land degradation, watershed management, or ecosystem management. Because of its abilities such as inexpensive, valuable and reliable, it is a powerful tool for this present world.

RS is the one part of the Geo-informatics which is based on principle, in other words, it is the spatial data deriving without a directly contact with the object on earth, the electromagnetic wave from the sun radiation for active RS – active RS can transmitted radiation to the target without sun as the important source of radiation – will transmitted to the object on earth and it reflect back to the sensor on the satellite in order to converted data in a digital format. Then data will be transferred to the ground station and turn out to be satellite image, which is a great tool for detection a change on the earth's surface. Because of its ability that can cover the large area in 1 scene and several of imagery (Tran et al., 2015). There are different types of satellite depend on its pixel resolution, so choosing the proper satellite image for the objective is important in land use change assessment.

GIS is a necessary tool to collect, analyze and display digital data for change detection and GPS is a great tool for assessment also. Because of its ability, which can define a location in almost any area on the earth's surface with a convenient, easy to use and accuracy, GPS has been effective tool to support and prove in change detection (Waiyasusri, 2011).

2.5 Flood hazard

There are several types of hazard happen on the earth, it can be classified into more couple categories including geological hazards, hydrological hazards, meteorological hazards and biological hazards (The Pennsylvania State University, 2016). Flood is natural hazards which classified as a hydrological hazard because water is an important agent in the hydrological process. In other words, flood hazards are a result of a volume of water is much more than usual which is caused of various hydrological factors includes, rainfall, the absorptive capacity of the soil, the capacity of the stream. In this study, a river flood is emphasized as a term of flood hazards, because the study area located in the floodplain area, where its river flow through those areas, moreover, flood vulnerability area doesn't close to the coastal area, so coastal flood doesn't affect to study area.

Flood hazards and flood disaster both of them seem to have the same meaning, but actually, they are distinguished meaning, because of interaction with people. In other words, flood disaster can occur in any place where there is an interaction between peoples and flood hazards, so if the extreme event occurs here, its area will be harm and lost, caused of damaging property and life.

Floodplain area is a topographic category, where almost all of the human communities usually settle their residences here, because it lies adjacent to a stream and water resources which is important factor for agricultural, industry and every activity, so it is easily accessible to provide water resources for human supply. On the other hand, the cons of floodplain area are a high opportunity to face flood disasters, because this risk area has many building, houses and all kind of infrastructures, so if there are more manmade structure, they will take more damaging back.

Floods can be generally considered in various types that depend on topographic, rainfall intensity and duration of rainfall.

- Flash flood is a phenomenon which can occurs in a short period of the time, it happens after high rate of precipitation that usually caused by thunderstorms and cyclone. All of water flows to a lower area with high velocity.
- River flood can occur when a high-water level flows over the natural levee of river, an area along the river would be inundation. Impacted area of this flood type can lead to losses of livestock and damage to agricultural productivities, also the settlement areas and infrastructures, in other words, large area of watershed will be impacted by river flood and also effect to whole communities.
- Urban flood caused by increasing incidence of heavy rainfall in a short period of time, because water can't absorb to the ground, so these exceeding waters would flow to lower area

Most of floods in Chanthaburi watershed belong to riverine floods which occur in floodplain area. The high intensity of rainfall influences a body of water in stream, so they flow over the bank to the outside, along stream area.

2.6 Vulnerability

There are several definitions of vulnerability, depending on the researcher point of view. The term of vulnerability started from definition only related to physical until more complex definition which are influenced by physical, economic, social and environmental factors (Zein, 2010).

Blaikie and Cannon (1994) defined vulnerability as the group or person's quality in term of their ability to manage, resist and recover from the hazardous impact, it consists of several factors which defined a degree of risk that affect to life and property.

Singh (2006) defined vulnerability as the degree or level of public, facility, structure or area which were damaged by natural and specific hazard, because of their nature, construction and proximity to hazardous topographies or a disaster risk area.

Schneiderbauer and Ehrlich (2004) clarified the meaning of vulnerability as the measurement by using environmental, physical, social, economic and environmental factors or procedures which increase the exposure of an individual, a community, assets or systems to the impacts of hazards.

Vulnerabilities can be categorized into 4 types

- Physical Vulnerability focuses on events that threaten physical body of human, food source, structures, and other life-sustaining services.
- Social vulnerability refers to the inability of people, organizations, and societies to resist impacts from hazards due to characteristics inherent in social interactions, institutions and systems of cultural values.
- Economic vulnerability evaluates the degree of vulnerability from disasters with parameters such as family income and housing prices.
- Environmental vulnerability emphasizes natural resource depletion and resource degradation from disastrous events

2.7 Previous investigation on land use change assessment

The previous investigations on LULC changes assessment have been studied in many parts of the world. Some important literatures have been briefly reviewed below.

Gumrukcuoglu et al. (2010) studied about a great flood event in 1993 that has caused damage on the Kansas River in the USA. The purpose of this study is to classify LULC changes which occurred along the river in study area after the great flood. The Landsat satellite images from 1988, 1991, 1993, 1996, and 1998 were used to identify the patterns of land use before and after the 1993 flood are compared. The results show a transformation in the agricultural area following the 1993 flood. As a result, this study indicated that agricultural land, the grassland, and the woodland reduced after 1993 flood event. The loss of agricultural land and a decrease in agricultural production are the result of 1993 flood. Moreover, the quantity of grassland returned almost to pre-1993 flood level. This study offers a valuable description for flood and LULC management using RS methods and could be guideline for decision makers, mitigation of flood effects and management strategies.

Ho et al. (2010) this study is to generate a flood hazard map using geomorphologic method which DEM and satellite image data were applied for this study. The LULC were generated by using supervised classification. Furthermore, the Modified Normalized Difference Water Index (MNDWI) is used to separated flood and non-flooded areas. DEM, NNDWI, geomorphologic characteristics and LULC, which was derived by unsupervised classification method, were applied to create the affected area of flooding. The results are compared with landform map and flood hazard map. The MNDWI can be a benefit for detection flood area and this outcome is compared with the landform map, elevation ranges which derived by DEM and LULC classification. The results of analysis revealed that the area which situated at 4 meters was identified as deltaic lowland and flood basin, due to saturated area, elevation and condition of flood. For higher areas are not affected by flood because its topographic features such as terraces and natural levees. Hence, this research proves MNDWI is a significant device for flood forecasting by using soil moisture that derived from RS method.

El-Kawy et al. (2011) used Landsat image data in 1984, 1999, 2005 and 2009 to provide a LULC pattern of western Nile delta. The Supervised classification with Maximum Likelihood method was applied to mapped and classified 5 LULC categories. The results indicated that barren land transform to agricultural land was the major change in study area because human activities caused land degradation in watershed. Hence, the policy and planning should be adapted for sustainable watershed management.

Singh and Kumar (2012) the purpose of this study is to prepare a management plan for increasing of the land productivity due to population growth in the middle part of Ganga plain of India. RS and GIS were applied to produce a LULC map for management plan which is comforted to the terrain and local resources.

Ehsan and Kazem (2013) applied the normalized difference vegetation index (NDVI) method and classification method provides change detection in LULC. This study is conducted in Ardakan, Iran, Landsat 7 ETM+ imageries in 1990 and 2006 were used in process of NDVI and image interpretation and classification. First step, two NDVI data were compared to identify and calculate the difference between two times data in the research area. The results indicated that the 18.83% of the NDVI values have reduced by about more than 10% from 1990 to 2006, while only 1.38% of it has increased at the same time. Moreover, supervised classification method was performed and change detection technique was used to obtain the result of changing in pattern of LULC. The result revealed that urban and built-up areas increased whereas, the agricultural lands declined.

Rawat et al. (2013) studied the LULC dynamics of the Uttarakand State which located in the foothill area. The results were obtained by using Landsat imageries data in 1990 and 2010. The supervised classification was employed by using Maximum Likelihood algorithm. LULC was categorized into 5 classes consists of vegetation area, urban area, agricultural land, sand bar and water bodies. The results reveal that urban area and sand bar of the study area have been increased. On the other hand, vegetation area, agricultural land and water bodies have been decreased. This study indicate that the Ramnagar town is expanding to the south of the town.

Ejenma et al. (2014) attempted to measure the spatial impact of river Kaduna flooding of Kaduna South, Local Government Area using satellite images. A Digital Elevation Model (DEM) was developed to classify flood prone areas along the middle course of the river. A flow accumulation model was shaped by using the DEM and was reclassified into very high risk, high risk, moderate risk, low risk and very low risk zones using equal interval of separation based on elevation. This was overlaid on the map of the settlement extracted from LULC classification of 1990, 2006 and 2010 Landsat ETM+ images to produce a vulnerability map of the area. The result of the analysis shows that about 30% is at very high risk to flood and the remaining 70% is either moderate or at low risk. It was shown that a flood map can be successfully used in disaster planning and flood risk management.

Butt et al. (2015) this study applied a supervised classification using maximum likelihood algorithm for detecting the pattern of LUCL changes in Simly watershed, Pakistan, Landsat 5 TM and SPOT 5 satellite imageries in 1992 and 2012 were an important tool for this research. LULC in watershed was classified into five classes consists of agriculture, vegetation, settlements, bare soil and rocks and water. The results show a shift from vegetation and water bodies to other LULC type, namely, bare soil and rock, agriculture and settlements, it reduced by 38.2% and 74.3% respectively. These land use and land cover changes are a serious topic to watershed resources. Hence, suitable management of the watershed is required.

CHAPTER III
DATA PREPARATION AND METHODOLOGY

The data and methodology are a significance element to fulfil the research problem, which there are various format of data depend on its processes. For this research, the preparation and processing of thematic data will be mainly described in this chapter.

3.1 Phases of land use changes mapping analysis in RS and GIS-based change detection techniques.

The following procedures in the process of land use change analysis using GIS (Van Westen (1994) cited in Yumuang (2006)). They are listed in logical order or sequence as follow:

- Preliminary phase:

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

- Data collection phase:

  Phase 2: Gathering of data (reports and maps with related information)

  Phase 3: Image interpretation (interpretation of images and making of a new maps)

  Phase 4: Filed work (to prove the interpretation)

  Phase 5: Laboratory analysis

- GIS work phase:

  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 conversion of the raw data into a type which can be used in the analysis)

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

Phase 11: Maps presentation (result of LULC change maps and attached report)

GIS and RS are the main implements to achieve the objectives for LULC cover interpretation and change detection on the earth's surface. The compatible data types, which consists of satellite images and GIS data-based, are required for the procedures to analyze all of them through a software which can perform spatial data and attribute data.

3.2 Thematic data preparation from RS and GIS techniques

The study of LULC and their change, all of thematic data which derived from RS and GIS sources is a greatly necessary, and they can be combined with several information layers.

This thesis consists of several data categories from different data sources. Table 1, they were digitized from maps, interpreted from imageries and investigation in the field. Input data of this thesis comprises elevation, hydrology, geology, infrastructure and human settlement, meteorology, flood area and LULC. These input data will be applied and generated to response the purpose of this study.

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

Main themes	Year	Sub-themes	Data preparation methodology
Elevation	2004	Digital elevation data	Derived from 1:50,000 scale digital map of The Royal Thai Survey Department
		Digital Elevation Model (DEM)	Derived from elevation data with GIS
		Topography	Derived from DEM with GIS
Hydrology	2004	Drainage system	Derived from 1:50,000 scale digital map of The Royal Thai Survey Department
		Watershed boundary	Derived with GIS
Geology		Rock Unit	Derived from 1:50,000 scale geological map of Department of Mineral Resources (DMR)
Land use Land cover		Land use and Land cover	Land Development Department (LDD)
Land use Land cover	1999, 2006, 2013	Land use and Land cover	Derived from interpretation of RS imageries and filed investigation
Infrastructure and human settlement	2005	Roads and Villages	Derived from 1:50,000 scale digital map of Land Development Department (LDD)
Meteorology	Various year	Mean annual precipitation	Interpolated from existing rainfall information of the observation stations
Flood area	2013	Flood area	GISTDA

3.3 Elevation

The contour line of elevation in topographic map normally was used to represent the height level of study area but this research would have brought them to create a continuous map called DEM. This DEM is 30 meters resolution and was generated in GIS software by using various vector data namely, spot height, contour line, lake and inland water body, stream and boundary of the study area. After that, the produced DEM will be converted into color-coded DEM (Figure 11)

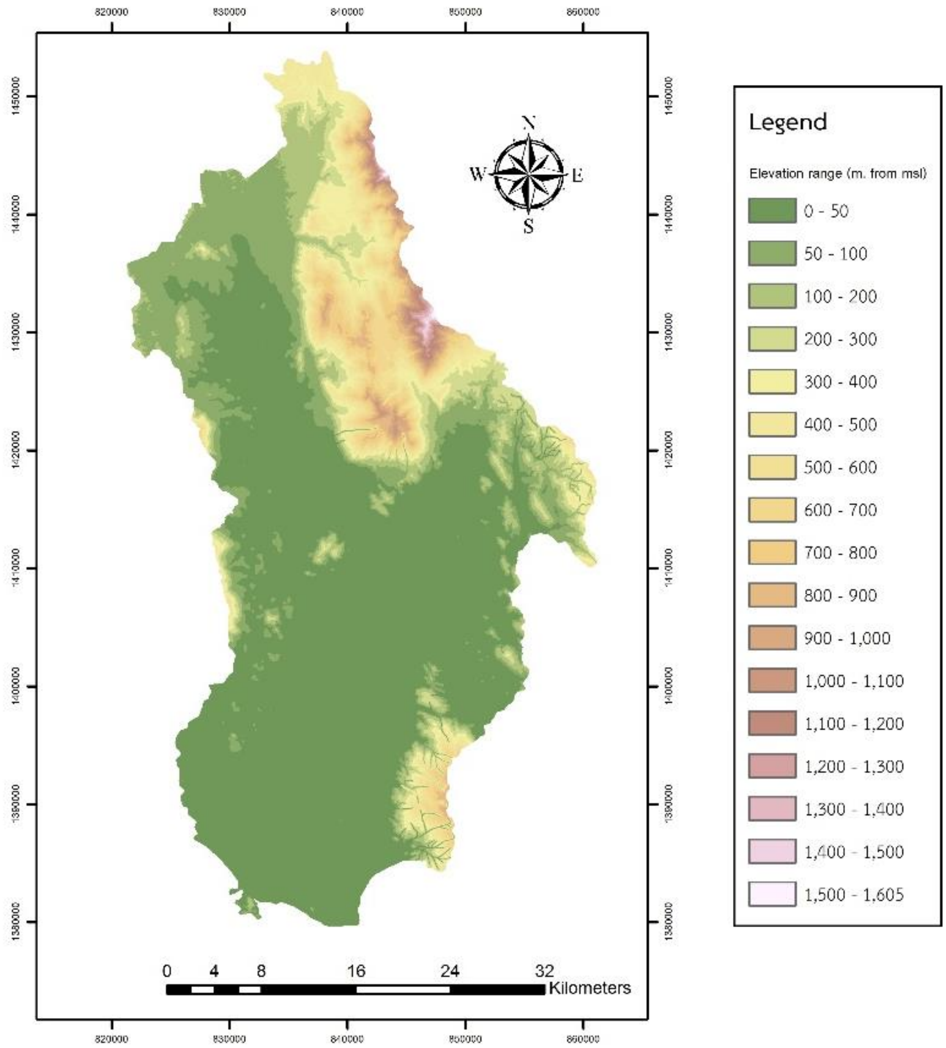

Figure 11 Color-coded DEM of the study area.

3.4 Drainage system

All of the drainage-lines data were from topographic map digitizing in the area of Chanthaburi watershed as a digital format. It was derived from 1:50,000 scale digital map of The Royal Thai Survey Department. They were overlaid on the area of study as shown in Figure 12.

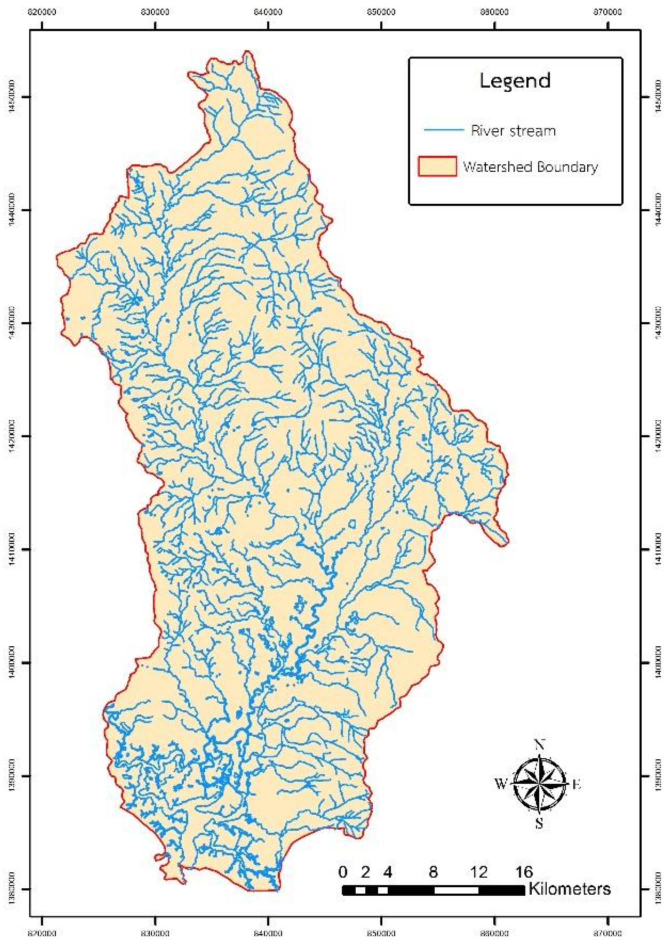

Figure 12 Drainage-lines in Chanthaburi watershed.

3.4 Geology

According to the geological map from Department of Mineral Resources (DMR), there are 9 rock units in Chanthaburi watershed, Terrace and Colluvial Deposits (Qt) covers the most part of this area, it covers alongside the stream and also Alluvial and Flood Plain Deposits (Qa) covers along the river in the lower part of the watershed area. The sediment of Quaternary age form in the Mangrove Tidal Deposits (Qfm) at river’s outlet. Moreover, there are a few of basalt rock of Quaternary age appeared in southern part, they comprise dark gray basalt and basalt olivine

Triassic Igneous Rock (TRgr1), Triassic Sandston (Trpn2), Upper Triassic Sandstone (Trpn) and Triassic Sandstone which consists of olive and greenish-gray sandstone (Trpn1) mainly exposed at the mountain area where located in the northern, western and the eastern part as shown in Figure 13.

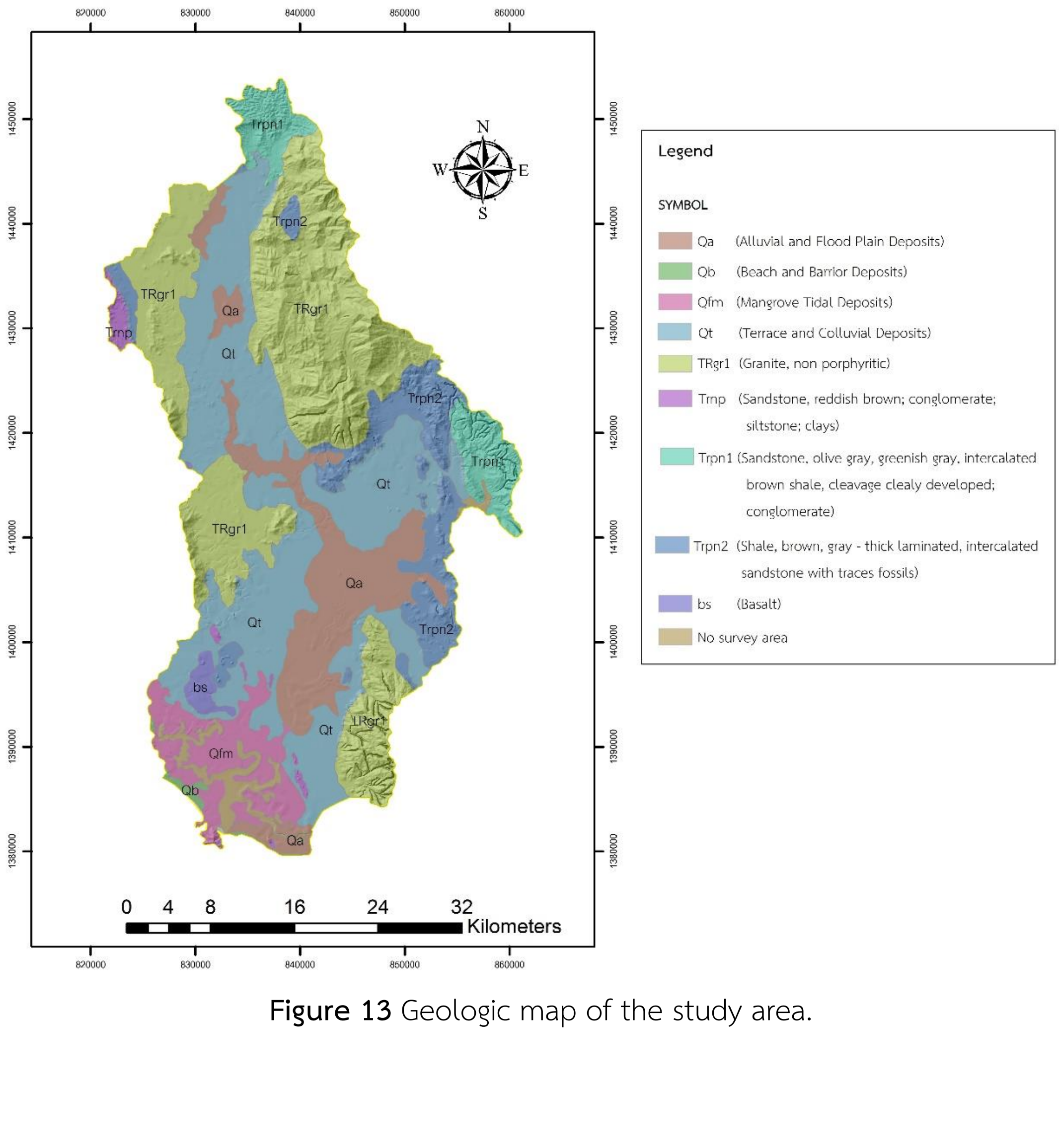

Figure 13 Geologic map of the study area.

3.5 Land Use and Land Cover

In this thesis, the LULC will be classified by using classification system which includes three major attributes of classification procedure as outlined by in Waiyasusri (2011):

- It gives names to classifications by essentially using accepted terminology
- It allows data to be transmitted
- It enables inductive generalizations to be made

The classification system can be more improvement based on more extended and varied use. At the more generalized levels it should meet the principle objective of providing LULC classification system for further managing and planning. Accomplishment of the further fundamental and long-range objective of providing a standardized system of LULC classification for local and global studies will rely on the improvement that should result from widespread use of the system (Anderson, 1976).

The minimum level of classification of LULC should be the Group level wherever possible. As a general classification rule should be recorded at the most detailed level that resources will permit. This offers the highest flexibility and capability to combine or reclassify at other levels of detail if required by other applications.

A basic characteristics of features on an image usually effect image interpretation, which consists of several elements – tone, pattern, texture, color, shape, size, height, site and association (Table 2). These elements always use in satellite image interpretation as shown in Figure 14.

Table 2 Elements of Image interpretation (Lillesand et al., 2014)

Interpretation elements	General characteristics
tone or color	Tone is the relative brightness of grey level on black and white image and hue for colored images.
pattern	Pattern refers to the spatial arrangement of the objects.
texture	Texture refers to the frequency of tonal variation in an image. It depends on shape, size, pattern and shadow of terrain features.
shape	Shape refers to the general form, configuration or outline of an individual object.
size	Size of objects on images must be considered in the context of the image scale or resolution.
site	Site refers to topographic or geographic location.
association	Association refers to the occurrence of certain features in relation to other objects in the imagery.
shadow	Shadow refers to in a height estimation of objects and identifying topography and landforms.

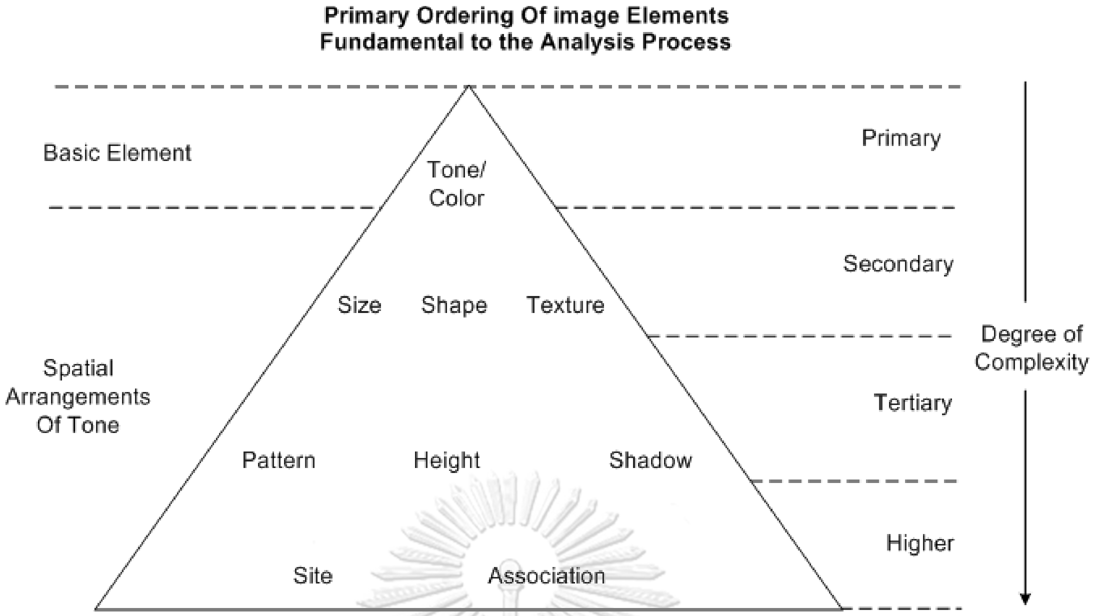

Figure 14 Primary ordering of image elements fundamental to the analysis process. (Lillesand et al., 2014)

Table 3 Land use and land cover classification system (Land Development Department, LDD) used in RS data interpretation in Chanthaburi watershed, Chanthaburi province.

LULC CODE		
LEVEL I	LEVEL II	LEVEL III
A Agricultural land	A1 Paddy field	A100 Abandoned paddy field
		A101 Rice paddy
	A2 Field crop	A200 Abandoned field crop
		A202 Corn
		A204 Cassava
		A205 Pineapple
	A3 Perennial	A301 Mixed perennial
		A302 Para rubber
		A303 Oil palm
		A304 Eucalyptus

LULC CODE		
LEVEL I	LEVEL II	LEVEL III
A Agricultural land	A3 Perennial	A305 Teak
		A308 Acacia
		A315 Bamboo
		A317 Betel palm
		A322 Agalloch
		A323 New Guinea labula
	A4 Orchard	A401 Mixed orchard
		A402 Orange
		A403 Durian
		A404 Rambutan
		A405 Coconut
		A406 Linchi
		A407 Mango
		A408 Cashew
		A411 Banana
		A412 Tamarind
		A413 Longan
		A415 Papaya
		A416 Jack fruit
		A417 Santol
		A419 Mangosteen
		A420 Langsat
		A421 Rakum, Sala
		A426 Dragon fruit
		A430 Burmese grape
	A5 Horticulture	A503 Floricultural
		A505 Pepper
	A7 Pasture and farm house	A703 Poultry farm house

LULC CODE		
LEVEL I	LEVEL II	LEVEL III
A Agricultural land	A7 Pasture and farm house	A704 Swine farm house
	A9 Aquacultural land	A900 Abandoned aquacultural land
		A901 Mixed aquacultural land
		A903 Shrimp farm
F Forest land	F1 Evergreen forest	F101 Dense evergreen forest
	F2 Deciduous forest	F200 Disturbed deciduous forest
		F201 Dense deciduous forest
	F3 Forest Plantation	F301 Dense mangrove forest
M Miscellaneous land	M1 Rangeland	M101 Grass
		M102 Scrub
		M103 Baoboo
	M2 Marsh and Swamp	
	M3 Mine, pit	M300 Abandoned mine, pit
		M302 Laterite pit
		M304 Soil pit
	M4 Other	M405 Landfill
U Urban and Built-up land	U1 City, Town, Commercial	
	U2 Village	U201 Village
	U3 Institutional land	
	U4 Transportation Communication and Utility	U401 Airport
		U405 Road
	U5 Industrial land	U502 Factory

LULC CODE		
LEVEL I	LEVEL II	LEVEL III
U Urban and Built-up land	U5 Industrial land	U503 Agricultural product trading centers
	U6 Others	U601 Recreation area
		U603 Cemetery
W Water body	W1 Natural water body	W101 River, Canal
		W102 Natural water resource
	W2 Reservoir (Built-up)	W201 Reservoir
		W202 Farm pond

The land use and land cover of Chanthaburi watershed was classified by using visual interpretation and digital interpretation which the method of classification was as follow:

3.5.1 Data Sources

In this study, RS data will be used for classification the pattern of LULC and detecting their change. Hence, the satellite images were required as sources for classification which comprises of Landsat 5 TM, Landsat 7 ETM+, and Landsat 8 OLI. Table 4 shows the RS data attributes and accessing periods which were used to achieve this study.

Table 4 The remote sensing data attributes and accessing periods for this study.

Image Types	Date	Scale and Resolution	Source
Landsat 5 TM Path 128 Row 051	2 February 1999 18 February 2005 4 November 2006 18 January 2011	30 m. (Multispectral)	The United States Geological Survey (USGS)
Landsat 7 TM Path 128 Row 051	27 December 1999	30 m. (Multispectral)	
Landsat 8 OLI Path 128 Row 051	26 January 2014	30 m. (Multispectral)	

3.5.2 Data Processing

All satellite images were analyzed by using the ERDAS imagine software version 2014 which can be a tool to achieve the result for LULC classification. For the next steps, these digital data will be analyzed by Arc Map GIS version 10.2.2 which their functions of digital data analysis techniques are consists of 2 steps. Firstly, image classification that is the process of making decision from image data, grouping pixels of image into several classes for physical object representing (Waiyasusri, 2011). And the second, the classification methods comprises unsupervised classification and supervised classification.

Unsupervised Classification

In case the data of LULC are not available in the interested area, the automatic classification method which is called unsupervised classification should be performed. This classification aims to separate the image pixels into natural groupings based on its spectrally similar. In other words, this method creates a raster layer by letting the program identify the pattern in data without an initially knowing of area.

The iterative self-organizing data analysis technique algorithm (ISODATA) Tou and Gonzalez (1974); Floyd and Sabins (1987) cited in ESRI (2016) , which is a widely used techniques, is used to accomplish unsupervised classification. Sisodia et al. (2014) assumed that in this procedure, clusters are combined if either the number of pixel in a cluster is less than a certain threshold or if the centers of two clusters are closer than a certain threshold. Clusters are further divided into two unique clusters if the cluster standard deviation exceeds a predefined value and the number of pixels is twice the threshold for the minimum number of members.

Supervised Classification

This classification method is based on initial knowing of the area. In other words, supervised classification must apply some knowledge about LULC of study area. The process is briefly summarized into 2 stages, first is the training stage, training area is chosen to represent as a set of pixels for the known area. And the second or classification stage, the unknown pixels of image are compared to the spectral patterns with the training area and they are assigned to a class as defined by some algorithm (Song et al., 2011).

There are several algorithms can be employed in supervised classification such as minimum-distance-to-means, parallelepiped, and maximum likelihood (Sisodia et al., 2014). The maximum likelihood classification algorithm is one of the widely used methods of classification in RS (Murayama, 2012). This technique had been accepted to be the most accurate technique in quantitatively evaluate both the variance and correlation of the category spectral reflectance pattern (Waiyasusri, 2011).

This method describes that the statistical probability that any pixel in an image belongs to a class of interested area can be calculated based on the mean vectors and covariance matrices. Each pixel is defined as the class that has the highest probability (Humboldt State University, 2015).

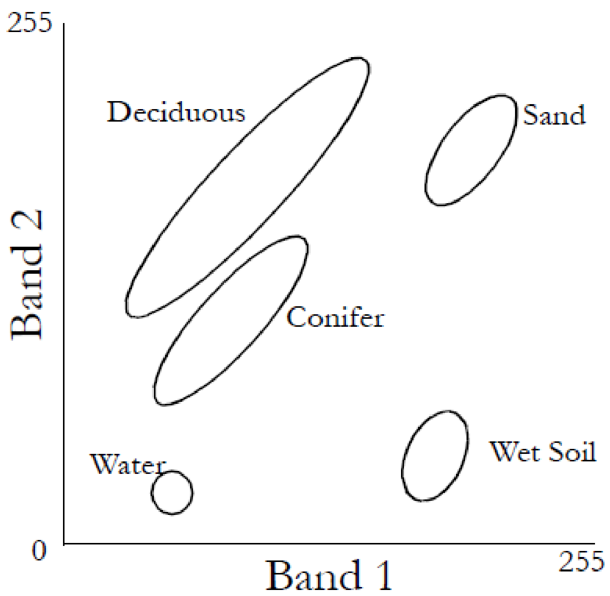

Figure 15 Maximum likelihood classification principle (Eastman, 1999)

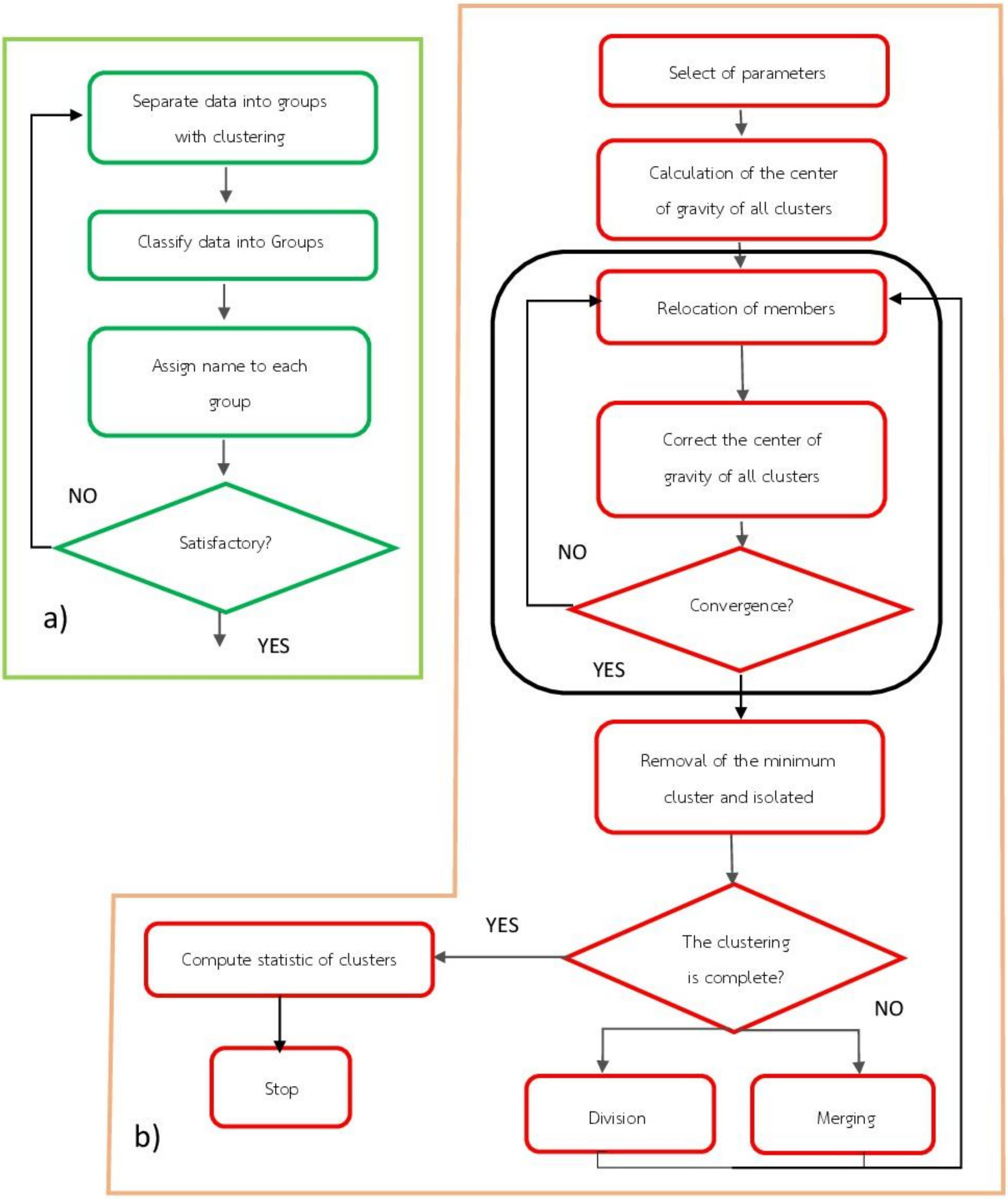

Figure 16 Unsupervised classification

a) Unsupervised classification

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

(Adapted from Lillesand et. al. (2014))

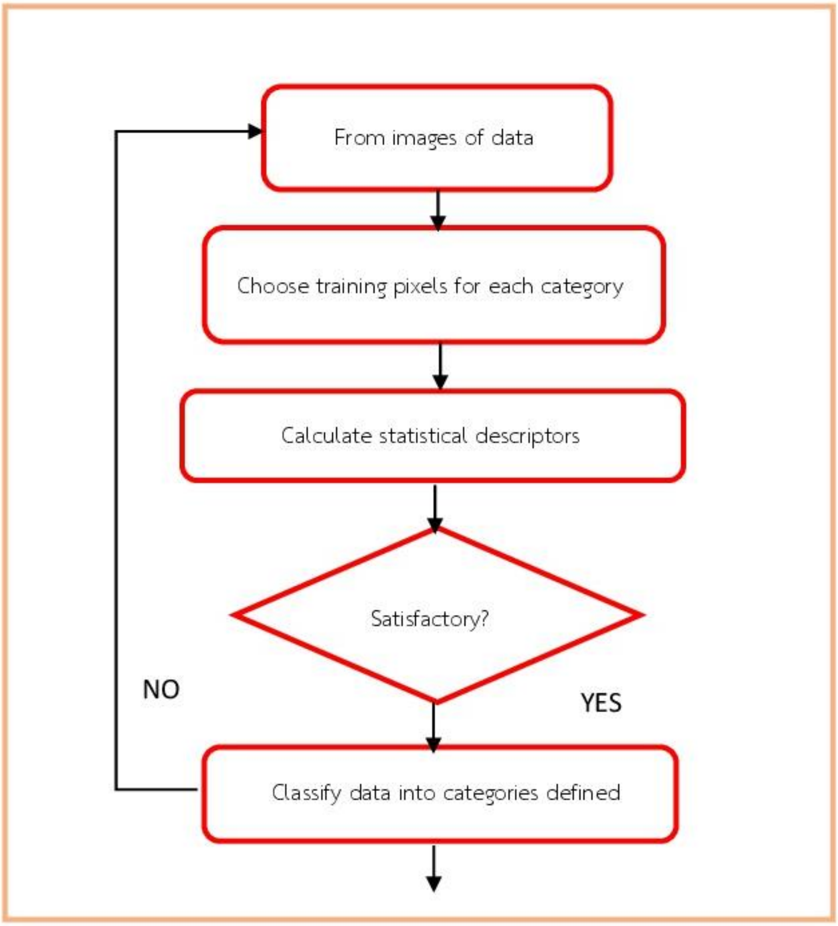

Figure 17 Supervised classification (Lillesand et. al., 2014)

3.5.3 Post-Processing

Post-classification processing is very significant for removing any mismatched locations of classified LULC that appeared in the map as a single pixel. These single pixels are a result of classification error, so the filter algorithm should be applied. The Filtering is the process of dividing the image into its constituent spatial frequencies, and selectively altering certain spatial frequencies to emphasize or deemphasize some image features (ESRI, 2016). Hence, this study applied filtering mode with 5 x 5 windows size to reduce all of noise and filter unwanted information from classification.

3.5.4 Accuracy Assessment

The accuracy assessment of classified data is next a critical step in the process of evaluating the reliability LULC data. It can be divided into two parts consists of overall accuracy which all of output data will be represented and map accuracy which a map user is interested in the reliability of map in how it can be represent the real features on the ground. The most commonly used methods for accuracy assessment is error matrix analysis.

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

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

Where

X_{ij} = a value of 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 is a measure of classifier performance derived from the error matrix but which, purportedly, is free of any bias resulting from chance agreement between the classifier output and the reference data (Richards and Richards, 1999), Kappa coefficient can be defined as

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

.... (Equation 3-2)

Where

r = number of rows in 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

(show as marginal total to right of matrix)

X_{+I} = total of observations in row i

(show as marginal total at the 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 (Lein, 2011)

< 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

CHAPTER IV
ANALYSIS AND RESULTS

In this chapter, all of the result after processing will be described which can be divided into 3 topics comprise LULC pattern before and after flood years, changes of LULC and flood vulnerability map of study area. The first and second topics explain the result of classification LULC change as LULC maps and quantity that showed in the table. The final topic explained the result of analysis a flood vulnerability area and also related with LULC of Chanthaburi watershed. All of the topics will be described in this chapter and will be discussed in Chapter 5.

4.1 Land use and land cover pattern of Chanthaburi watershed

Various types of satellite images consist of Landsat 5 TM, 7 ETM+ and 8 OLI in years 1999, 2006 and 2013 were used for classification processes by band combination process which made difference features stand out and supervised classification process. This section shows the result of LULC classification of Chanthaburi watershed in term of spatial data and quantity data for detecting a change in the next section, it can be seen that there are a few changes in LULC pattern following all of these results.

4.1.1 Land use and land cover map of Chanthaburi watershed before and after 1999 flood.

According to the LULC classification result by Landsat 5TM and 7 ETM+ satellite images through supervised classification processing, there are 9 types of LULC related to LULC level of Land Development Department (LDD) consists of paddy field (A01), field crop (A02), para rubber (A03), orchard (A04), aquacultural land (A05), forest land (F01), mangrove (F02), urban and built-up land (U00) and water bodies (W00). The trends of LULC changes in this study area before 1999 and after 1999 flood are shown in following Table 5 and Figure 18 and LULC distribution as a map can be seen in Figure 21 and 23.

In summary, the result in LULC classification before and after 1999 flood reveal that paddy field, para rubber, aquacultural land, urban and built-up land increased, whereas field crop, orchard, forest, mangrove, and water bodies decreased.

Table 5 Comparative result of land use and land cover in Chanthaburi watershed by Landsat satellite images before and after 1999 flood.

Land use land cover code	Land use land cover pattern	Before Flood 1999		After Flood 1999	
		Sq. km	%	Sq. km	%
A01	Paddy field	91.68	5.75	102.23	6.39
A02	Field crop	249.76	15.66	223.19	13.95
A03	Para rubber	104.35	6.52	128.65	8.04
A04	Orchard	509.82	31.97	505.85	31.61
A05	Aquacultural land	67.38	4.22	73.83	4.61
F01	Forest	480.93	30.16	476.54	29.78
F02	Mangrove	17.99	1.13	14.82	0.93
U00	Urban and Built-up land	32.71	2.05	33.15	2.07
W00	Water bodies	45.58	2.86	41.94	2.62
Total		1600.2	100.00	1600.2	100.00

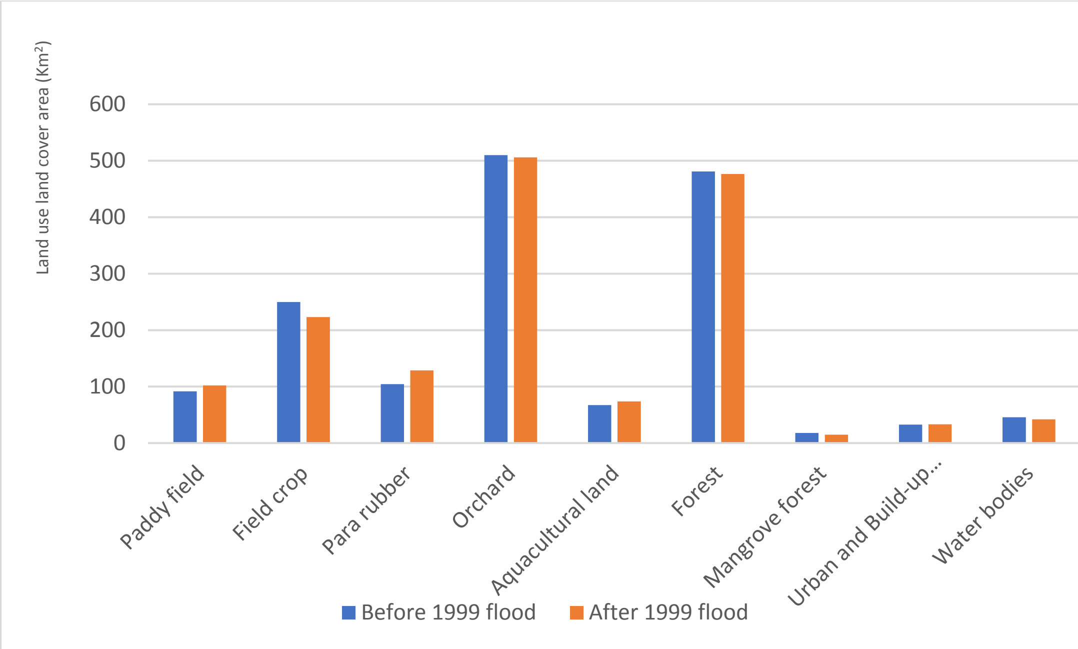

Figure 18 Graph shows land use and land cover area in Chanthaburi watershed before and after 1999 flood.

4.1.2 Land use and land cover map of Chanthaburi watershed before and after 2006 flood.

According to the LULC classification result by Landsat 5TM satellite images through supervised classification processing, there are 9 types of LULC, namely paddy field, field crop, para rubber, orchard, aquacultural land, forest land, mangrove, urban and built-up land and water bodies. The trends of LULC changes in this study area before 2006 and after 2006 flood are shown in following Table 6 and Figure 19 and LULC distribution as a map can be seen in Figure 25 and 27.

In summary, the result in LULC classification before and after 2006 flood reveal that paddy field, aquacultural land, orchard, forest, urban, built-up land and water bodies increased, whereas field crop, para rubber and mangrove decreased.

Table 6 Comparative result of land use and land cover in Chanthaburi watershed by Landsat satellite images before and after 2006 flood.

Land use land cover code	**Land use land cover pattern**	**Before Flood 2006**		**After Flood 2006**	
		Sq. km	%	Sq. km	%
A01	Paddy field	94.08	5.88	129.43	8.09
A02	Field crop	259.42	16.21	191.48	11.97
A03	Para rubber	106.06	6.63	94.28	5.89
A04	Orchard	505.37	31.58	544.11	34.00
A05	Aquacultural land	70.67	4.42	76.41	4.78
F01	Forest	468.13	29.25	468.19	29.26
F02	Mangrove	18.92	1.18	15.12	0.94
U00	Urban and Built-up land	33.74	2.11	35.59	2.22
W00	Water bodied	43.81	2.74	45.59	2.85
Total		1600.2	100.00	1600.2	100.00

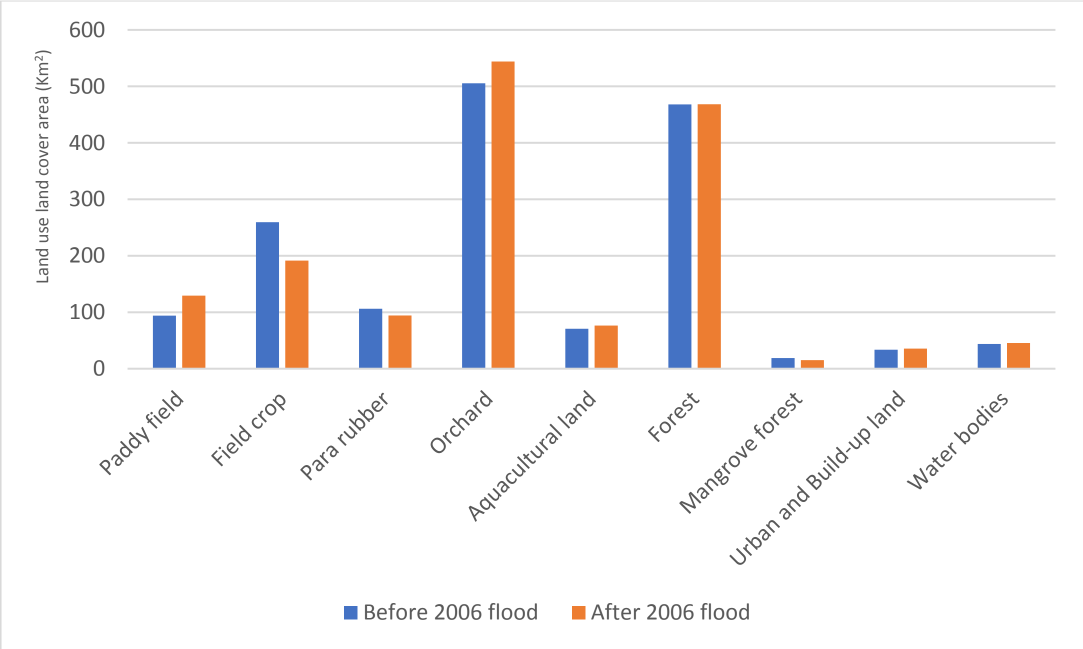

Figure 19 Graph shows land use and land cover area in Chanthaburi watershed before and after 2006 flood.

4.1.3 Land use and land cover map of Chanthaburi watershed before and after 2013 flood.

According to the LULC classification result by Landsat 5TM and 8 OLI satellite images through supervised classification processing, there are 9 types LULC consists of paddy field, field crop, para rubber, orchard, aquacultural land, forest land, mangrov, urban and built-up land and water bodies. The trends of LULC changes in the study area before 2013 and after 2013 flood are shown in following Table 7 and Figure 20 and LULC distribution as a map can be seen in Figure 29 and 31.

In summary, the result in LULC classification before and after 2013 flood reveal that paddy field, field crop, aquacultural land, orchard, forest and urban built-up land increased, whereas Para rubber, mangrove and water bodies decreased.

Table 7 Comparative result of land use and land cover in Chanthaburi watershed by Landsat satellite images before and after 2013 flood.

Land use land cover code	**Land use land cover pattern**	**Before Flood 2013**		**After Flood 2013**	
		Sq. km	%	Sq. km	%
A01	Paddy field	98.46	6.15	102.76	6.42
A02	Field crop	36.83	2.30	54.73	3.42
A03	Para rubber	233.42	14.59	184.19	11.51
A04	Orchard	586.75	36.67	599.89	37.49
A05	Aquacultural land	71.52	4.47	77.53	4.85
F01	Forest	470.64	29.41	471.31	29.45
F02	Mangrove	21.26	1.33	19.70	1.23
U00	Urban and Built-up land	37.39	2.34	46.61	2.91
W00	Water bodies	43.93	2.75	43.48	2.72
Total		1600.2	100.00	1600.2	100.00

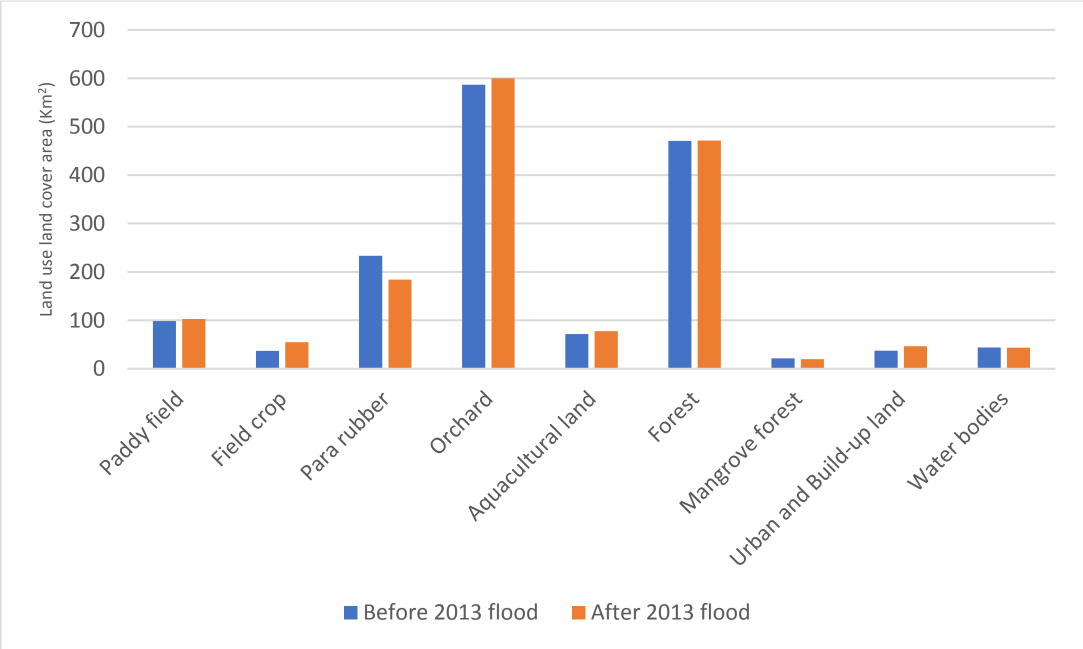

Figure 20 Graph shows land use and land cover area in Chanthaburi watershed before and after 2013 flood.

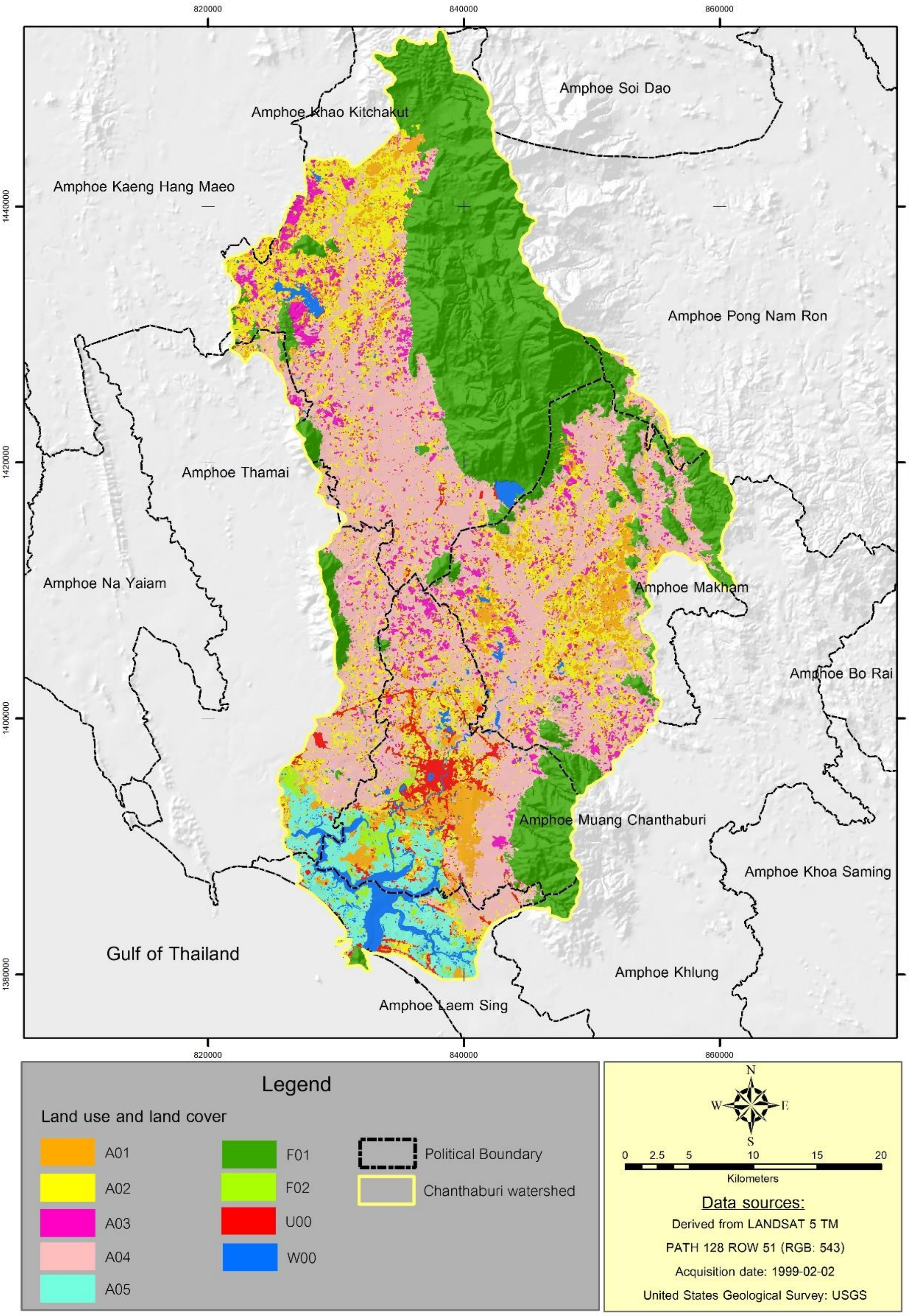

Figure 21 Land use and land cover pattern in Chanthaburi watershed before 1999 flood.

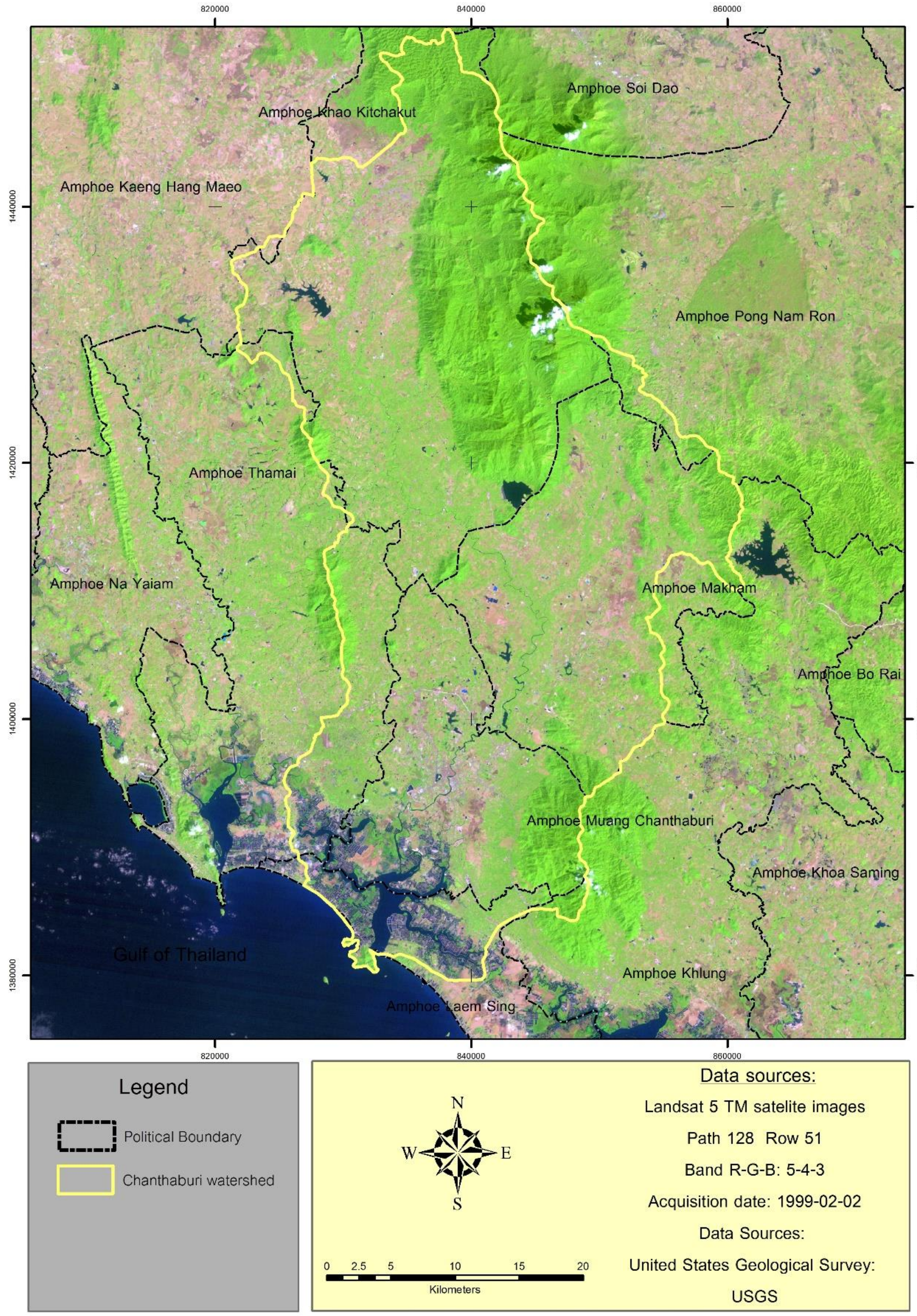

Figure 22 Landsat 5 TM satellite image of Chanthaburi watershed before 1999 flood.

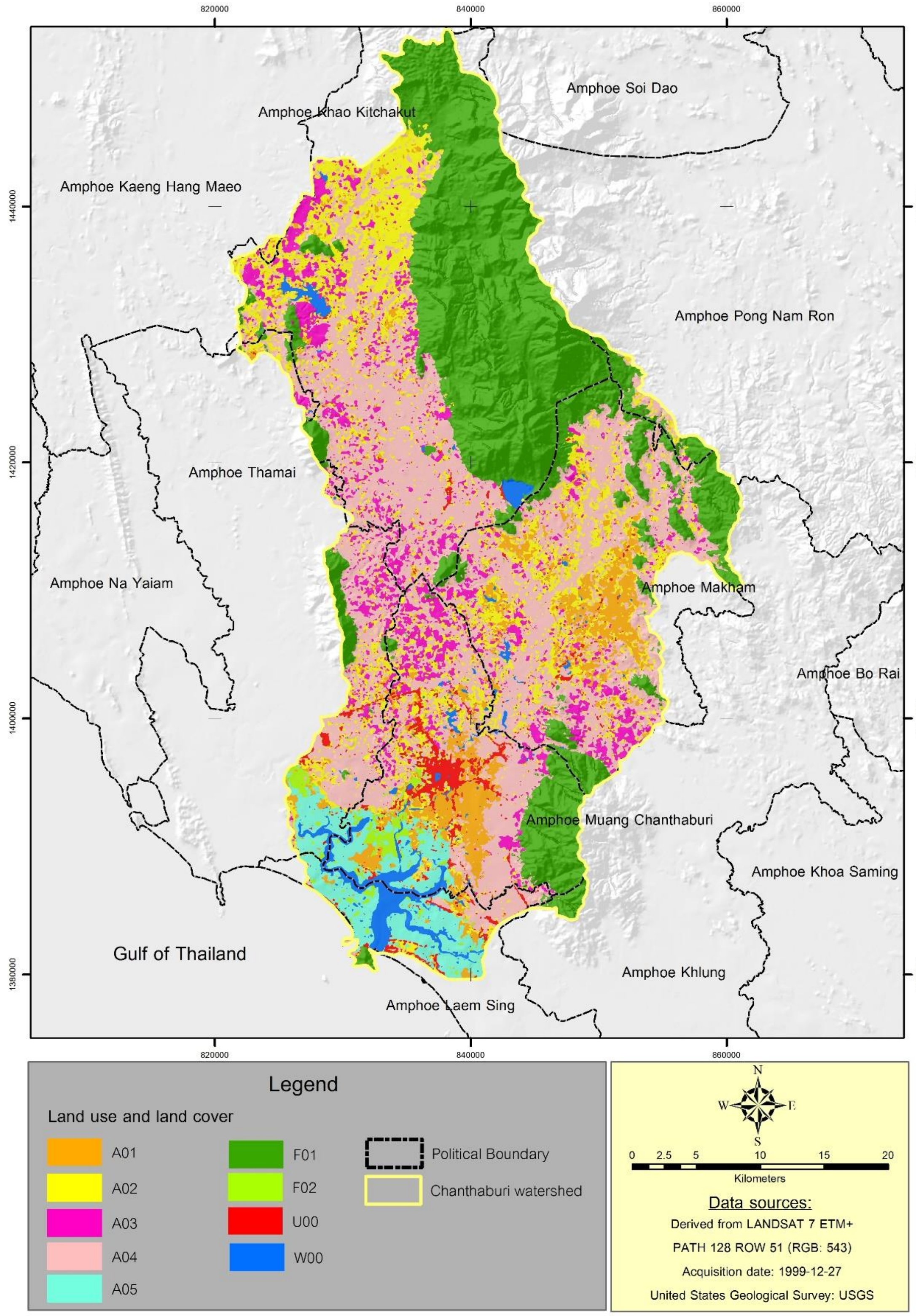

Figure 23 Land use and land cover pattern in Chanthaburi watershed after 1999 flood.

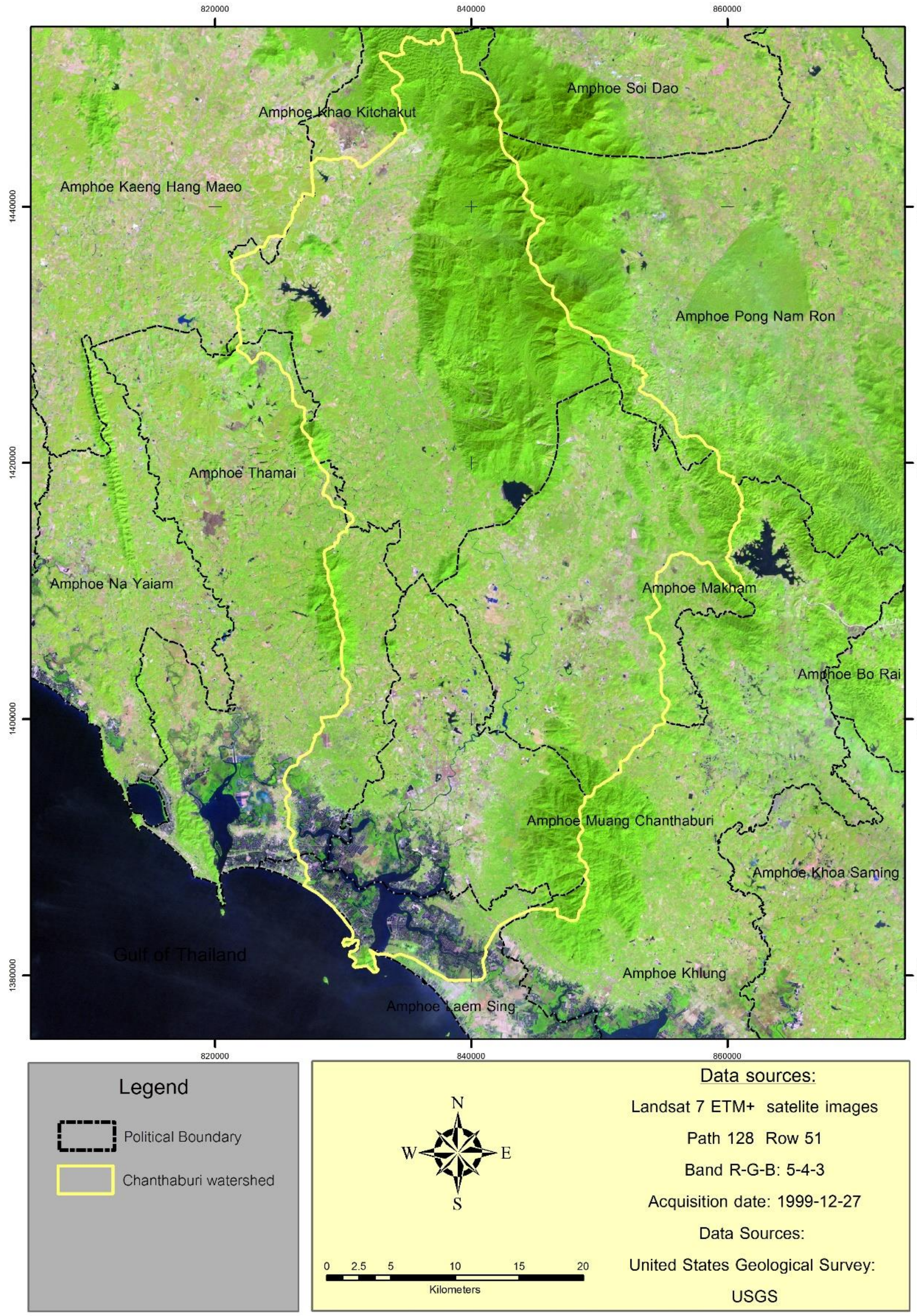

Figure 24 Landsat 7 ETM+ satellite image of Chanthaburi watershed after 1999 flood.

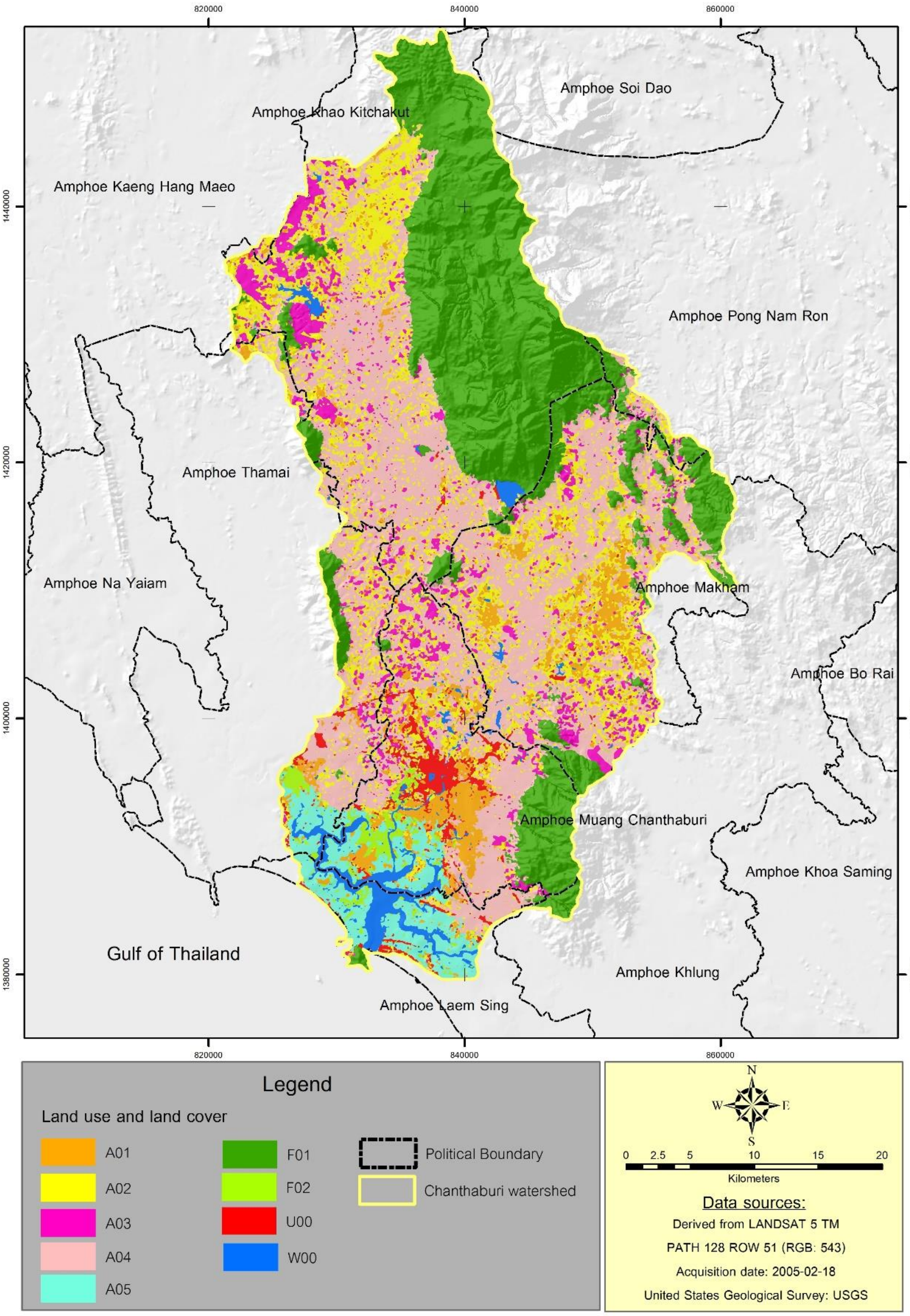

Figure 25 Land use and land cover pattern in Chanthaburi watershed before 2006 flood.

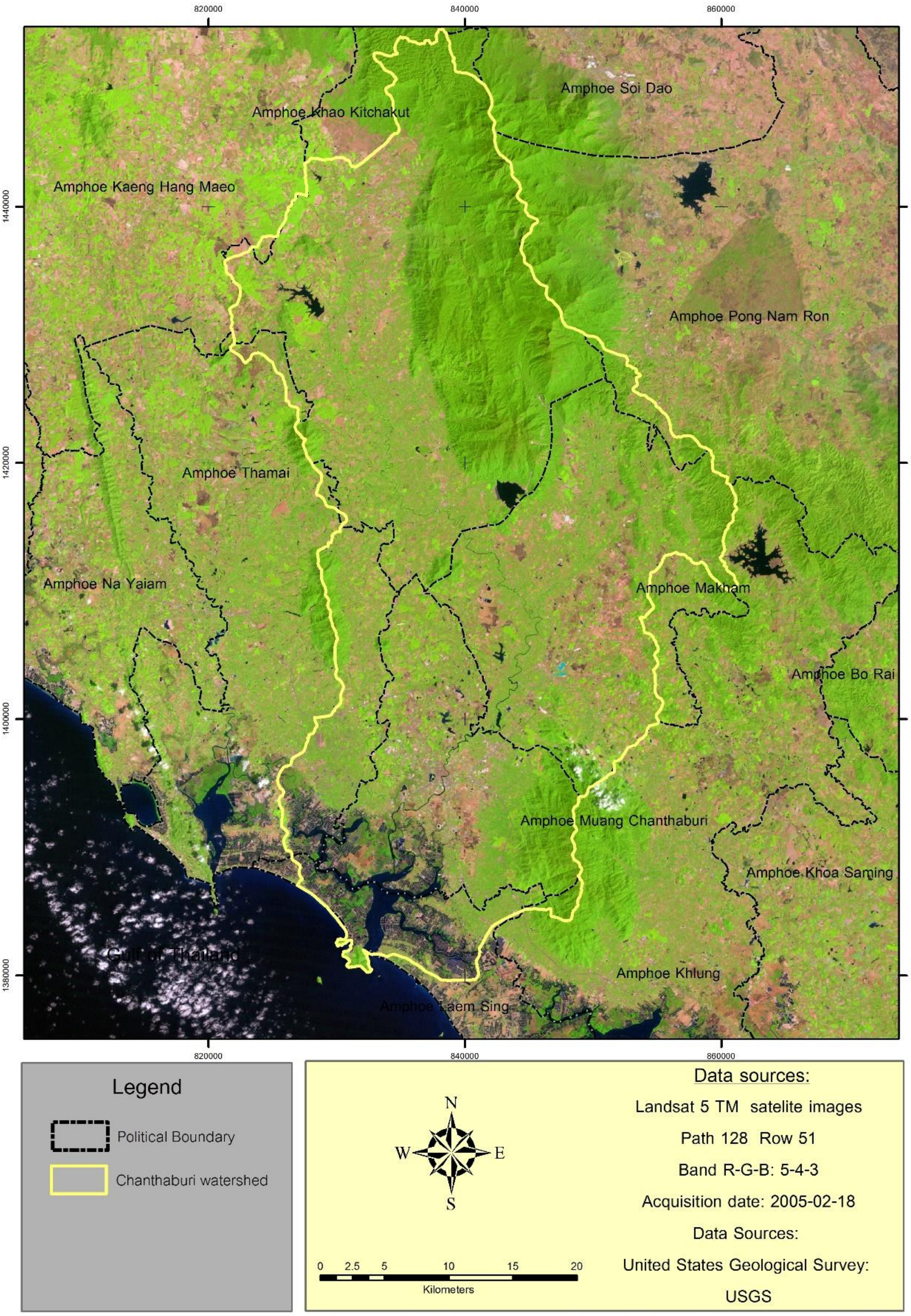

Figure 26 Landsat 5 TM satellite image of Chanthaburi watershed before 2006 flood.

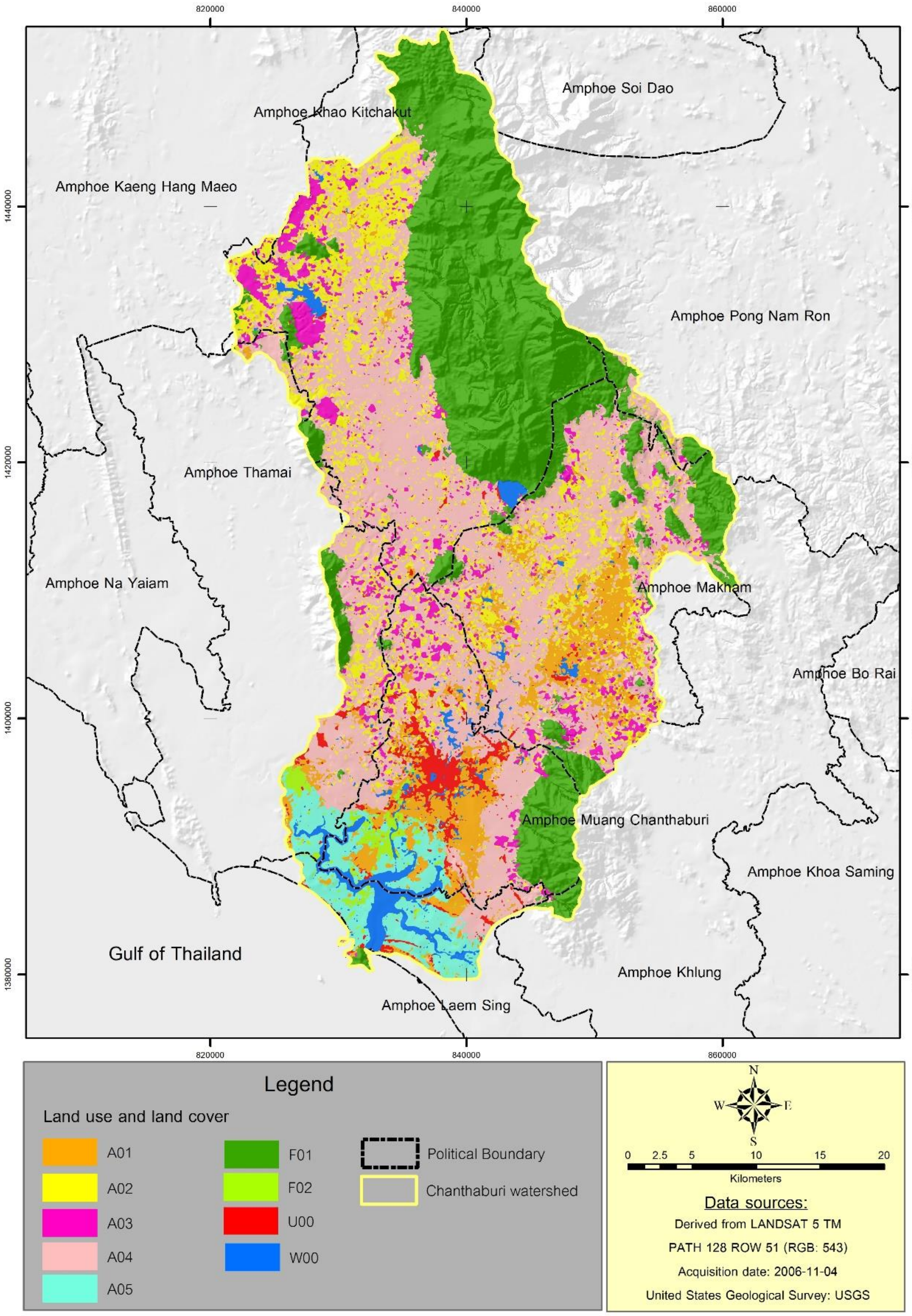

Figure 27 Land use and land cover pattern in Chanthaburi watershed after 2006 flood.

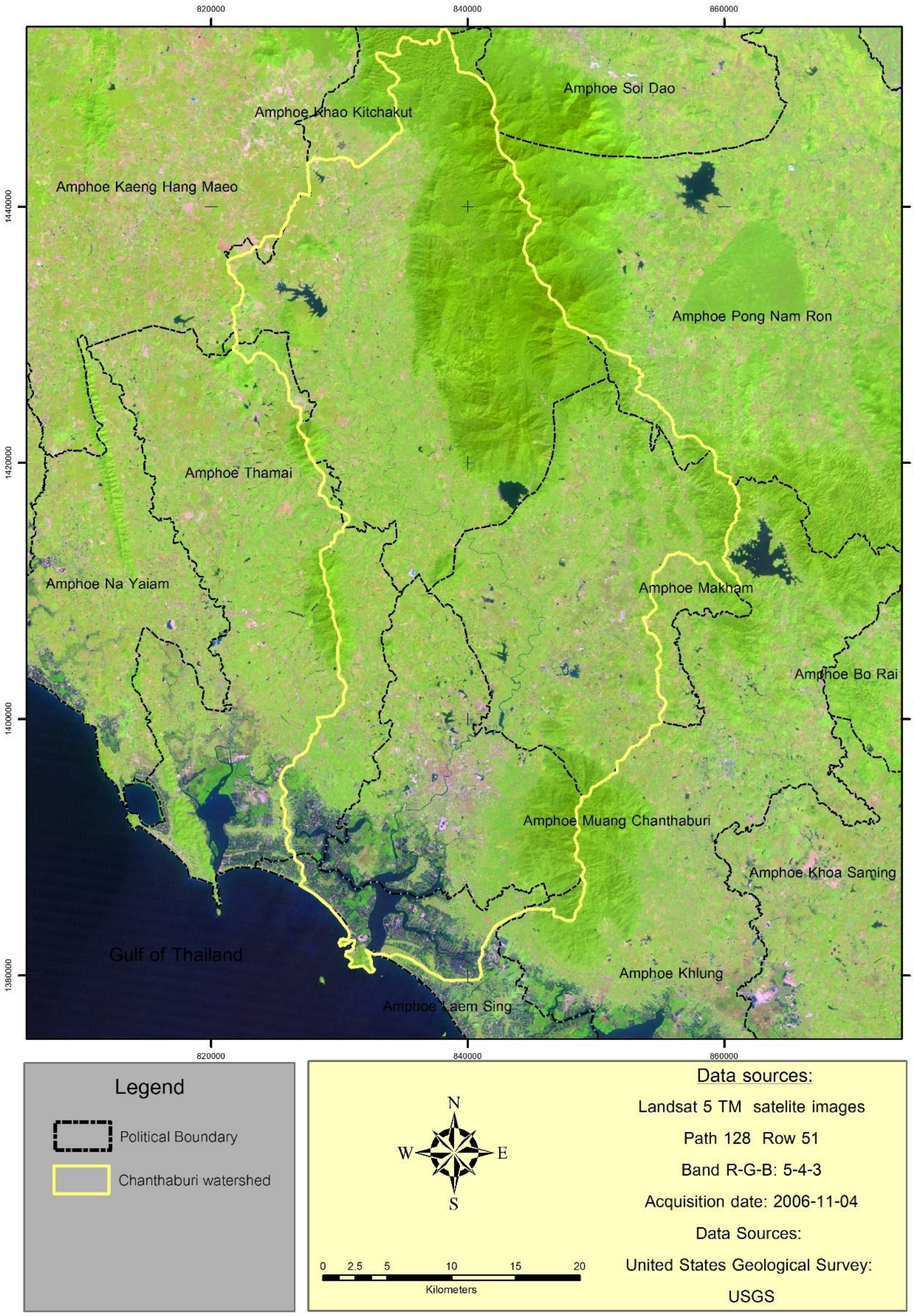

Figure 28 Landsat 5 TM satellite image of Chanthaburi watershed after 2006 flood.

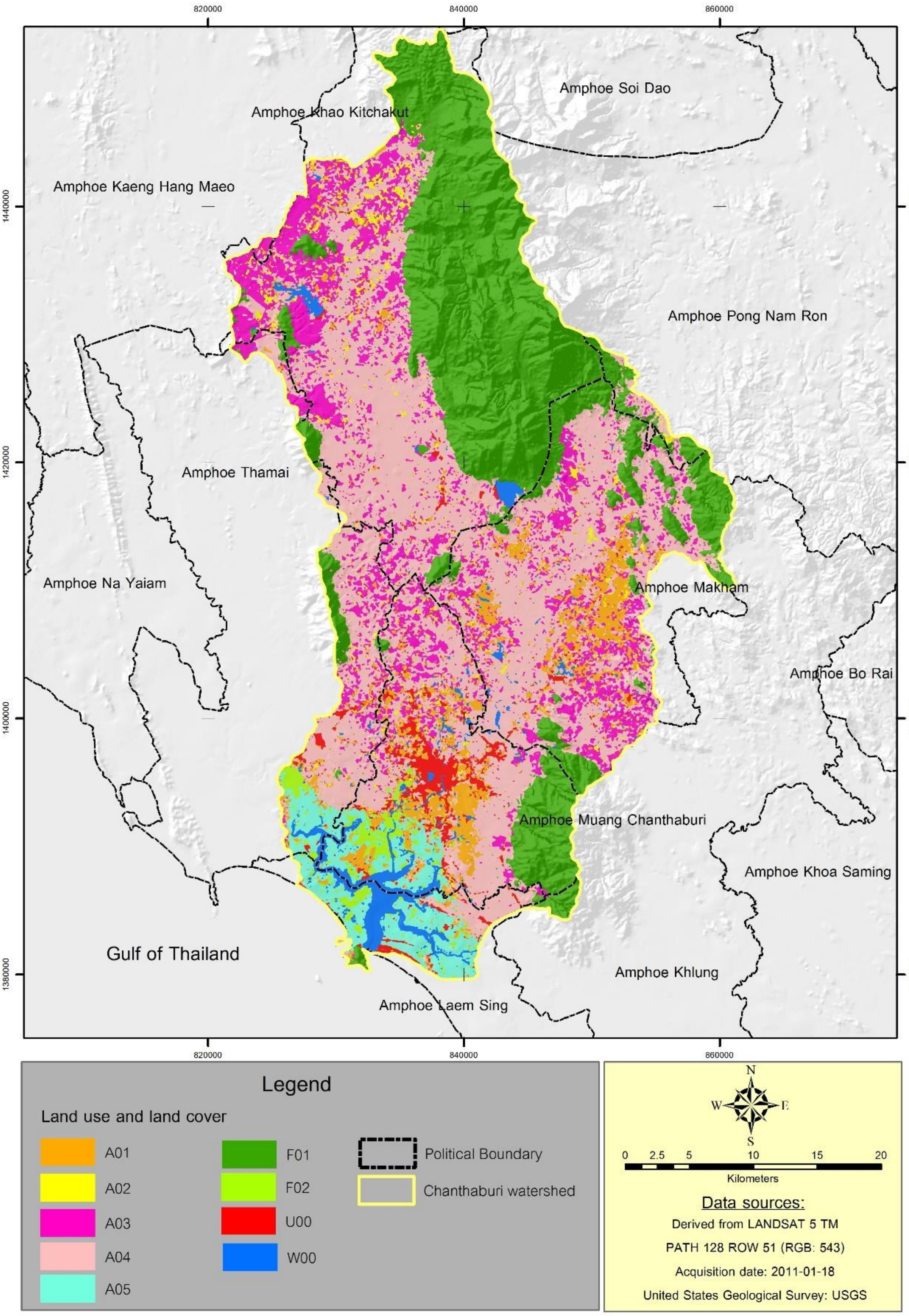

Figure 29 Land use and land cover pattern in Chanthaburi watershed before 2013 flood.

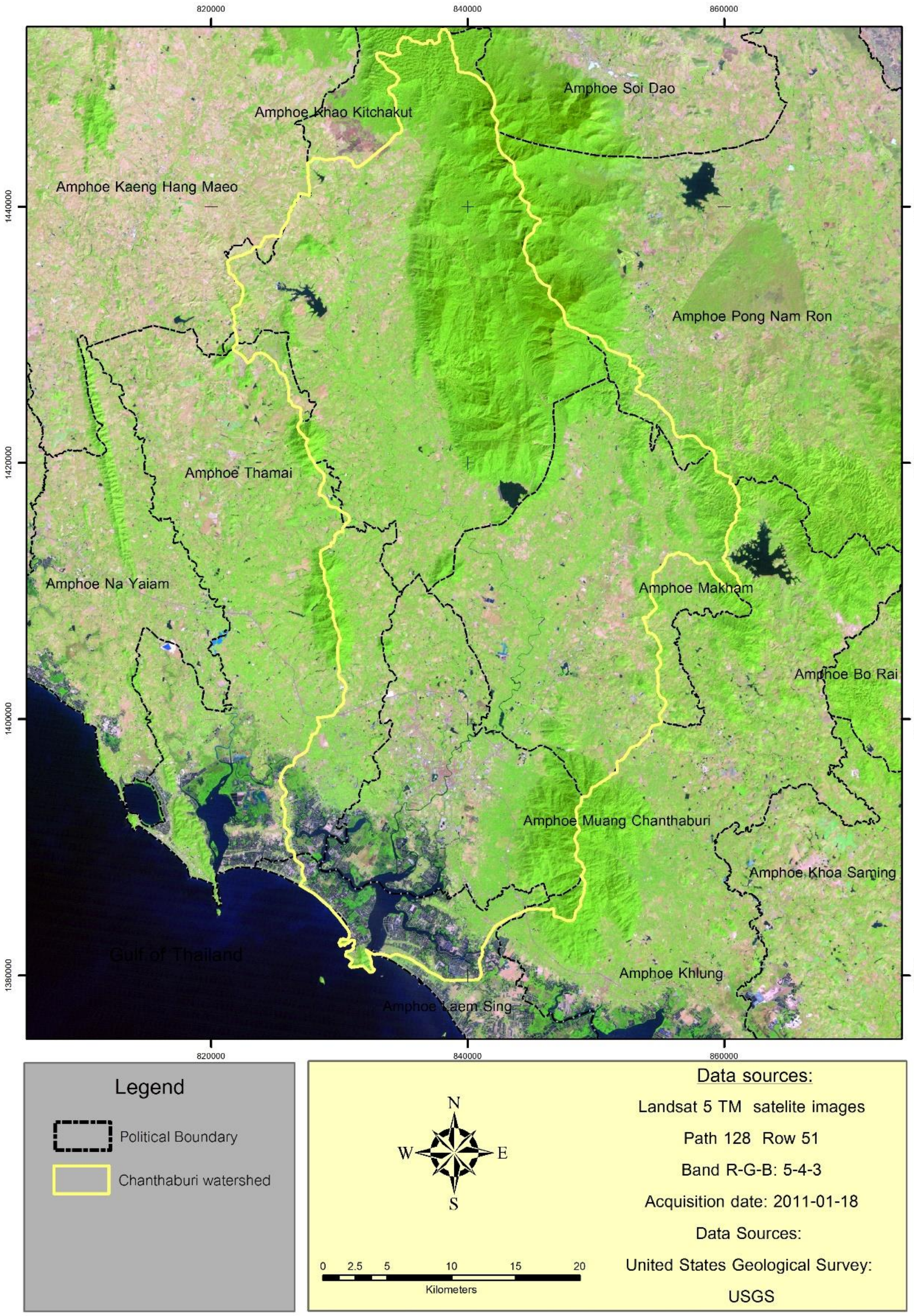

Figure 30 Landsat 5 TM satellite image of Chanthaburi watershed before 2013 flood.

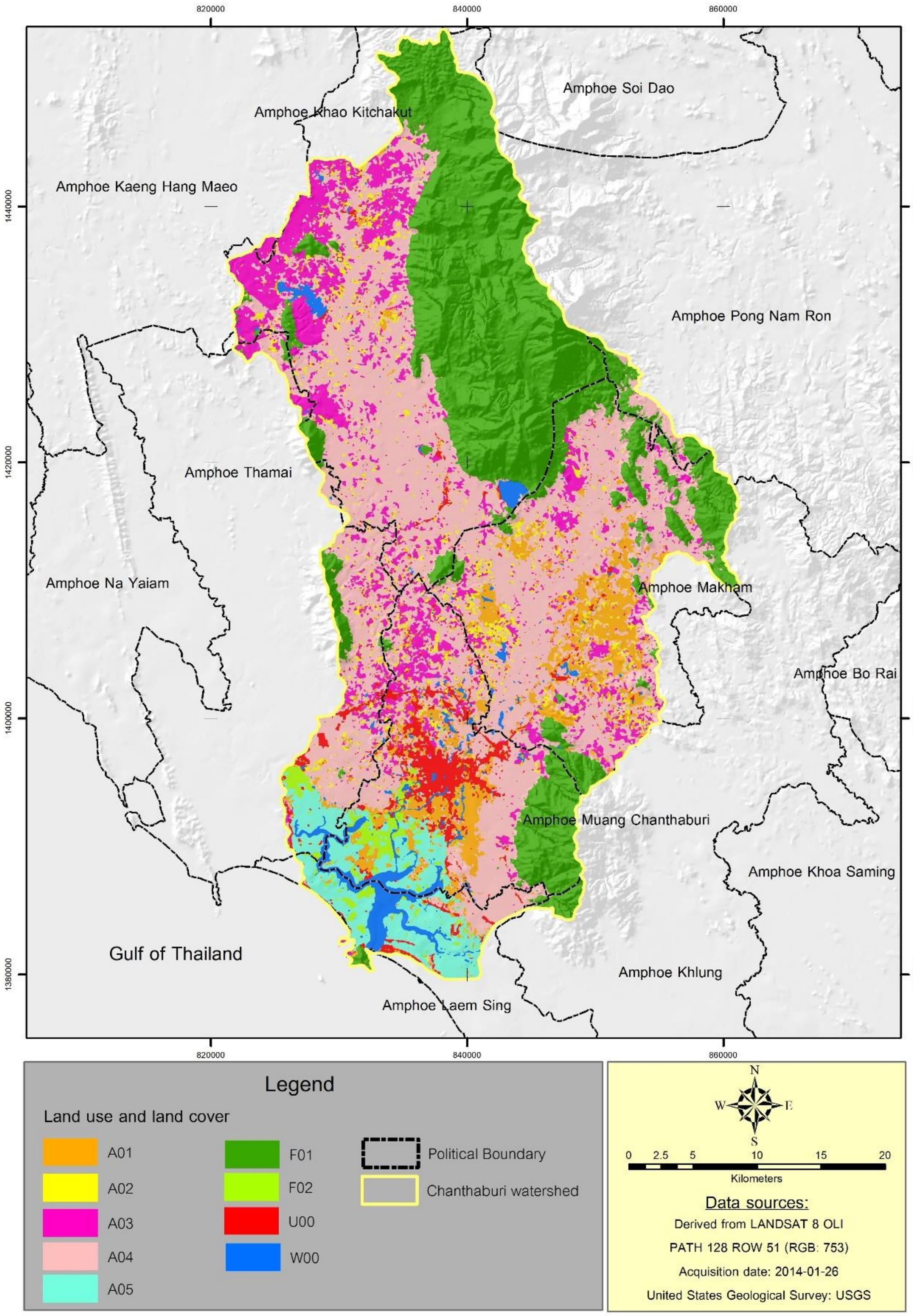

Figure 31 Land use and land cover pattern in Chanthaburi watershed after 2013 flood.

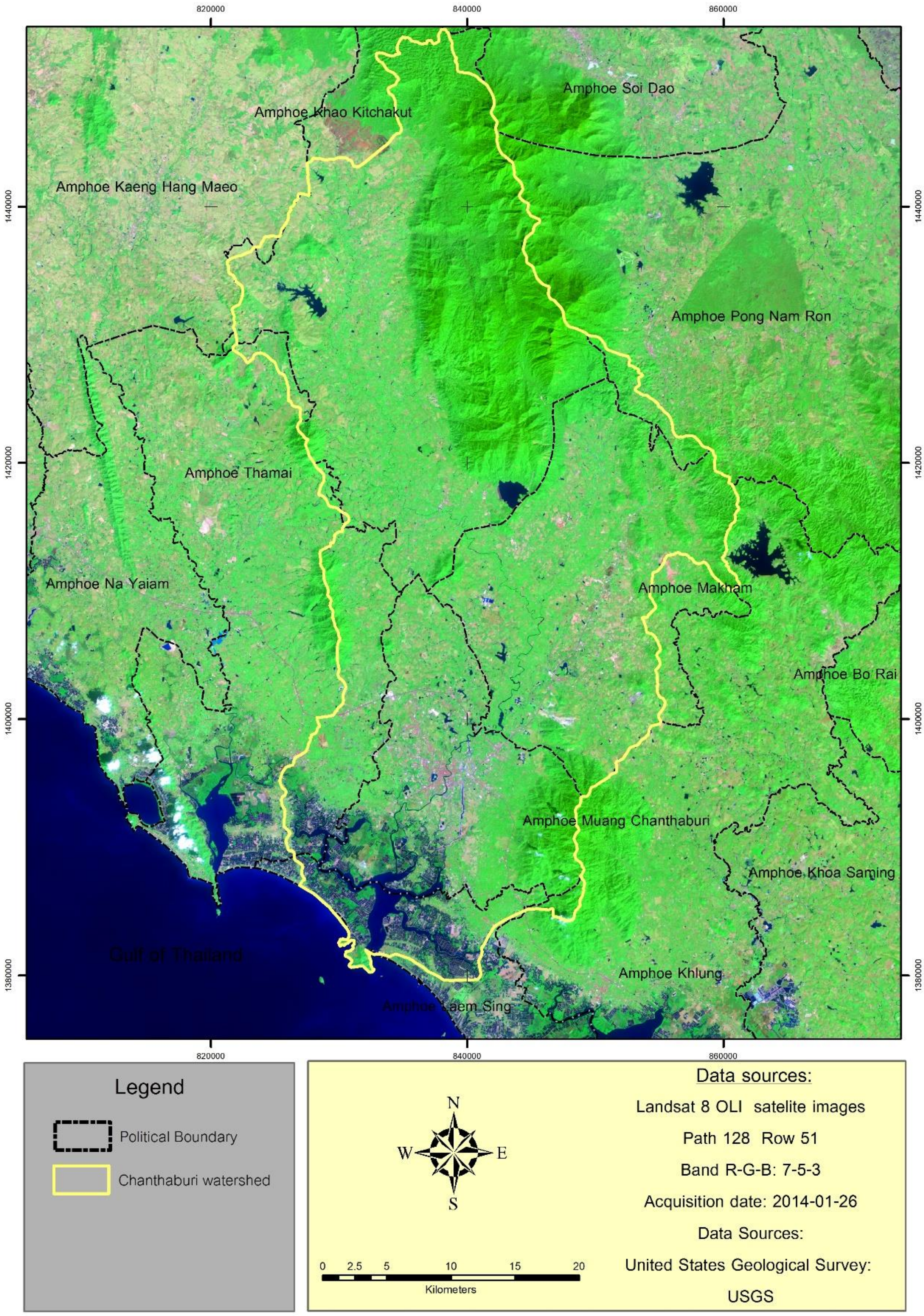

Figure 32 Landsat 8 OLI satellite image of Chanthaburi watershed after 2013 flood.

4.1.4 Accuracy assessment for land use and land cover classification

Accuracy assessment for LULC classification before 1999 flood

Accuracy assessment for LULC classification is operated for LULC which is derived from Landsat 5 TM satellite images before 1999 flood. This procedure was done by using 150 sample area which used as a training area from Landsat satellite image, LULC data from Land Development Department and QuickBird satellite imageries from google earth software and field investigation for considering a sample area as a polygon. The result of overall accuracy assessment is 89.2% or 0.89 and Kappa coefficient is 0.88. as shown in Table 8

Table 8 revealed that mangrove area has the highest producer's accuracy (PA value), which is 99.12 %, following by water bodies area, forest area, orchard area, urban and built-up area, para rubber area and aquaculture area and paddy field area. The field crop area has the least PA, which is 45.43%. As a result, the value indicate that mangrove has the highest probability of a reference site being correctly classified.

In user's accuracy calculation (CA value), forest area has the highest CA value, which is 98.05%, following by aquaculture area, water bodies area, orchard area, paddy field area, urban and built-up area, para rubber area and field crop area. The mangrove area has the least CA, which is 49.43%

Accuracy assessment for LULC classification after 1999 flood

Accuracy assessment for LULC classification is operated for LULC which is derived from Landsat 7 ETM+ satellite images after 1999 flood. This procedure was done by using 150 sample points from satellite image and field investigation. The result of overall accuracy assessment is 86.8% or 0.87 and Kappa coefficient is 0.85, as shown in Table 9.

Accuracy assessment for LULC classification before 2006 flood

Accuracy assessment for LULC classification is operated for LULC which is derived from Landsat 5 TM satellite images before 2006 flood. This process was done by using 150 sample points from satellite image and field investigation. The result of overall accuracy assessment is 85.1% or 0.85 and Kappa coefficient is 0.83, as shown in Table 10.

Accuracy assessment for LULC classification after 2006 flood

Accuracy assessment for LULC classification is operated for LULC which is derived from Landsat 5 TM satellite images after 2006 flood. This process was done by using 150 sample points from satellite image and field investigation. The result of overall accuracy assessment is 87.4% or 0.87 and Kappa coefficient is 0.86, as shown in Table 11.

Accuracy assessment for LULC classification before 2013 flood

Accuracy assessment for LULC classification is operated for LULC which is derived from Landsat 5 TM satellite images before 2013 flood. This process was done by using 150 sample points from satellite image and field investigation. The result of overall accuracy assessment is 87.0% or 0.87 and Kappa coefficient is 0.85, as shown in Table 12.

Accuracy assessment for LULC classification after 2013 flood

Accuracy assessment for LULC classification is operated for LULC which is derived from Landsat 8 OLI satellite images after 2013 flood. This process was done by using 150 sample points from satellite image and field investigation. The result of overall accuracy assessment is 89.2% or 0.89 and Kappa coefficient is 0.88, as shown in Table 13.

Table 8 Accuracy assessment of land use and land cover classification before 1999 flood.

Classified map	Reference Map									Row Total	CA (%)
	W00	U00	F02	F01	A03	A05	A01	A02	A04		
W00	10484	0	0	0	0	916	0	7	0	11407	91.91
U00	14	2076	0	4	10	243	157	443	64	3011	68.95
F02	22	0	1463	536	0	27	0	14	898	2960	49.43
F01	0	0	1	82191	0	0	0	1	1635	83828	98.05
A03	0	8	0	11	6320	0	575	2658	786	10358	61.02
A05	261	14	4	0	1	8793	20	43	12	9148	96.12
A01	9	44	0	0	273	27	8605	2432	41	11431	75.28
A02	9	178	2	25	368	49	1469	5517	2157	9774	56.45
A04	5	7	6	3228	118	0	51	1029	48889	53333	91.67
Column Total	10804	2327	1476	85995	7090	10055	10877	12144	54482	195250	
PA (%)	97.04	89.21	99.12	95.58	89.14	87.45	79.11	45.43	89.73		
Overall accuracy = 89.3% or 0.89						Kappa Index = 0.88					

Table 9 Accuracy assessment of land use and land cover classification after 1999 flood.

Classified map	Reference Map									Row Total	CA (%)
	W00	U00	F02	F01	A03	A05	A01	A02	A04		
W00	10427	0	0	0	0	1162	0	17	0	11606	89.84
U00	3	2049	2	16	4	424	159	448	226	3331	61.51
F02	24	0	1670	625	4	39	17	27	1169	3575	46.71
F01	0	0	0	80297	21	0	0	23	2851	83192	96.52
A03	0	1	0	206	9731	0	186	1344	2697	14165	68.70
A05	291	35	10	2	2	8306	144	50	9	8849	93.86
A01	2	88	4	43	202	78	8453	3097	185	12152	69.56
A02	7	123	1	373	387	46	1323	6375	2047	10682	59.68
A04	6	21	9	3274	508	0	120	1505	42067	47510	88.54
Column Total	10760	2317	1696	84836	10859	10055	10402	12886	51251	195062	
PA (%)	96.91	88.43	98.47	94.65	89.61	82.61	81.26	49.47	82.08		
Overall accuracy = 86.8% or 0.87							Kappa Index = 0.85				

Table 10 Accuracy assessment of land use and land cover classification before 2006 flood.

Classified map	Reference Map									Row Total	CA (%)
	W00	U00	F02	F01	A03	A05	A01	A02	A04		
W00	10105	0	4	0	0	1564	17	15	1	11706	86.32
U00	39	1974	3	1	3	254	383	187	125	2969	66.49
F02	58	1	1857	414	8	162	26	58	947	3531	52.59
F01	2	0	0	76095	429	0	0	15	3242	79783	95.38
A03	1	2	0	1436	9545	0	15	637	1709	13345	71.52
A05	348	17	12	0	1	7616	438	95	25	8552	89.06
A01	23	107	9	1	211	255	8055	2483	79	11223	71.77
A02	28	198	3	180	438	178	1257	6790	2869	11941	56.86
A04	7	18	9	3207	489	1	140	3205	39420	46496	84.78
Column Total	10611	2317	1897	81334	11124	10030	10331	13485	48417	189546	
PA (%)	95.23	85.20	97.89	93.56	85.81	75.93	77.97	50.35	81.42		
Overall accuracy = 85.1% or 0.85						Kappa Index = 0.83					

Table 11 Accuracy assessment of land use and land cover classification after 2006 flood.

Classified map	Reference Map									Row Total	CA (%)
	W00	U00	F02	A03	F01	A05	A01	A02	A04		
W00	10585	0	0	0	0	1554	0	4	0	12143	87.17
U00	10	2133	0	3	35	273	119	177	204	2954	72.21
F02	24	0	1773	2	97	138	47	13	751	2845	62.32
A03	0	0	0	11941	865	0	5	964	1909	15684	76.13
F01	0	0	0	125	80025	0	0	9	956	81115	98.66
A05	391	18	12	4	0	7562	293	62	48	8390	90.13
A01	18	106	21	99	35	299	6956	1987	1445	10966	63.43
A02	0	39	0	513	198	10	908	6713	2680	11061	60.69
A04	1	10	34	566	2591	2	457	2405	36147	42213	85.63
Column Total	11029	2306	1840	13253	83846	9838	8785	12334	44140	187371	
PA (%)	95.97	92.50	96.36	90.10	95.44	76.87	79.18	54.43	81.89		
Overall accuracy = 87.4% or 0.87							Kappa Index = 0.86				

Table 12 Accuracy assessment of land use and land cover classification before 2013 flood.

Classified map	Reference Map									Row Total	CA (%)
	W00	U00	F02	F01	A03	A05	A01	A02	A04		
W00	9845	0	0	0	0	1379	3	0	2	11229	87.67
U00	2	1954	1	2	10	429	331	17	195	2941	66.44
F02	43	1	2605	724	13	495	18	1	943	4843	53.79
F01	0	0	0	80574	5	0	0	0	2410	82989	97.09
A03	3	10	1	51	11343	1	1166	747	3466	16788	67.57
A05	471	42	30	3	6	7494	253	8	81	8388	89.34
A01	39	108	8	2	662	166	5687	479	462	7613	74.70
A02	6	45	0	62	1101	14	887	1286	809	4210	30.55
A04	3	24	10	4029	1249	7	271	123	40082	45798	87.52
Column Total	10412	2184	2655	85447	14389	9985	8616	2661	48450	184799	
PA (%)	94.55	89.47	98.12	94.30	78.83	75.05	66.01	48.33	82.73		
Overall accuracy = 87.0% or 0.87						Kappa Index = 0.85					

Table 13 Accuracy assessment of land use and land cover classification after 2013 flood.

Classified map	Reference Map									Row Total	CA (%)
	W00	U00	F02	F01	A03	A05	A01	A04	A02		
W00	10205	0	1	0	0	932	3	3	0	11144	91.57
U00	6	2371	2	14	85	153	200	433	8	3272	72.46
F02	44	2	2507	265	7	250	25	400	2	3502	71.59
F01	0	0	0	78338	14	0	0	2388	0	80740	97.03
A03	0	39	0	78	10269	1	216	1653	344	12600	81.50
A05	331	12	27	0	8	7069	102	160	1	7710	91.69
A01	11	108	7	10	494	253	5802	685	76	7446	77.92
A04	10	25	5	2352	1640	4	261	40697	195	45189	90.06
A02	1	7	0	10	3034	0	560	2233	689	6534	53.57
Column Total	10608	2564	2549	81067	15551	8662	7169	48652	4126	178137	
PA (%)	96.20	92.47	98.35	96.63	66.03	81.61	80.93	83.65	84.83		
Overall accuracy = 88.6% or 0.89							Kappa Index = 0.87				

4.2 Change detection of land use and land cover in Chanthaburi watershed.

LULC maps were derived from 6 scenes of Landsat imageries by classification. In this topic, the images are classified into 4 categories (Figure 34 to 39) which based on LULC type in level 1 and more accuracy for change detection. The result of change detection of LULC before and after 1999, 2006 and 2013 flood are as follow:

The result revealed that change detection of LULC before and after 1999 flood, it can be seen that agricultural land and urban and built-up land are increasing, whereas forest land and water bodies tend to decrease as shown in Table 14 and Figure 34 and 35.

Table 14 Comparative result of land use and land cover level 1 in Chanthaburi watershed by Landsat satellite images before and after flood events in 1999 flood

Land use land cover code	**Land use land cover pattern**	**Before Flood 1999**		**After Flood 1999**	
		Sq. km	%	Sq. km	%
A	Agricultural land	1022.98	63.93	1033.75	64.60
F	Forest land	498.94	31.18	491.36	30.71
U	Urban and built-up land	32.7	2.04	33.15	2.07
W	Water bodies	45.58	2.85	41.94	2.62
	Total	1600.2	100.00	1600.2	100.00

The result revealed that change detection of LULC before and after 2006 flood, it can be seen that agricultural land and urban and built-up land are increasing, whereas forest land and water bodies tend to decrease as shown in Table 15 and Figure 36 and 37.

Table 15 Comparative result of land use and land cover level 1 in Chanthaburi watershed by Landsat satellite images before and after 2006 flood

Land use land cover code	Land use land cover pattern	Before Flood 2006		After Flood 2006	
		Sq. km	%	Sq. km	%
A	Agricultural land	1035.6	64.72	1035.71	64.72
F	Forest land	487.05	30.44	483.31	30.20
U	Urban and built-up land	33.74	2.11	35.59	2.22
W	Water bodies	43.81	2.74	45.59	2.85
Total		1600.2	100.00	1600.2	100.00

The result revealed that change detection of LULC before and after 2013 flood, it can be seen that only urban and built-up land is increasing, whereas agricultural land, forest land and water bodies tend to decrease as shown in Table 16 and Figure 38 and 39.

Table 16 Comparative result of land use and land cover level 1 in Chanthaburi watershed by Landsat satellite images before and after 2013 flood.

Land use land cover code	Land use land cover pattern	Before Flood 2013		After Flood 2013	
		Sq. km	%	Sq. km	%
A	Agricultural land	1026.98	64.18	1019.1	63.69
F	Forest land	491.9	30.74	491.01	30.68
U	Urban and built-up land	37.39	2.34	46.61	2.91
W	Water bodies	43.93	2.75	43.48	2.72
Total		1600.2	100.00	1600.2	100.00

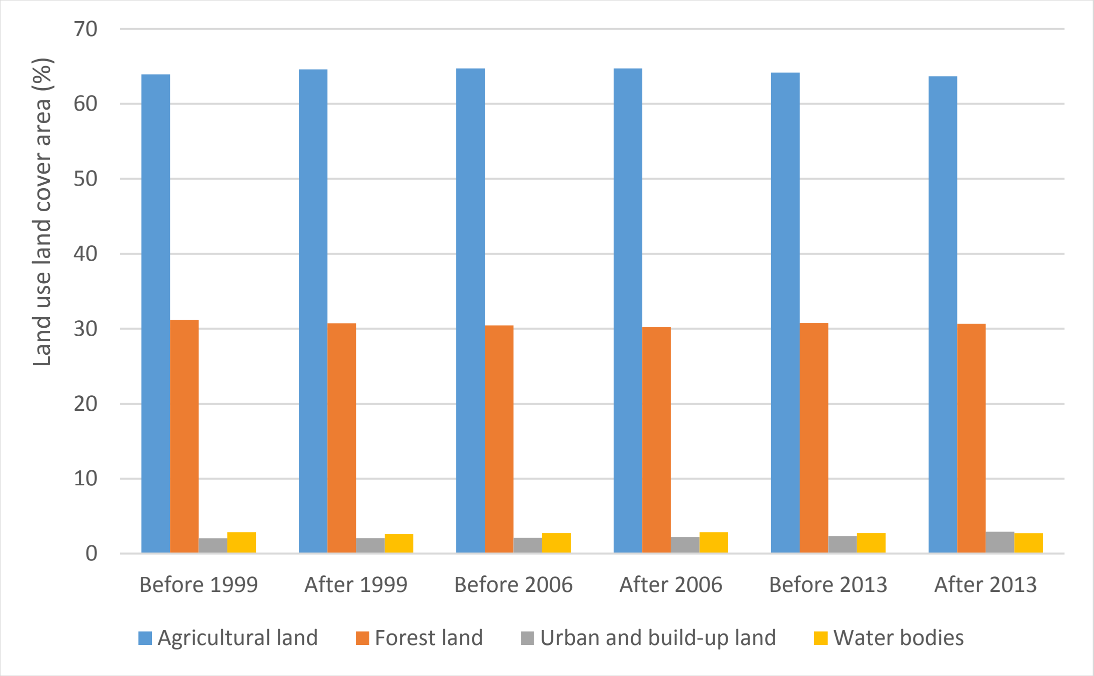

Figure 33 Graph shows trend of land use and land cover change in Chanthaburi watershed before and after 1999, 2006 and 2013 flood.

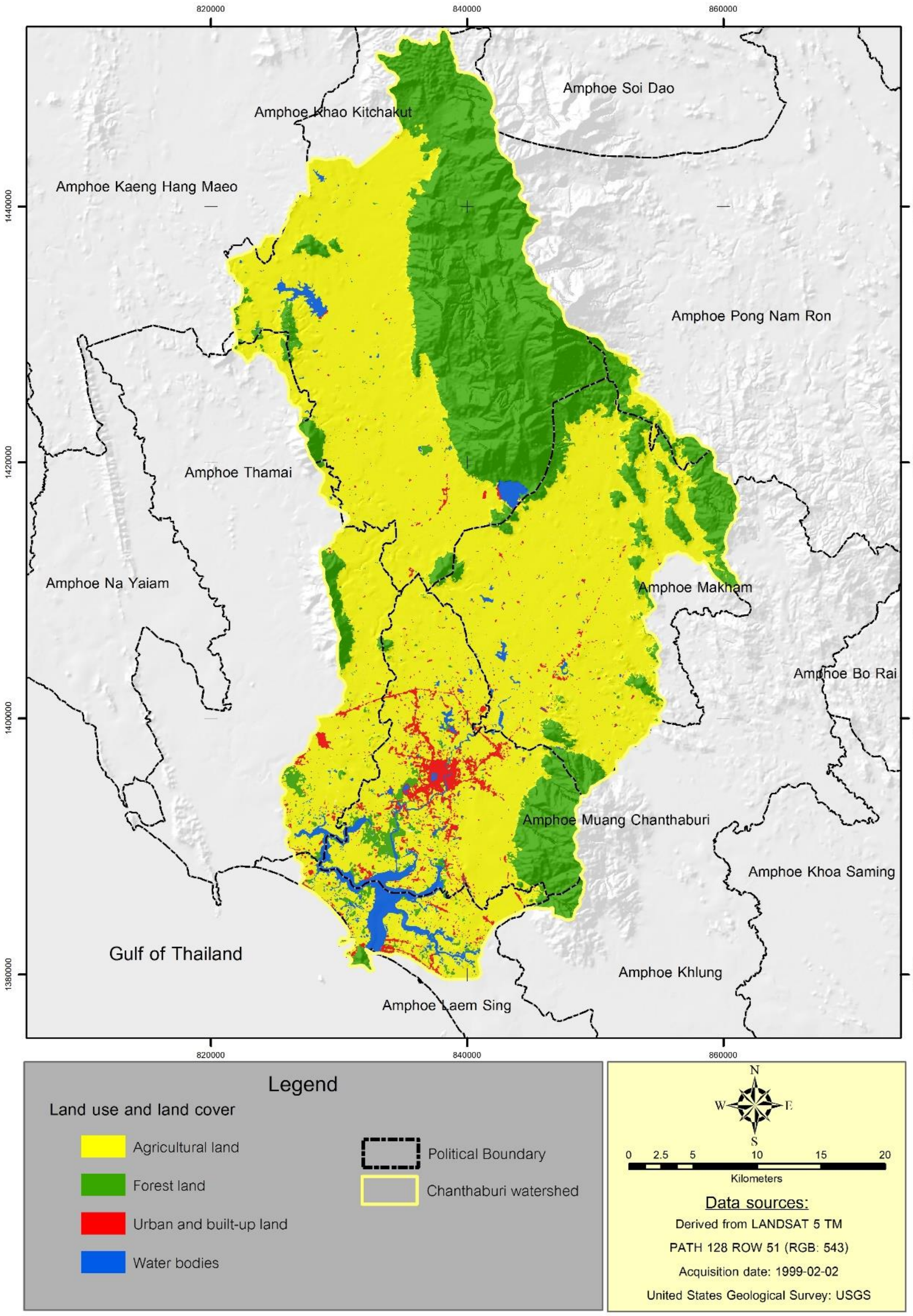

Figure 34 Reclassified land use and land cover level 1 of Chanthaburi watershed before 1999 flood.

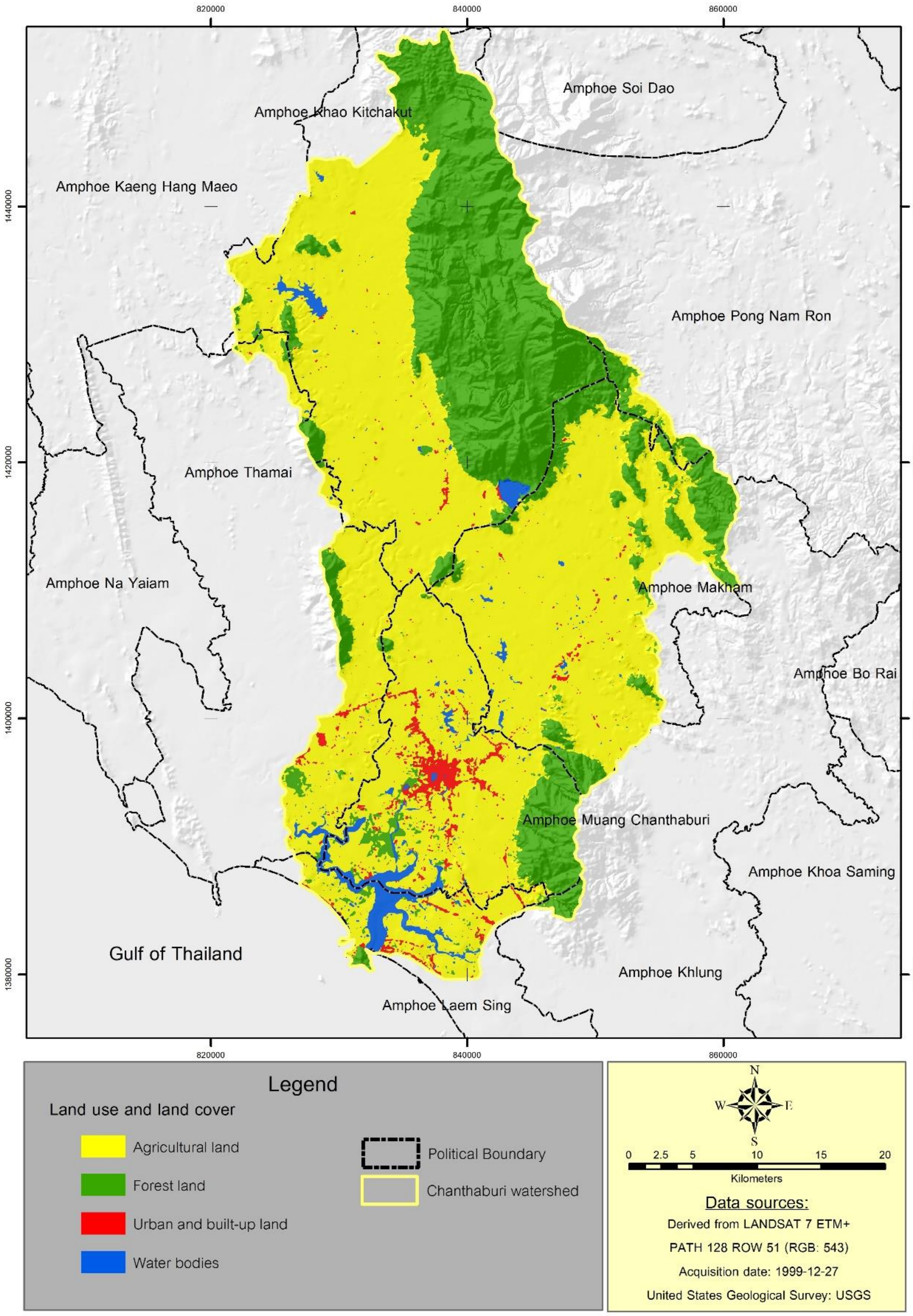

Figure 35 Reclassified land use and land cover level 1 of Chanthaburi watershed after 1999 flood.

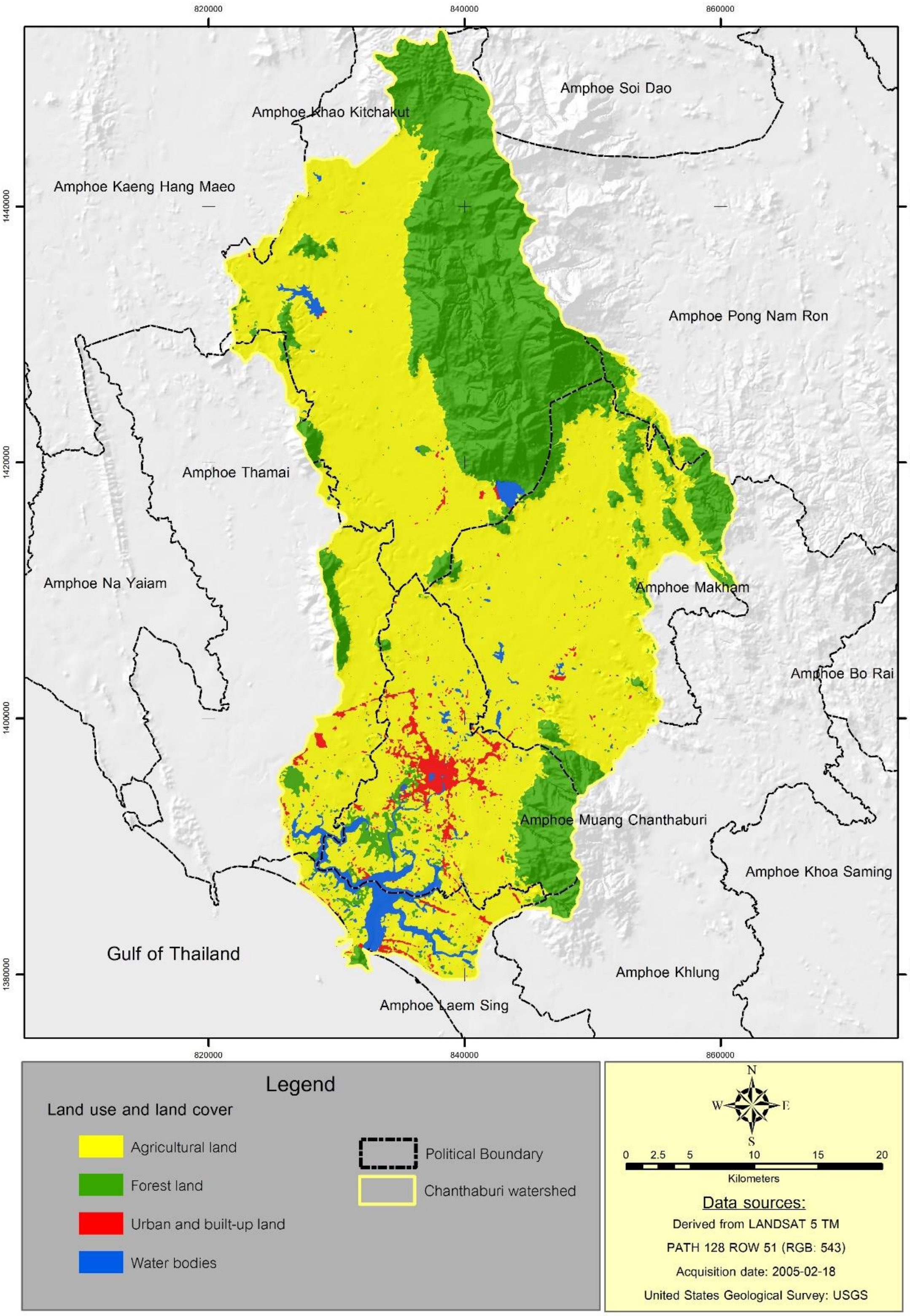

Figure 36 Reclassified land use and land cover level 1 of Chanthaburi watershed before 2006 flood.

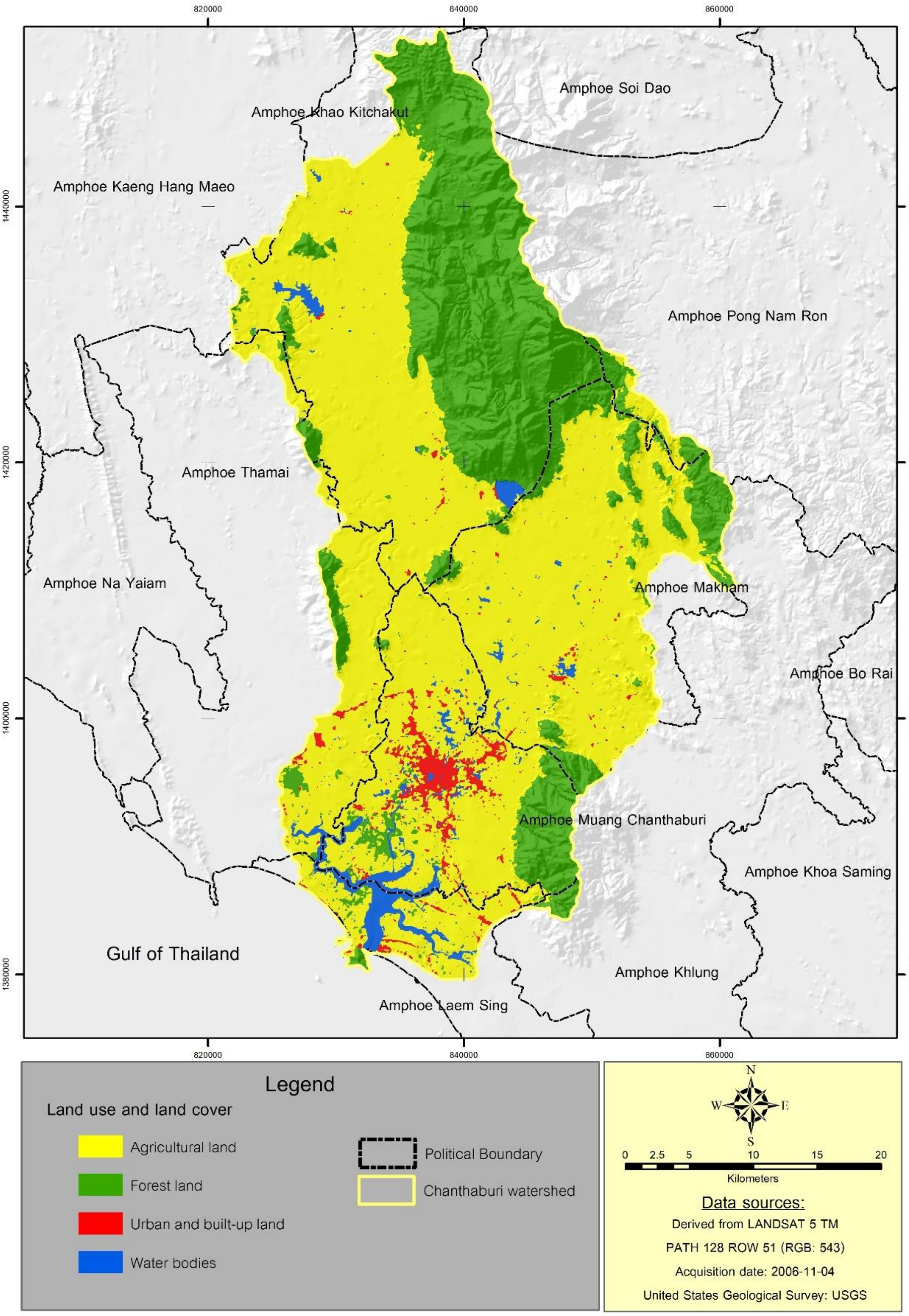

Figure 37 Reclassified land use and land cover level 1 of Chanthaburi watershed after 2006 flood.

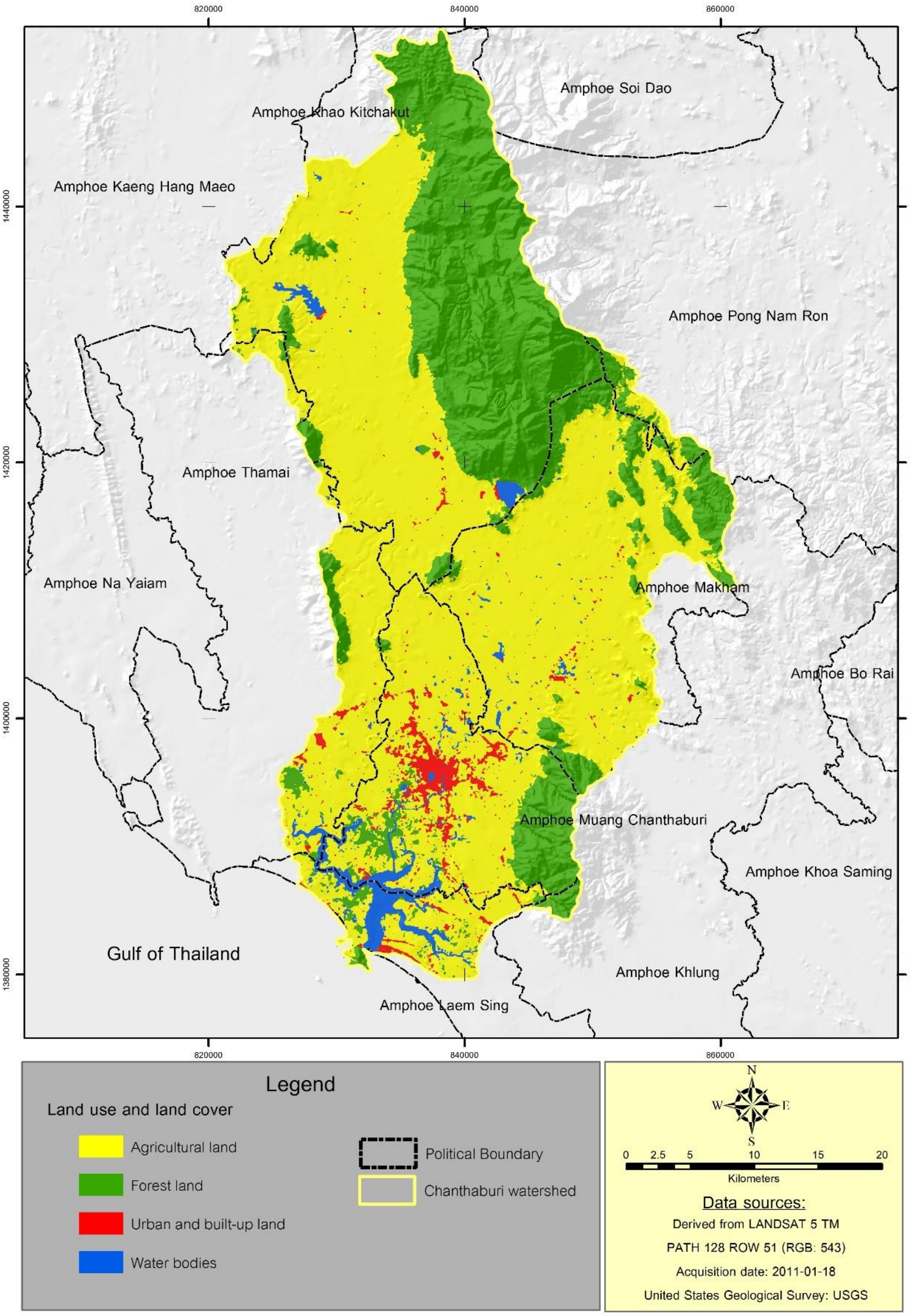

Figure 38 Reclassified land use and land cover level 1 of Chanthaburi watershed before 2013 flood.

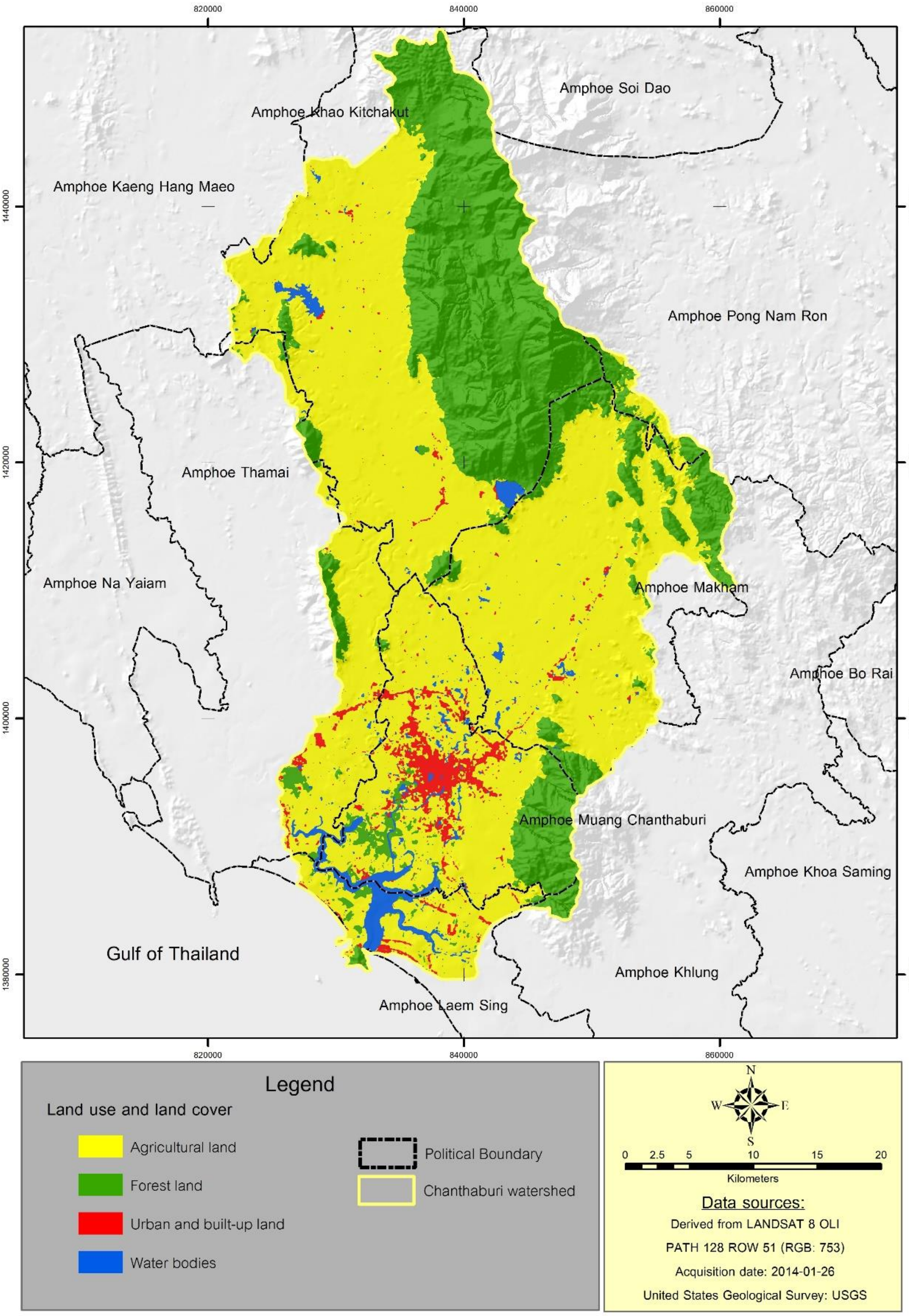

Figure 39 Reclassified land use and land cover level 1 of Chanthaburi watershed after 2013 flood.

4.2.1 Land use and land cover change before and after 1999 flood.

The LULC classification map before and after 1999 flood was overlaid and the result was showed in Table 17 to 18 and Figure 40.

Agricultural land increased with area of 10.77 km^2 or 47.99% of LULC change. Moreover, most of agricultural land transformed to urban and built-up land with an area 5.01 km^2, followed by forest land with area of 9.12 km^2 and water bodies area with area of 3.58 km^2.

Forest land decreased with area of 7.58 km^2 or 33.78% of LULC. Most of forest land transformed to agricultural land with area of 16.87 km^2, followed by water bodies area with area of 0.74 km^2 and urban and built-up land with area of 0.31 km^2.

Urban and built-up land increased with area of 0.45 km^2 or 2.01% of LULC change. Most of Urban and built-up land transformed to agricultural land with area of 1.63 km^2, followed by forest land with area of 0.33 km^2 and water bodies with area of 0.31 km^2.

Water bodies area decreased with area of 3.16 km^2 or 16.22% of LULC change. Most of Water bodies area transformed to agricultural land with area of 7.63 km^2, followed by urban and built-up land with area of 0.64 km^2 and urban and forest land with area of 0.46 km^2.

Table 17 Changes in areas of different land use and land cover types in Chanthaburi watershed before and after flood events in 1999

	Area (kilometer^2)			
	Before 1999 flood year	After 1999 flood year	Land use land cover change	Percentage of total LULC change
Agricultural land	1022.98	1033.75	10.77	47.99
Forest land	498.94	491.36	-7.58	33.78
Urban and built-up land	32.70	33.15	0.45	2.01
Water bodies	45.58	41.94	-3.64	16.22
Total	1600.20	1600.20	22.44	100

Table 18 Matrix of land use and land cover change in Chanthaburi watershed before and after 1999 flood.

	Agricultural land	Forest land	Urban and built-up land	Water bodies	Total area
Agricultural land	998.82	9.12	5.01	3.58	1022.98
Forest land	16.87	481.27	0.31	0.74	498.94
Urban and built-up land	1.63	0.33	32.41	0.31	32.70
Water bodies	7.63	0.46	0.64	37.18	45.58
Total area	1033.75	491.36	33.15	41.94	1600.20

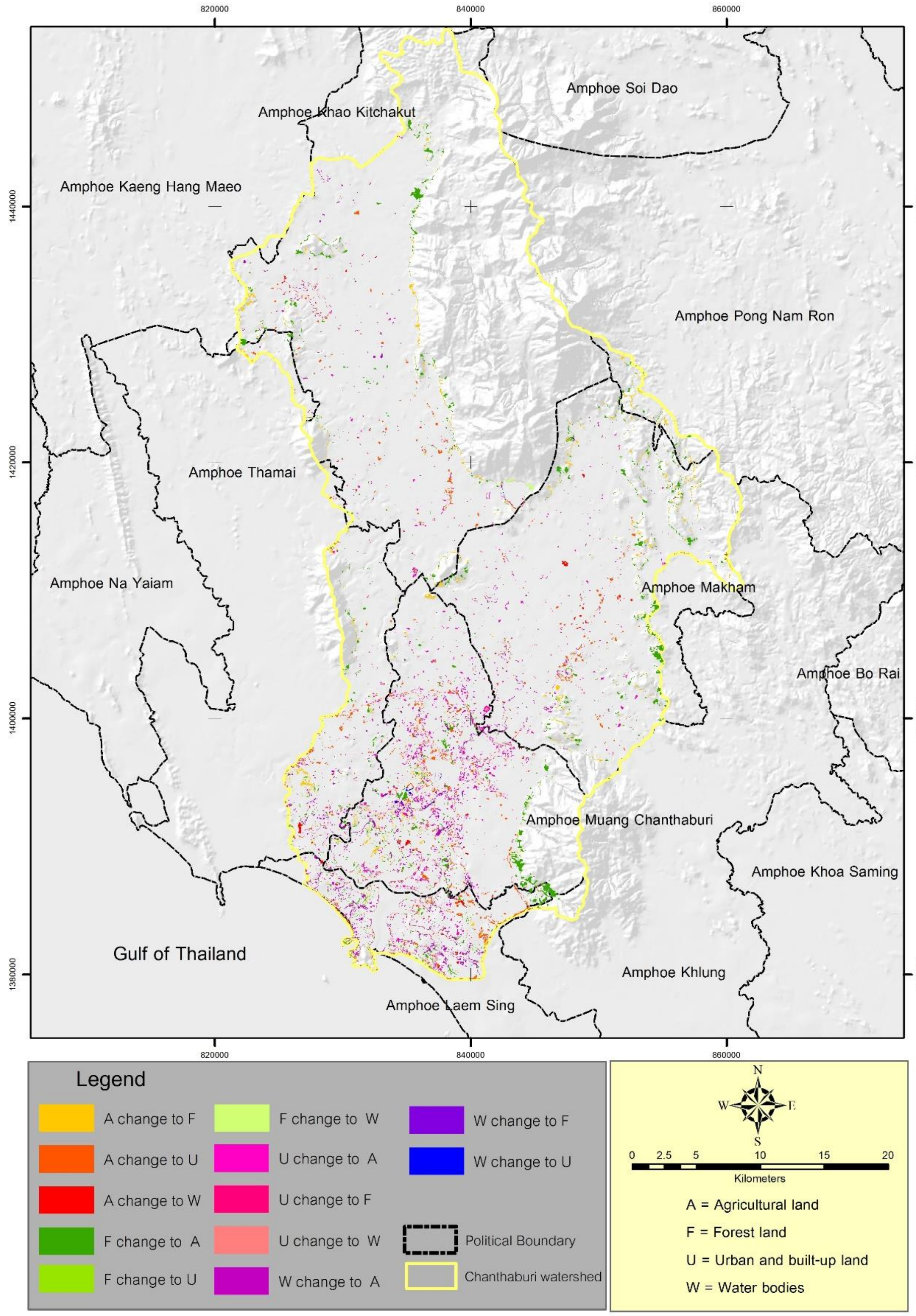

Figure 40 Land use and land cover change of Chanthaburi watershed before and after 1999 flood.

4.2.2 Land use and land cover change before and after 2006 flood.

The LULC classification map before and after 2006 flood was overlaid and the result was showed in Table 19 to 20 and Figure 41.

Agricultural land increased with area of 0.11 km^2 or 1.47% of LULC change. Moreover, most of agricultural land transformed to forest land with an area 14.25 km^2, followed by urban and built-up land with area of 4.94 km^2 and water bodies area with area of 8.20 km^2.

Forest land dropped with area of 3.74 km^2 or 50.00% of LULC change. Most of forest land transformed to agricultural land with area of 16.81 km^2, followed by water bodies area with area of 0.61 km^2 and urban and built-up land with area of 0.20 km^2.

Urban and built-up land rise with area of 1.85 km^2 or 24.73% of LULC change. Most of Urban and built-up land shifted to agricultural land with area of 0.25 km^2, followed by water bodies area with area of 0.38 km^2 and forest land with area of 0.03 km^2.

Water bodies area increased with area of 1.78 km^2 or 23.80% of LULC change. Most of Water bodies area shifted to agricultural land with area of 6.61 km^2, followed by urban and built-up land with area of 0.28 km^2 and urban and forest land with area of 0.13 km^2.

Table 19 Changes in areas of different land use and land cover types in Chanthaburi watershed before and after flood events in 2006

Land use land cover	Area ($kilometer^2$)			
	Before 2006 flood year	After 2006 flood year	Land use land cover change	Percentage of total LULC change
Agricultural land	1035.60	1035.71	0.11	1.47
Forest land	487.05	483.31	-3.74	50.00
Urban and built-up land	33.74	35.59	1.85	24.73
Water bodies	43.81	45.59	1.78	23.80
Total	1600.20	1600.20	7.48	100

Table 20 Matrix of land use and land cover change in Chanthaburi watershed before and after 2006 flood.

	Agricultural land	Forest land	Urban and built-up land	Water bodies	Total area
Agricultural land	1005.17	14.25	4.94	8.20	1035.60
Forest land	16.81	469.29	0.20	0.61	487.05
Urban and built-up land	0.25	0.03	30.75	0.38	33.74
Water bodies	6.61	0.13	0.28	36.66	43.81
Total area	1035.71	483.31	35.59	45.59	1600.20

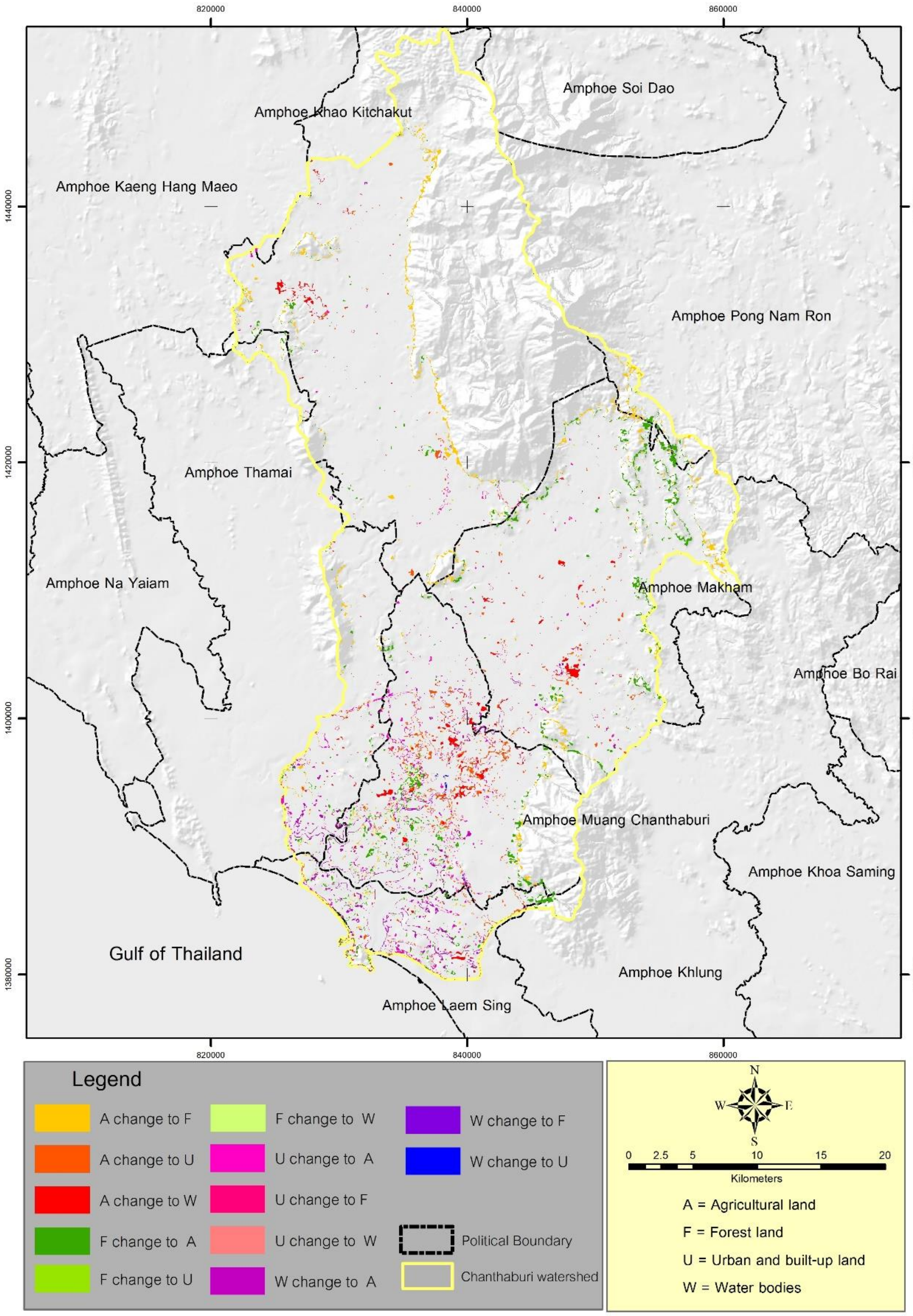

Figure 41 Land use and land cover change of Chanthaburi watershed before and after 2006 flood.

4.2.3 Land use and land cover change before and after 2013 flood.

The LULC classification map before and after 2013 flood was overlaid and the result was showed in Table 21 to 22 and Figure 42.

Agricultural land was decrease with area of 7.88 km^2 or 42.73% of LULC change. Moreover, most of agricultural land shifted to urban and built-up land with an area 11.58 km^2, followed by forest land with area of 10.86 km^2 and water bodies area with area of 6.23 km^2.

Forest land reduced with area of 0.89 km^2 or 4.83% of LULC change. Most of forest land turned to be agricultural land with area of 10.74 km^2, followed by water bodies area with area of 0.46 km^2 and urban and built-up land with area of 0.26 km^2.

Urban and built-up land rise with area of 9.22 km^2 or 50.00% of LULC change. Most of Urban and built-up land turned to be agricultural land with area of 0.64 km^2, followed by water bodies area with area of 0.49 km^2 and forest land with area of 0.15 km^2.

Water bodies area dropped with area of 0.45 km^2 or 2.44% of LULC change. Most of Water bodies area shifted to agricultural land with area of 6.53 km^2, followed by urban and built-up land with area of 0.64 km^2 and urban and forest land with area of 0.36 km^2.

Table 21 Changes in areas of different land use and land cover types in Chanthaburi watershed before and after flood events in 2013

Land use land cover	**Area (kilometer^2)**			
	Before 2013 flood year	After 2013 flood year	Land use land cover change	Percentage of total LULC change
Agricultural land	1026.98	1019.1	-7.88	42.73
Forest land	491.9	491.01	-0.89	4.83
Urban and built-up land	37.39	46.61	9.22	50.00
Water bodies	43.93	43.48	-0.45	2.44
Total	1600.20	1600.20	18.44	100

Table 22 Matrix of land use and land cover change in Chanthaburi watershed before and after 2013 flood.

	Agricultural land	Forest land	Urban and built-up land	Water bodies	Total area
Agricultural land	999.10	10.86	11.58	6.23	1026.98
Forest land	10.74	479.63	0.26	0.46	491.90
Urban and built-up land	0.64	0.15	35.87	0.49	37.39
Water bodies	6.53	0.36	0.64	36.20	43.93
Total area	1019.01	491.01	46.61	43.48	1600.20

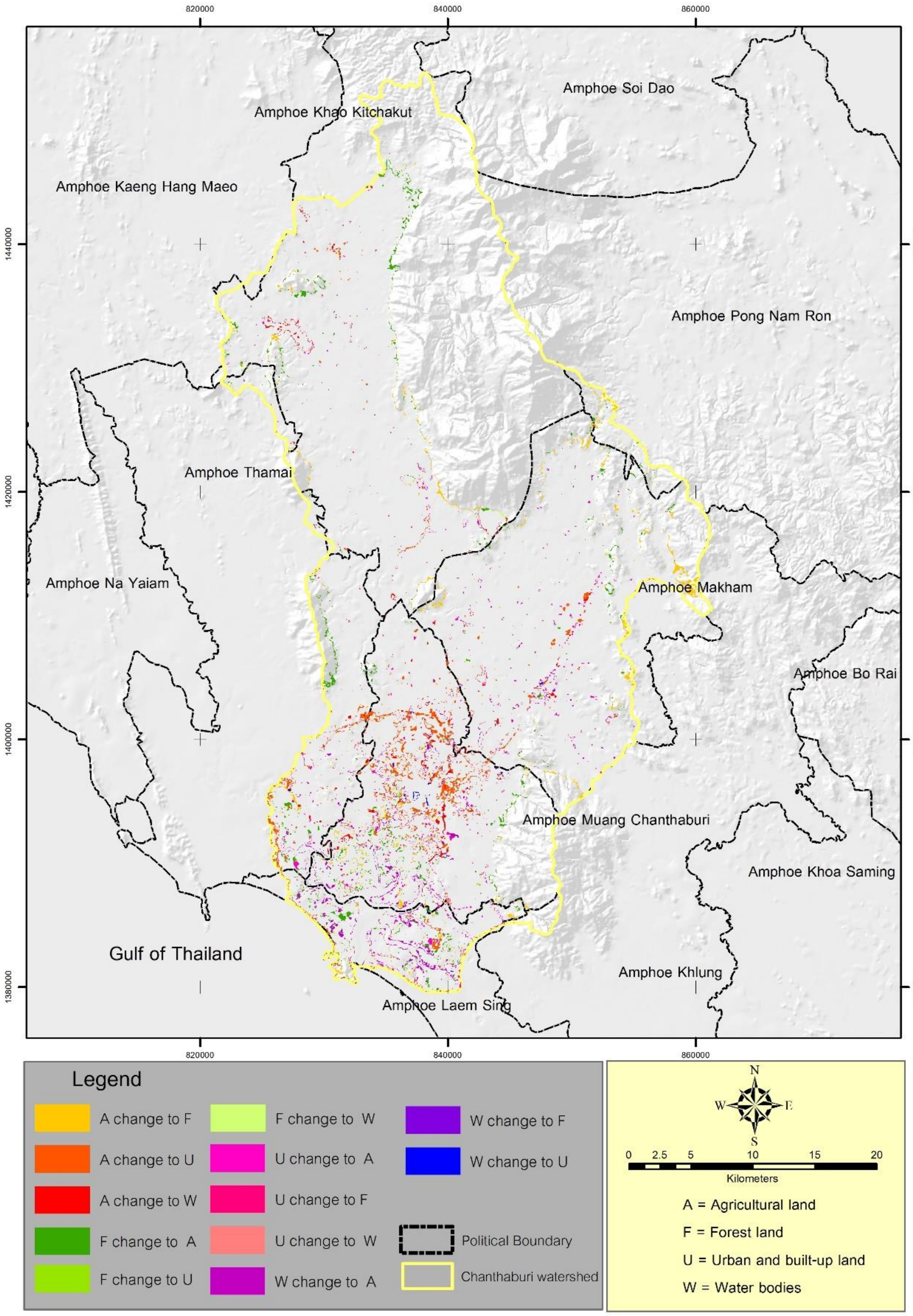

Figure 42 Land use and land cover change of Chanthaburi watershed before and after 2013 flood.

4.3 Flood vulnerability area

The various data were applied to analyze flood vulnerability area were as follow: LULC, landform, flood inundation area and DEM.

LULC data derived from satellite image after 2013 flood using supervised classification with Maximum likelihood algorithm. This classification divided LULC into 9 classes and reclassified into 4 classes, namely agricultural land, forest land, urban and built-up area and water bodies as shown in Figure 39.

Landform data is an important factor which related to flood hazard area (Ho et al., 2010), it was derived from geological map analysis (Department of Mineral Resources) as shown in Figure 44 and coastal morphology from Department of Marine and Coastal Resources. Its data was classified into 12 classes consists of Intertidal flat, Old tidal flat, Floodplain, Low plain, Plain, Undulating plain, Low hills, Hills, High hills, Mountains, Sand beach and Lagoon (Figure 43).

Flood inundation area derived from RADARSAT-2 satellite imagery which was captured the inundation area in 2013 (Figure 45). Moreover, DEM was generated by various GIS data consists of stream line, watershed boundary, water body and elevation from topographic map (Figure 46). All spatial data were used as a significant tool to provide several spatial studies especially flood vulnerability mapping (Figure 48).

According to previous research of Ho et al. (2010), Veenstra (2013) and Ejenma et al. (2014), their study applied a thematic data to classified flood vulnerability area using scoring method by overlay various layers (Liu et al., 2016), each class has difference score depend on the related to flood vulnerability as shown in Table 23.

Table 23 The main factor, with its score and classes that were used to generate flood vulnerability area.

Flood Vulnerability	Score	Classes
Land use and land cover	1	Agricultural land
	0	Forest land
	1	Urban and built-area
	0	Water bodies
Geomorphology	1	Intertidal flat
	1	Old tidal flat
	1	Floodplain
	1	Low plain
	1	Plain
	0	Undulating plain
	0	Low hills
	0	Hills
	0	High hills
	0	Mountains
	0	Sand beach
	0	Lagoon
Flood inundation area	1	Flood area
	0	Non-flood area
Digital Elevation Model (DEM)	1	0–3 meters
	1	3-4 meters
	0	4-6 meters
	0	6-20 meters
	0	>20 meters

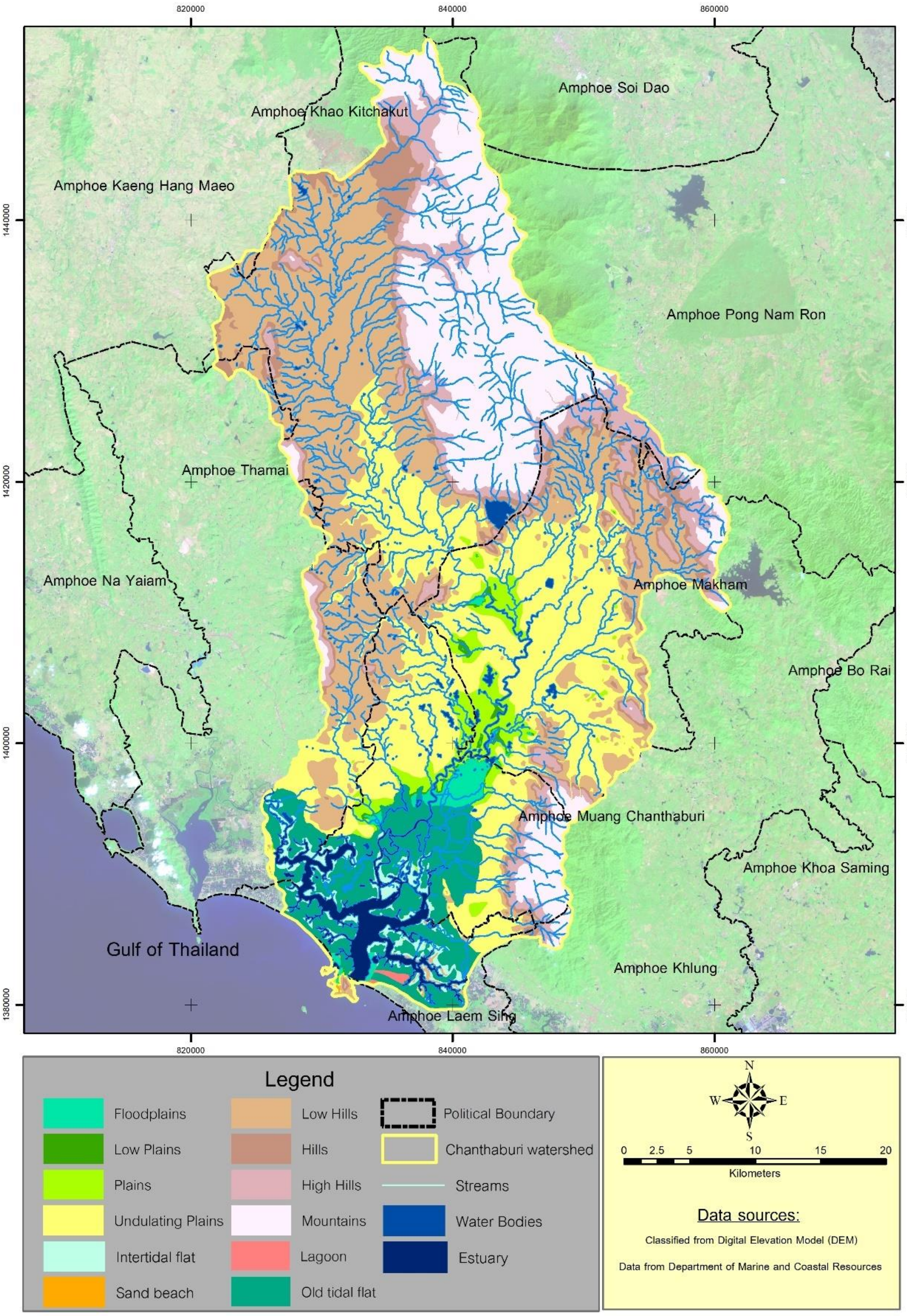

Figure 43 Map of landform in Chanthaburi watershed.

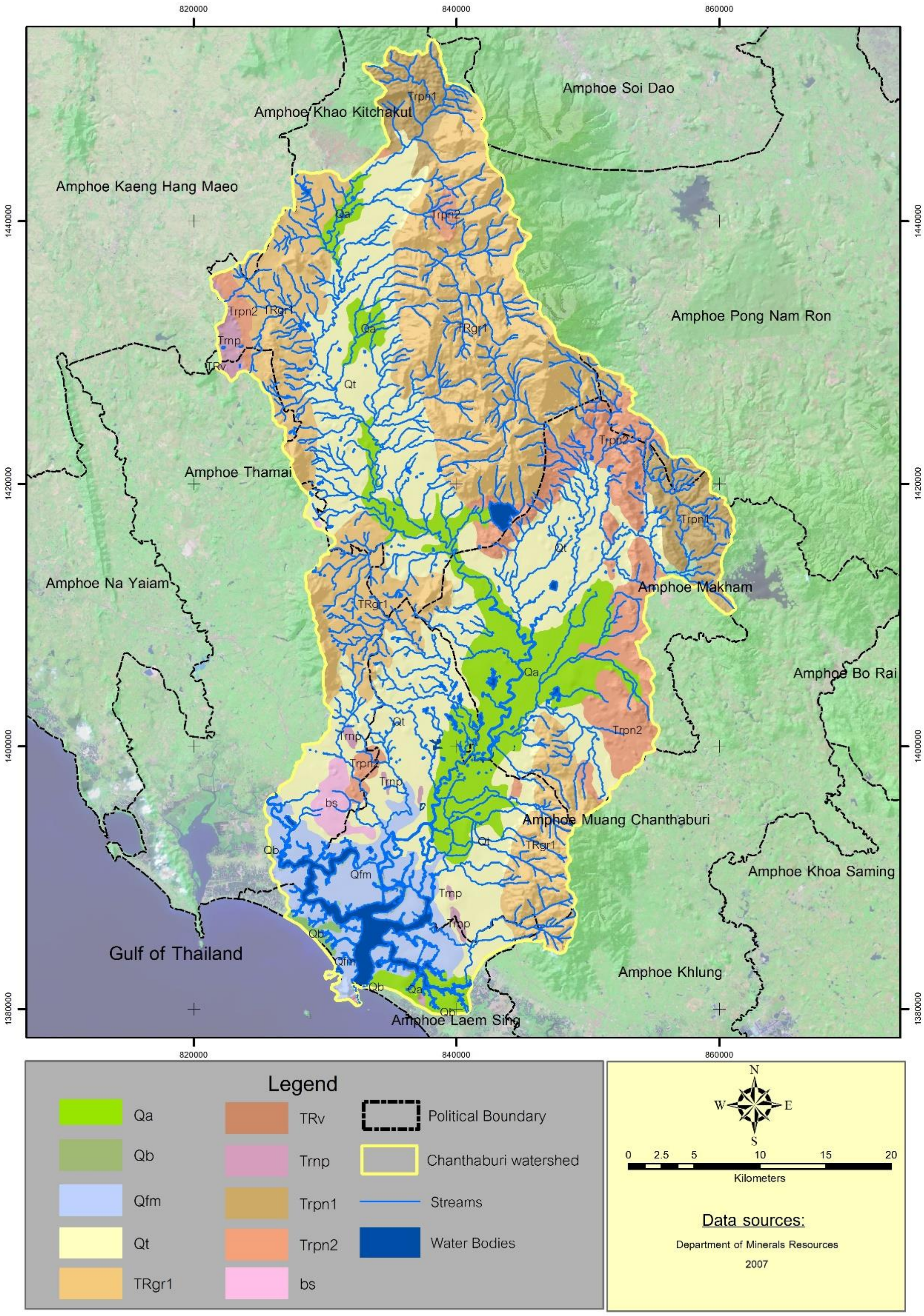

Figure 44 Map of geologic rock units in Chanthaburi watershed. (Source from Department of Mineral Resources)

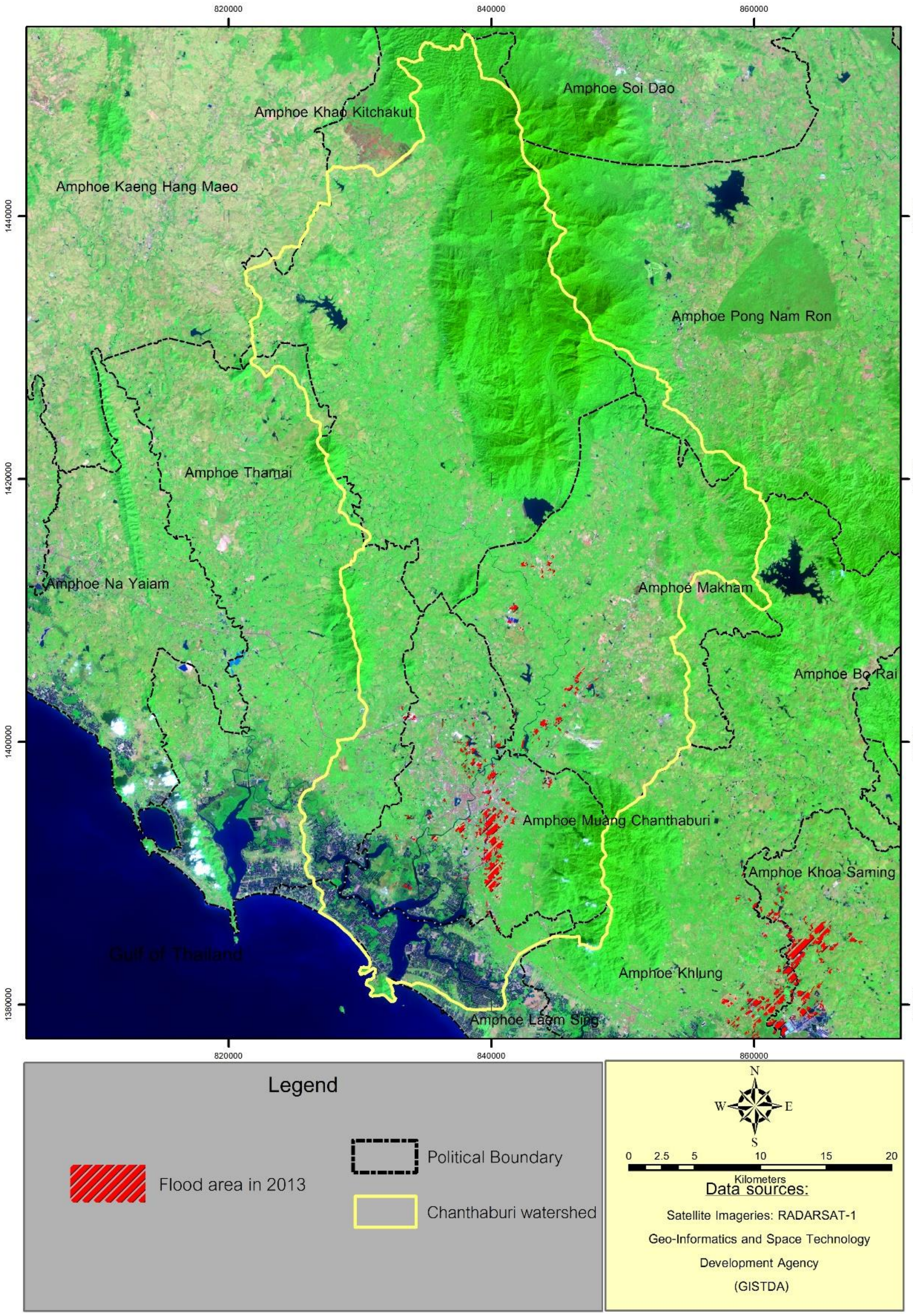

Figure 45 Map of flood inundation area during 2013, in Chanthaburi watershed. (Source from Geo-Informatics and Space Technology Development Agency: GISTDA)

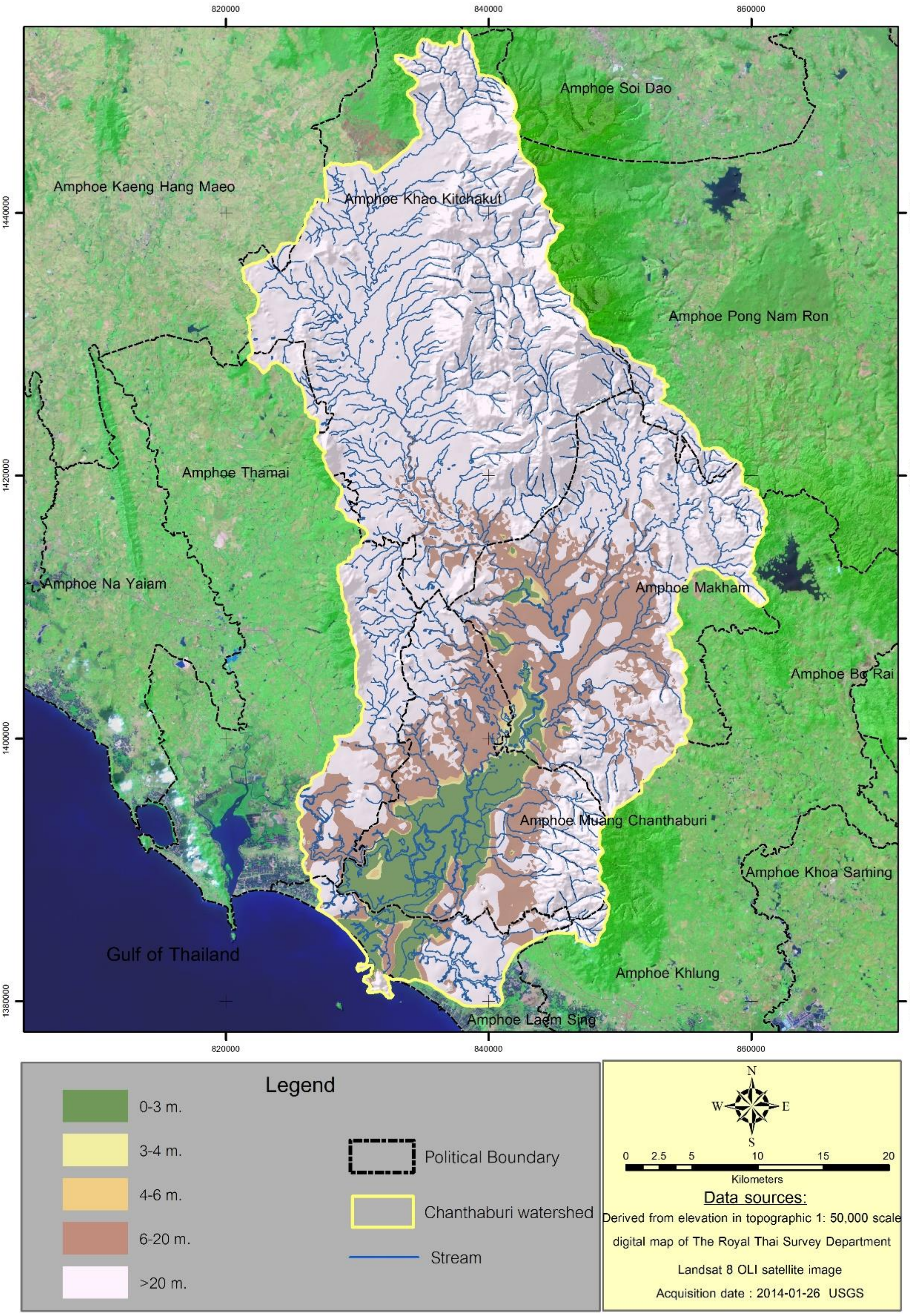

Figure 46 Map of elevation in Chanthaburi watershed was classified by DEM.

The accumulative score which generated by various thematic layers ranged from 0-5 shows in Figure 46. The flood vulnerability map was created by range reclassification which divided into 3 classes, the area under low flood vulnerability, high flood vulnerability and non-flood vulnerability are 176.36 km^2, 59.63 km^2, 1,370.32 km^2, respectively (Figure 47).

Low flood vulnerability area covers about 10.98% with the flood vulnerability scores of 2-3. These area scatter in the lower part of Chanthaburi watershed, some area of urban and built-up and agricultural settle in this class.

The area that obtained flood vulnerability score of 4-5 was defined as the high flood vulnerability which covers about 3.71%. It covers in the lower part of watershed at the center of Muang Chanthaburi city area, adjacent Chanthaburi river.

Non-flood vulnerability area covers most area of Chanthaburi watershed about 85.31%. These areas indicate as non-flood hazard area and non-vulnerability area. In other words, accumulative score in these areas ranged 0-1.

The results of this study can be used as a valuable tool of planning, decision making in order to achieve a mitigation and improve the preparedness for flood hazard, especially to reduce future flood vulnerability.

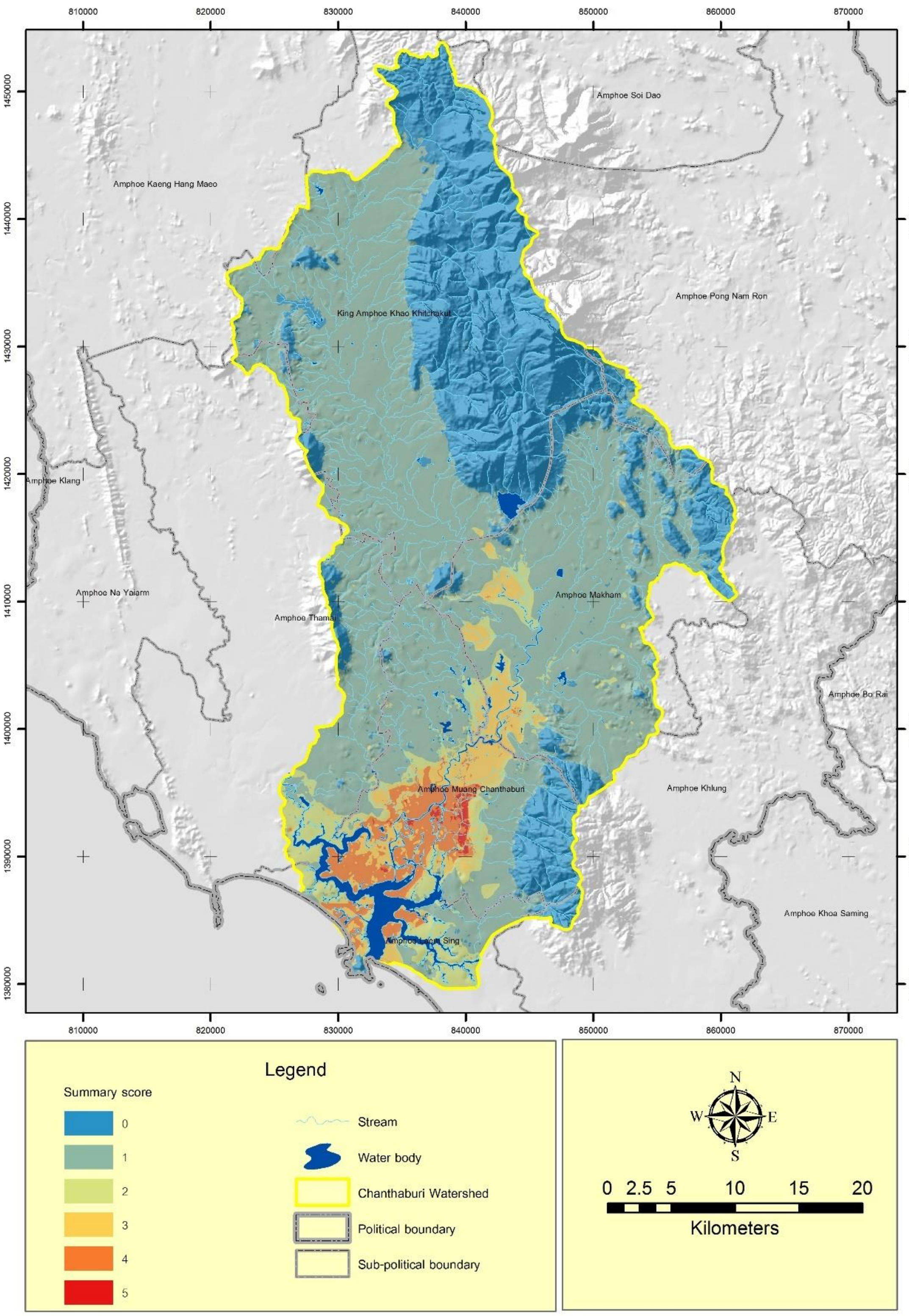

Figure 47 The summary score map was derived from overlaying of several factors.

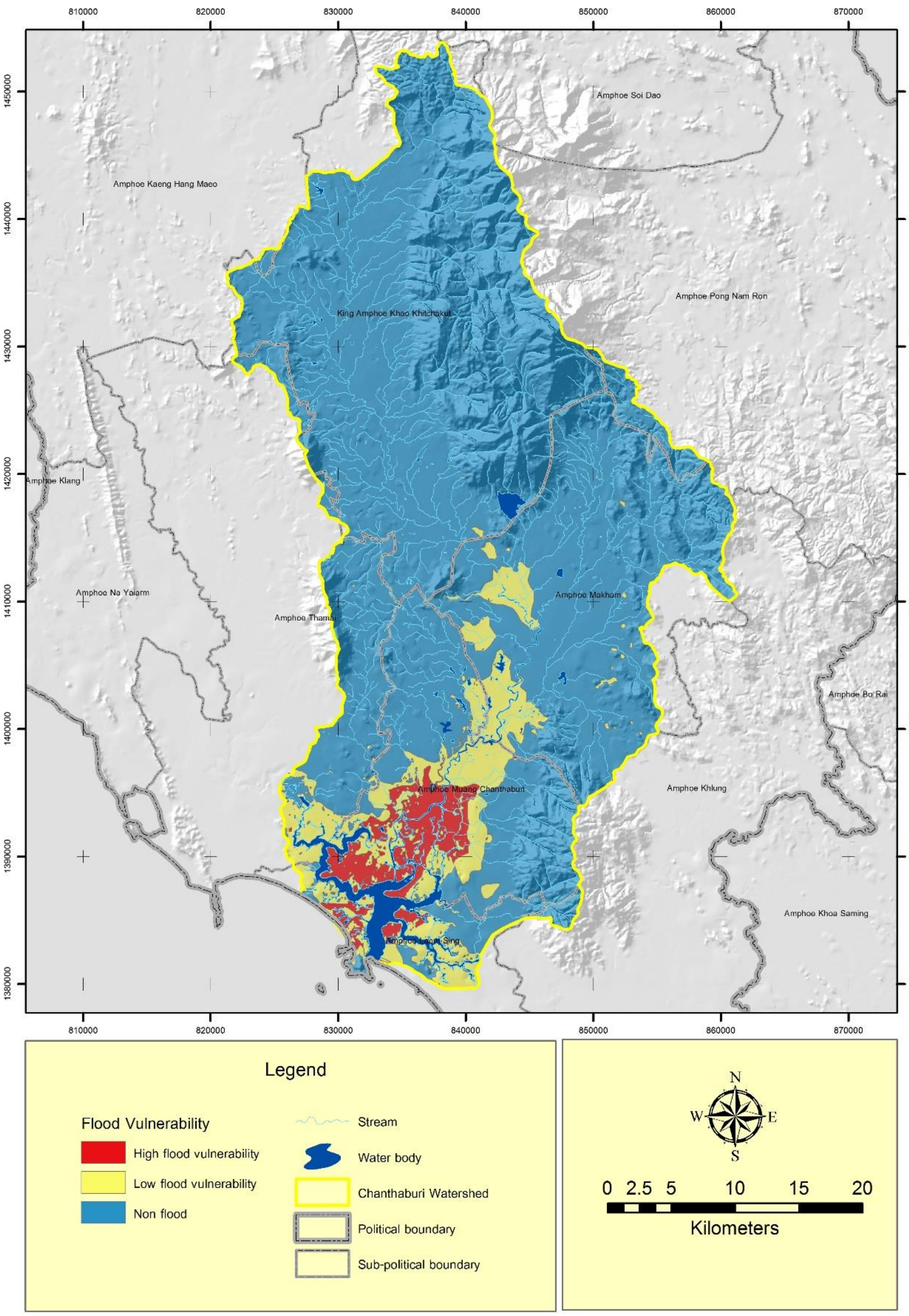

Figure 48 Flood vulnerability map of Chanthaburi watershed.

CHAPTER V
DISCUSSION AND CONCLUSION

5.1 Discussion

The results of this study will be discussed in this chapter, which can be divided in 3 sections, namely LULC pattern of Chanthaburi watershed, LULC change of Chanthaburi watershed after floods and flood vulnerability map. At the end of this chapter, conclusion and recommendation of this study were summarized and proposed.

5.1.1 Land use and land cover pattern of Chanthaburi watershed before and after 1999, 2006 and 2013 floods.

In this research, Landsat 5 TM, 7 ETM+ and 8 OLI satellite images before and after 1999, 2006 and 2013 floods were used as a data to classify LULC types by using supervised classification process. There are 9 categories of LULC that were used in this study, namely paddy field, field crop, para rubber, orchard, aquaculture, forest, mangrove, urban and built-up area and water bodies.

The orchard has been the most LULC type, which covered more than 31% of all Chanthaburi watershed area. Orchard include durian, mangosteen, rambutan, another perennial plantation, it has continuous increased since 1999 to 2013 due to more demanding of global market, especially durian. In other words, Chanthaburi province has the most durian plantation area and productive in Thailand due to climate suitability consists of temperature, humidity. The area of orchard scatters in every part of watershed, especially area along the Chanthaburi river.

The para rubber has increased during 1999 and 2006 floods, after that, its area has deceased after 2013 flood, because the price of para rubber has decrease to lower level than before and the price of durian has continuous increased, so many agriculturists decided to change their plantation area form para rubber and field crop to durian plantation area. In addition, the paddy field area can be found on eastern part of downtown and resident area of Chanthaburi city. It located in floodplain area where the flood is occurred in monsoon season and always covered by water.

This study divided the forest into 2 types, namely mangrove and forest (mountain forests). Mangrove appear along estuaries and deltas on coastal area in the southern of Chanthaburi watershed. Forest appear in mountain area which located around the watershed.

Urban and built-up area can be found along the road and center of the district, such as Muang Chanthaburi, Tha Mai, Makham, Khao Khitchakut, Laem Sing etc. The consistent increase in the urban built-up area is significant in this watershed as it is mostly due to the population growth and new building and Infrastructure construction.

5.1.2 Land use and land cover change of Chanthaburi watershed before and after 1999, 2006 and 2013 floods.

After LULC classification, 9 classes of LULC in Chanthaburi watershed were dissolved into 4 classes, namely agricultural land, forest land, urban and built-up area and water bodies. Change detections of LULC in Chanthaburi watershed after flood were analyzed using overlay technique in Arc GIS 10.2.2. The result revealed that after 1999 flood, the total change areas were 22.44 km^2 or 1.40% of total change areas. The most type of LULC change areas was agricultural land that was increased 10.77 km^2 (0.67%) or 47.99% of total change areas and also urban and built-up land was increased too; whereas, forest land and water bodies were decreased.

The result of change in LULC in 2006 flood reveled that the total change areas were 7.48 km^2 or 0.47% of total change areas. There is a similarity in trend of forest land; in other words, forest land in the only LULC type that was decreased 3.74 km^2 (0.23%) or 50.00% of total change areas; whereas, agricultural land, urban and built-up area and water bodies were increased.

The result of change in LULC in 2013 flood reveled the difference trend form the other years, because urban and built-up area was the only LULC type that was increased by 9.22 km^2 (0.58%) or 50.00% of total change areas. Agricultural land was decreased in this year after constantly increased since 1999 – 2006, it was decreased

7.88 km^2 (0.49%) or 42.73% of total change areas; moreover, forest land, water bodies were decreased too.

In this study, agricultural land and urban and the built-up area located in the floodplain area. Forest land has decreased in every year after the flood, but the forest land is not located in flood inundation area, so the forest land was converted to agricultural land due to responding of more consumer consumption form the domestic and overseas. In other words, value of durian that exported to China, which is the biggest trade for Thailand's durian exporting, have constantly increased from 234,303.50 USD in 2011 to 693,577.20 USD (Value in '000s USD) in 2016 (Tantrakonnsab and Tantrakoonsab, 2018). Water bodies in this watershed have various types for the various purposes, the majority purpose is to use in agriculture such as the orchard, paddy field, crop land etc.

Chanthaburi watershed was dominated by agricultural land, it was increased after 1999 and 2006 floods, because of the transformation of forest land. The government support in plantation and export were the cause of change in LULC type and type of plants. After 2013 flood, agricultural land was escalated by the invasion of urban and built-up area, especially in Muang Chanthaburi district where the high rate of built-up area has increased. There are many reasons for urban and built-up area increasing, various infrastructure developments, economic changes, population growth and new building and residential construction. The data in Table 24 reveals that the number of population and housing in Muang Chanthaburi has been constantly increased since 1999 – 2017, influence urban expansion towards all directions along the road except the eastern direction due to dominance of orchard and mountainous area which control the urban growth (Figure 49).

Table 24 Number of population and housing in Muang Chanthaburi (Source from Official Statistics Registration Systems).

Year	Population	Number of Housing
1999	No data	43,500
2006	118,364	50,908
2013	125,924	61,315
2017	128,708	67,590

Moreover, as a research of Gumrukcuoglu et al. (2010), in their work on the LULC change after floods of upper Kansas river floodplain have concluded that flood played important roles in LULC changes in the Kansas River. The flooding leads to the change in agricultural land and grassland. In this research, can be found that flood doesn't play important roles in LULC change in Chanthaburi watershed because the socioeconomics is the main factor that affects LULC, especially in agricultural land, forest land and urban and built-up area.

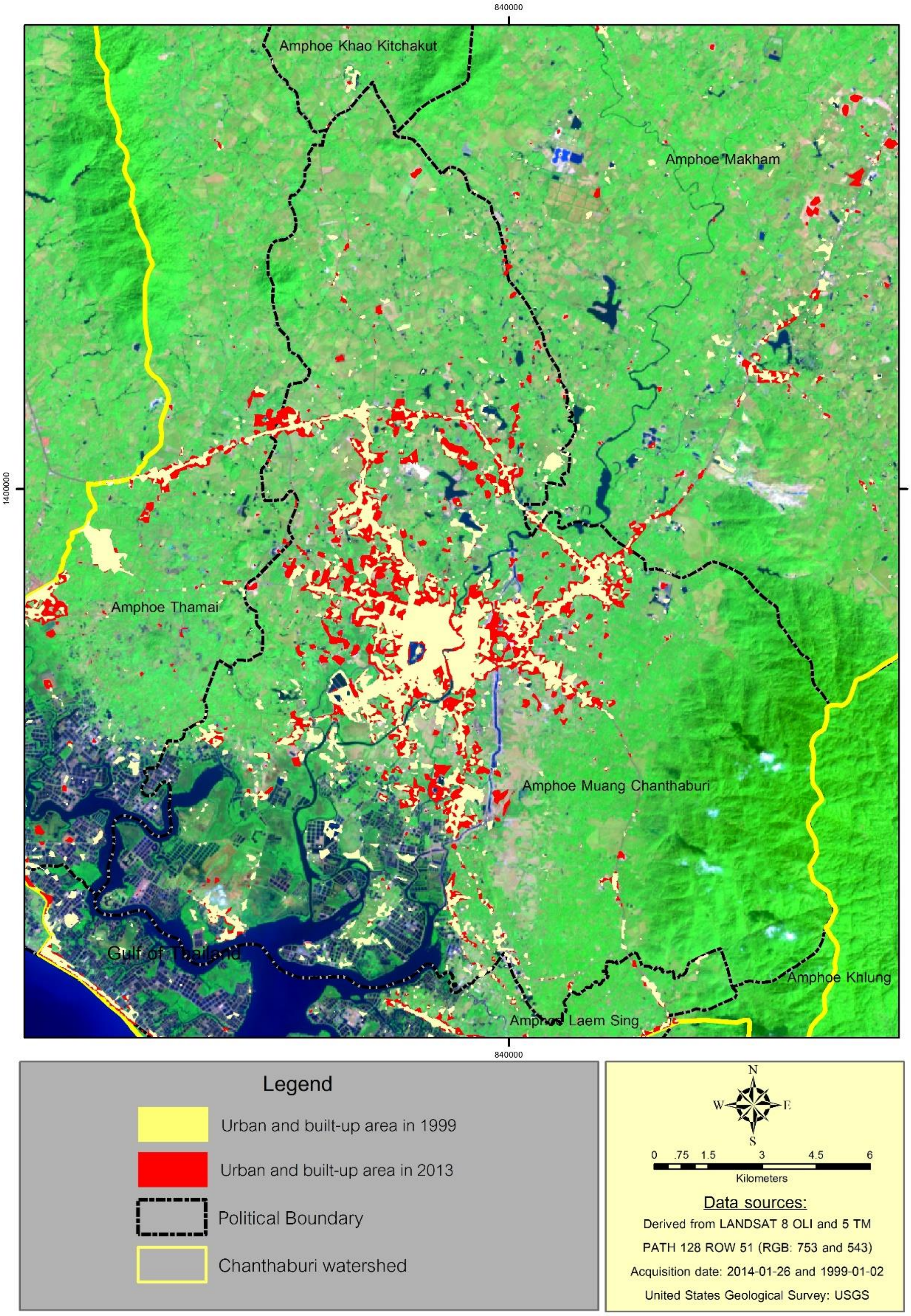

Figure 49 Maps of urban and built-up area in 1999 and 2013

5.1.3 Flood vulnerability in Muang Chanthaburi

From chapter 4, flood vulnerability map was classified by various thematic data consists of DEM, landform, flood inundation area and LULC, flood vulnerability map was delineated and classified into 3 level of vulnerability, namely high flood vulnerability, low flood vulnerability and non-flood vulnerability. Urban and built-up area is an important area where many building, residences and peoples live in. So, flood is a crucial problem because it affects to economics area and population area, causes property damage and loss of life. In the other word, level of flood vulnerability in the urban and built-up area is higher than other LULC types (Figure 50).

High flood vulnerability zone covers the area of Tambon Ko Khwang, Tambon Talat, Tambon Chanthanimit, Tambon Wat Mai and some part of Tambon Phlapphla, Tambon Khlong Na Rai, Tambon Nong Bua and Tambon Bang Kacha. These areas are the location of Urban and built-up area and agricultural include government office of Chanthaburi, colleges and schools, residences, markets, department stores, hospitals and others commercial area. Due to the high economic value of this zone, flood occurrence will affect more than others vulnerability zone in Chanthaburi watershed.

Low flood vulnerability zone is the area where residence and agricultural are located, it covers the area of Tambon Ko Khwang, Tambon Bang Kacha, Tambon Chanthanimit some part of Tambon Phlapphla, Tambon Khlong Na Rai, Tambon Kom Bang, Tambon Tha Chang and Tambon Salaeng. This area is safer than the other locations due to its topographic and elevation.

Non-flood vulnerability zone is the area where forest and water bodies are located, because the vulnerability score of these 2 LULC types are zero. Besides, this area is not affected by flood hazard due to the topography include undulating plain, low hills, hills, high hills, mountains, sand beach and lagoon. This flood vulnerability zone covers the area of Tambon Salaeng, Tambon Tha Chang, Tambon Phlapphla, Tambon Khlong Na Rai, Tambon Kom Bang, Tambon Nong Bua and some part of Tambon Bang Kacha.

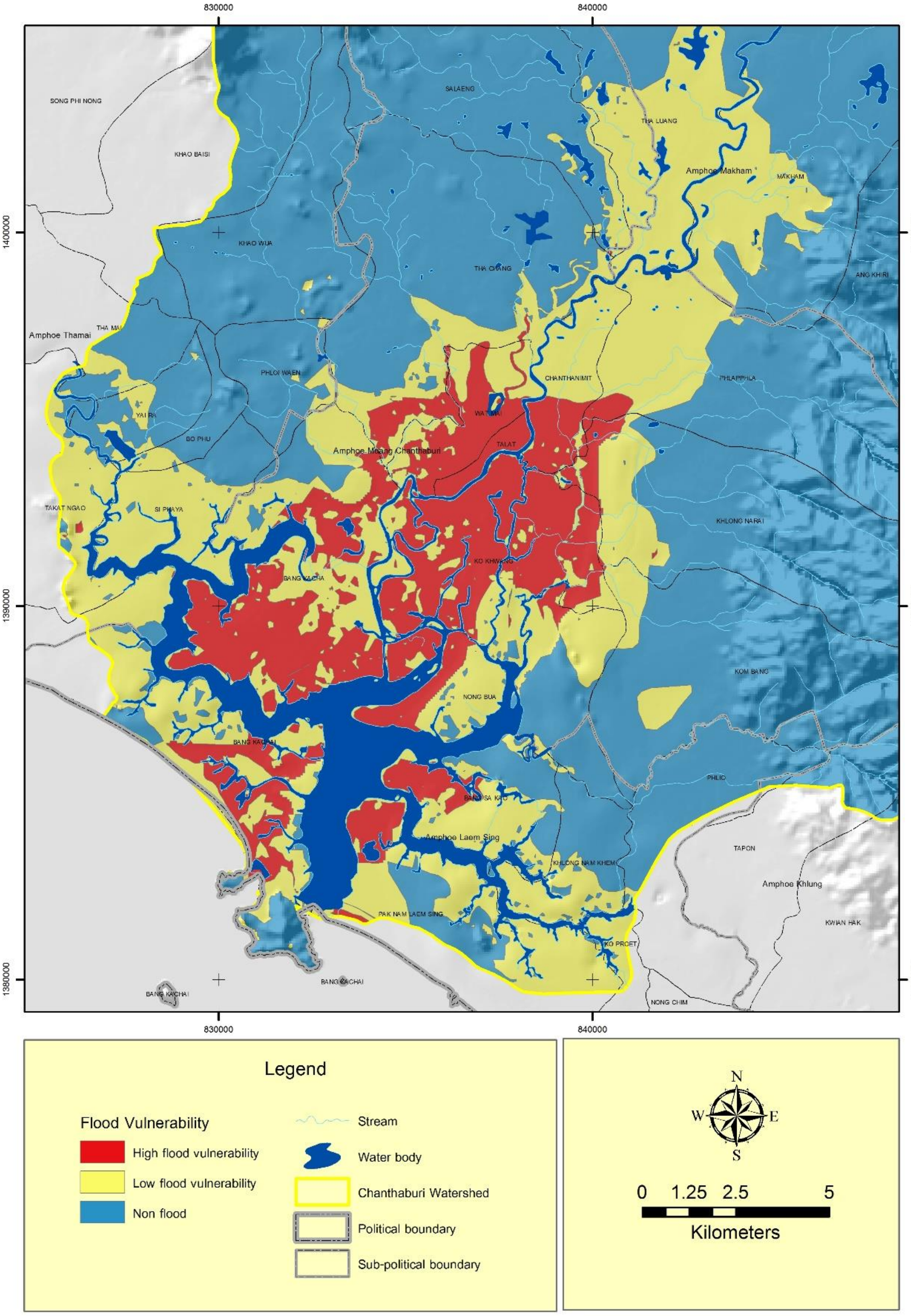

Figure 50 Flood vulnerability area in Muang Chanthaburi

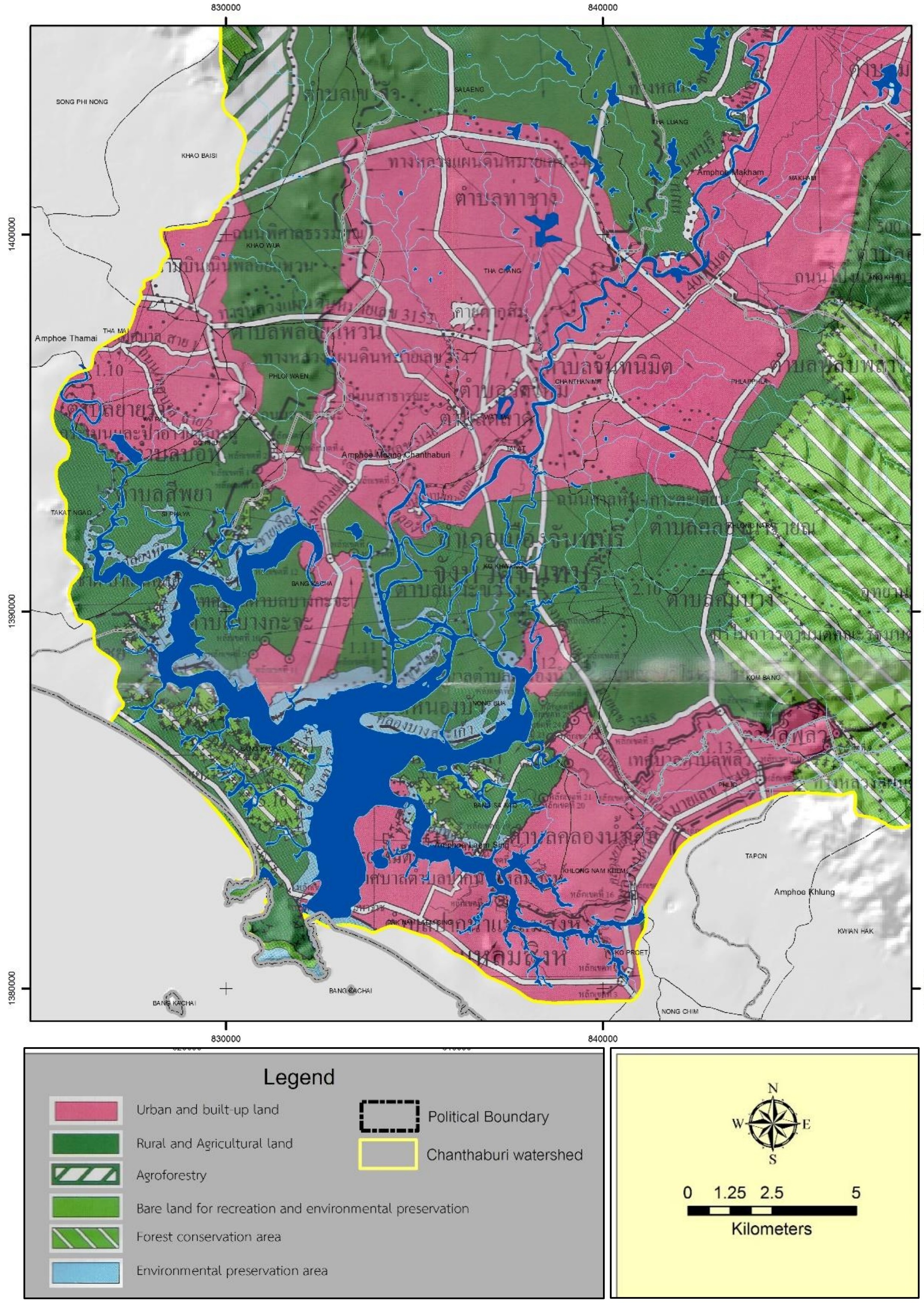

Figure 51 Principles city plan of Chanthaburi watershed (Source from Department of Public Works and Town & Country Planning)

Flood vulnerability map can use as a guideline for principle city plan in the future, urban and built-up land as shown in Figure 51 (e.g., new building, public service and transportation) should build in the non-flood vulnerability zone to mitigate flood damage in Muang Chanthaburi.

There are various types of flood in Chanthaburi watershed, especially in Muang Chanthaburi, where the high flood vulnerability zone is located, because of topographic, location, urbanization and precipitation.

Muang Chanthaburi locates in floodplain area, where flood event usually occurs, mountainous areas in the north and east are the important factor for obtaining more precipitation. The Chanthaburi river flows through the city, it can cause riverine flood when the upper area of the watershed faces extremely rainfall (Figure 52 and 53).

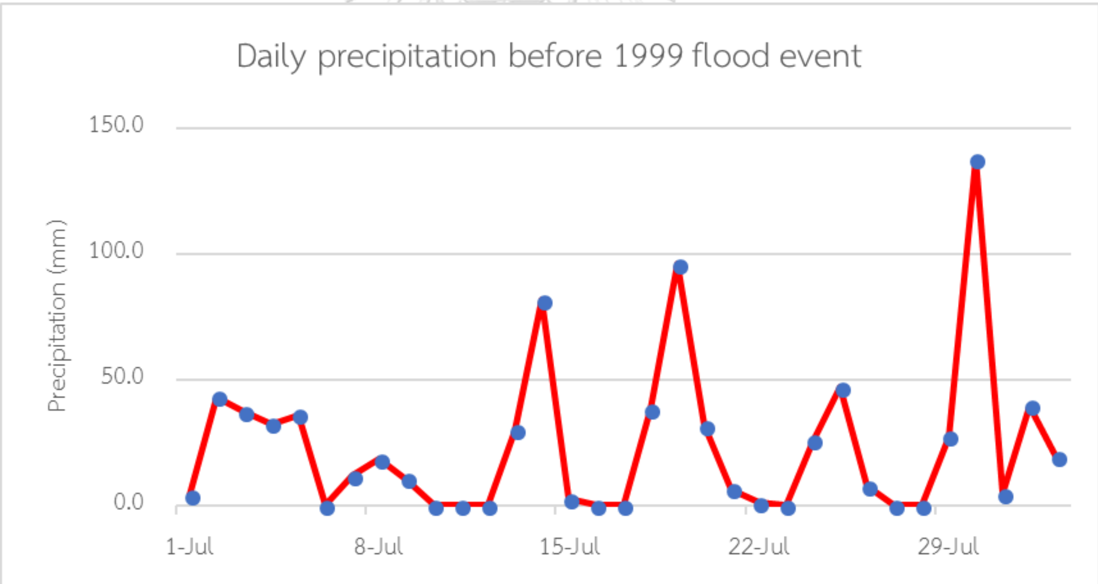

Figure 52 Daily precipitation of Muang Chanthaburi at Chanthaburi Meteorological Station in 1999 flood event. (Source from Climate Information Services, Thai Meteorological Department)

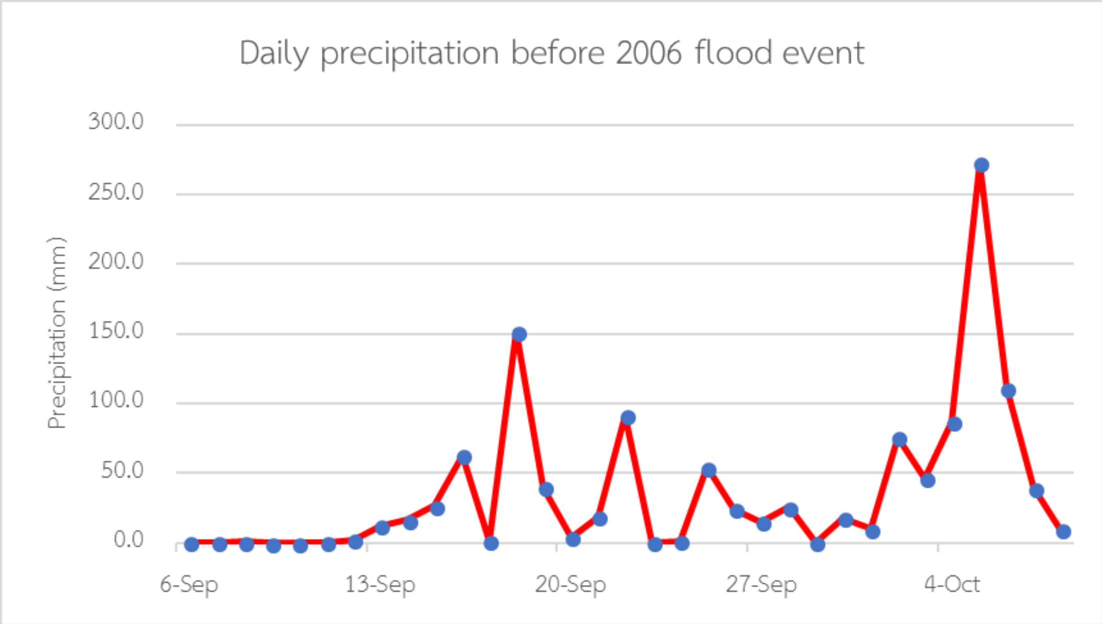

Figure 53 Daily precipitation of Muang Chanthaburi at Chanthaburi Meteorological Station in 2006 flood event. (Source from Climate Information Services, Thai Meteorological Department)

As shown in figure 55, the river flood in 1999 and 2006 cause damage to infrastructure and building in urban area of Muang Chanthaburi.

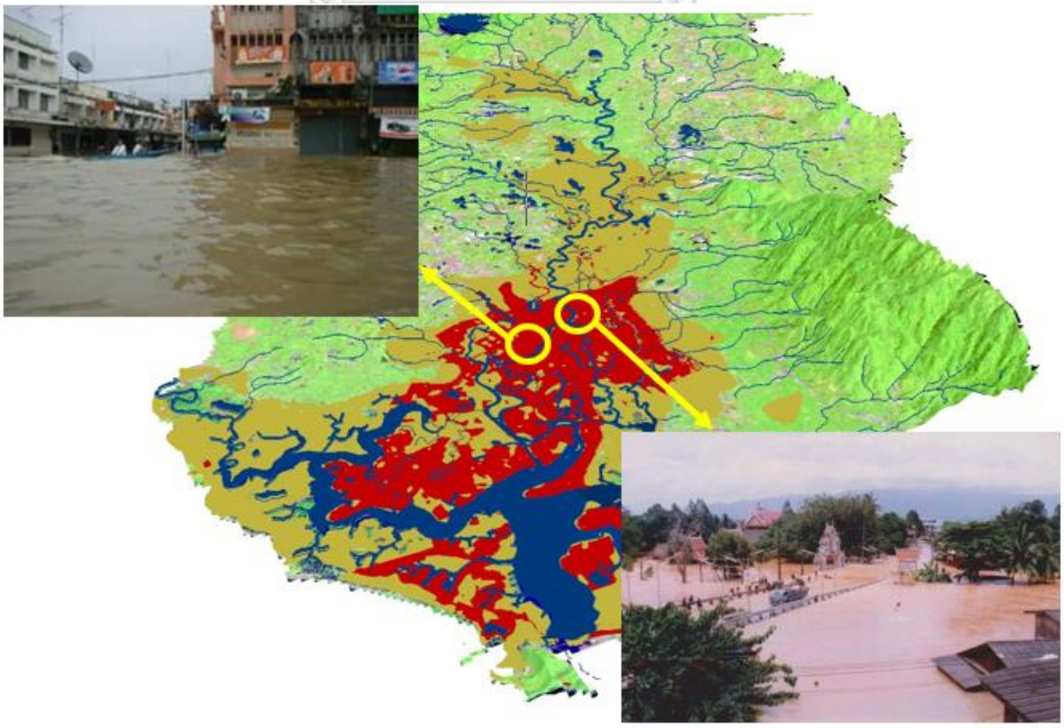

Figure 54 Affected areas of 1999 and 2006 river flood in Muang Chanthaburi.

By the way, even if urban and built-up area of Muang Chanthaburi located in flood area, the urban area has expanded after flood year and non-flood year. Besides, in recent year, there is a construction of floodway as known as Khlong Bhakti Rambhai or Bhakti Rambhai Canal (Figure 56). Its flow direction is north-south, from Chanthaburi river at the point before the stream flows through the city to an outlet of the river, its length is proximately 11 kilometers.

The floodway is capable of handling 300 cubic meters per second of water flow to reduce a water volume that flows through the city and reduce the flooding along the Chanthaburi river during the monsoon. Moreover, this floodway can reserve a water for use in agriculture activities during the dry period and prevent a salted water encroachment. On the other hand, there is a sub-watershed area which located on eastern side of the city, next to the high mountain area are affected by flash flood.

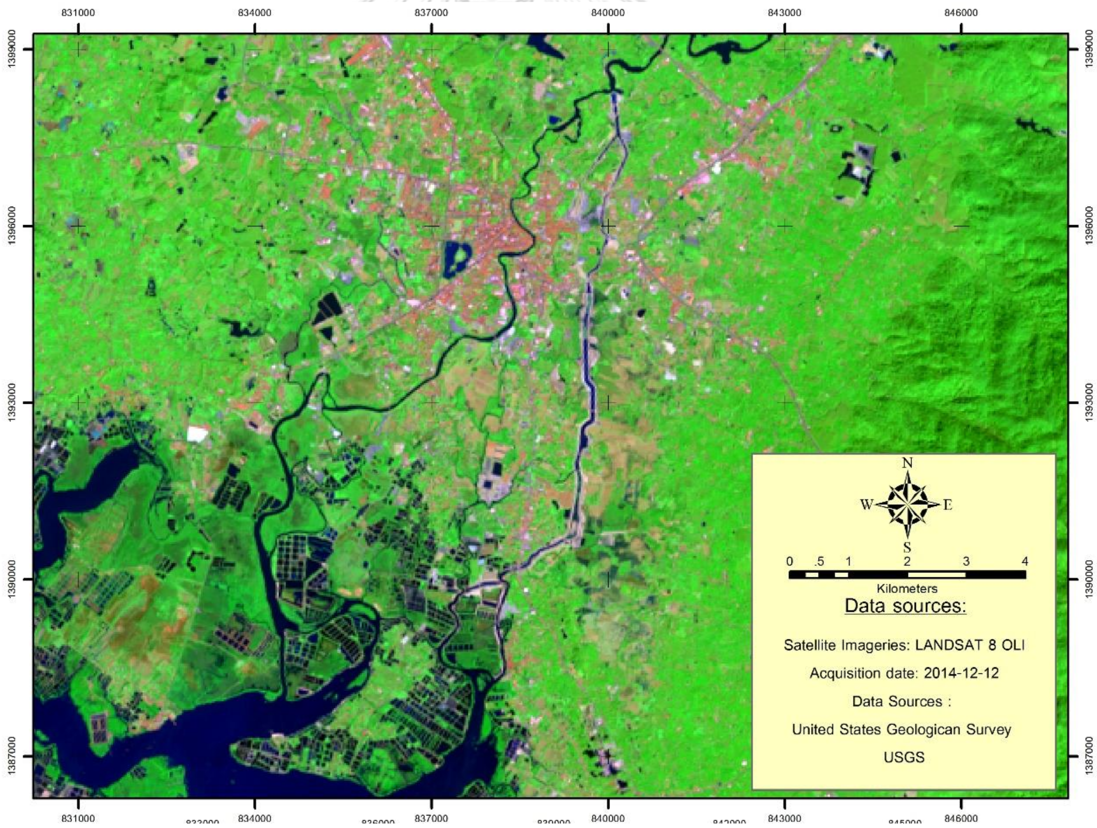

Figure 55 Map of flood way (Khlong Bhakti Rambhai) and Chanthaburi river comparative with land use and land cover level 1 of Chanthaburi watershed.

Although the impact of the riverine flood can be prevented by flood control structure, there is the impact of the urban flood that can occur in Chanthaburi city due to the urban expansion in flood area which is a result of lack of proper management, road and infrastructure in urban area. Especially, Chanthaburi city is influenced by southwest monsoon and its location is available for orographic precipitation, so the rain precipitation of Chanthaburi city is very high than the average of Thailand. It can be measured 394.9 millimeters in 24 hours during 22-23 July 2013 (Figure 56) at the Meteorological station of Chanthaburi, cause a 2013 great urban flood (Figure 57 and 58) in downtown and vulnerability area of Muang Chanthaburi and followed by riverine flood.

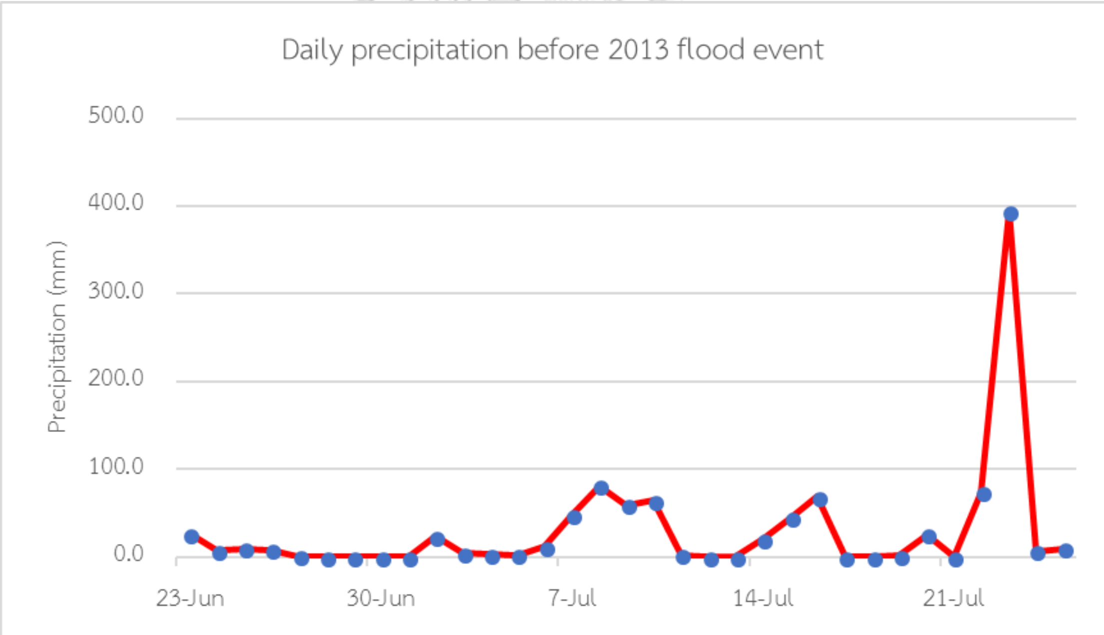

Figure 56 Daily precipitation of Muang Chanthaburi at Chanthaburi Meteorological Station in 2006 flood event. (Source from Climate Information Services, Thai Meteorological Department)

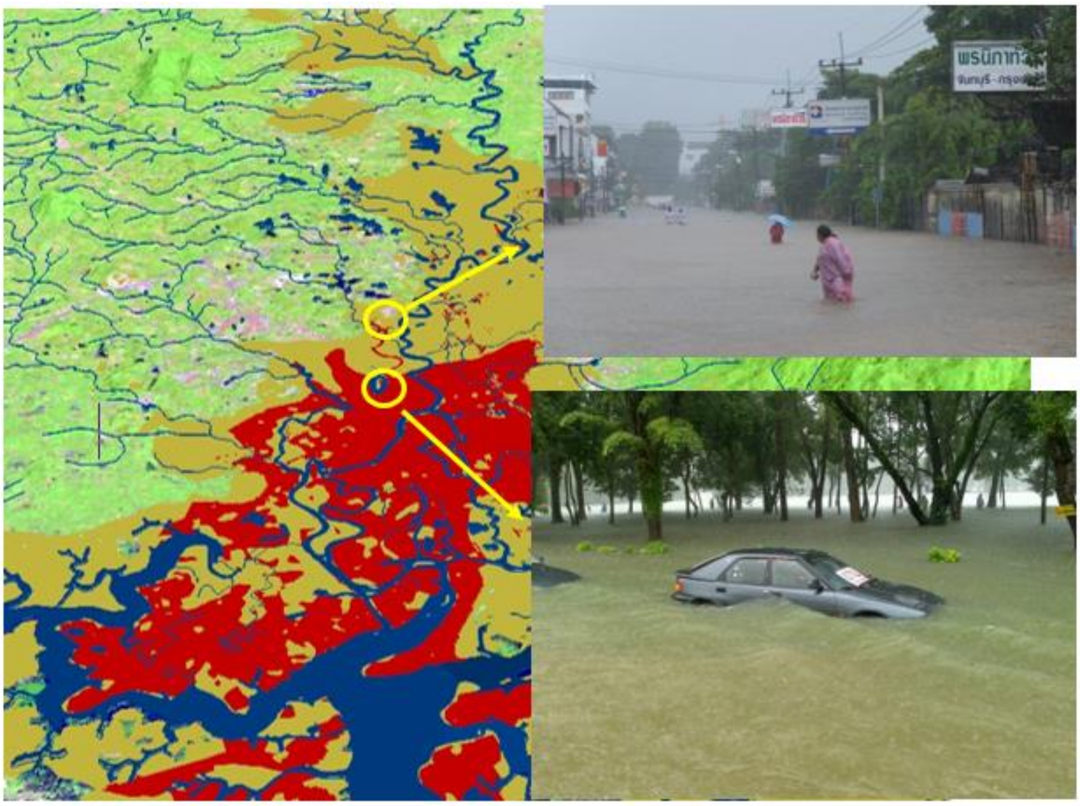

Figure 57 Affected areas of 2013 urban flood in Muang Chanthaburi.

Figure 58 Affected areas of 2013 urban flood in Muang Chanthaburi.

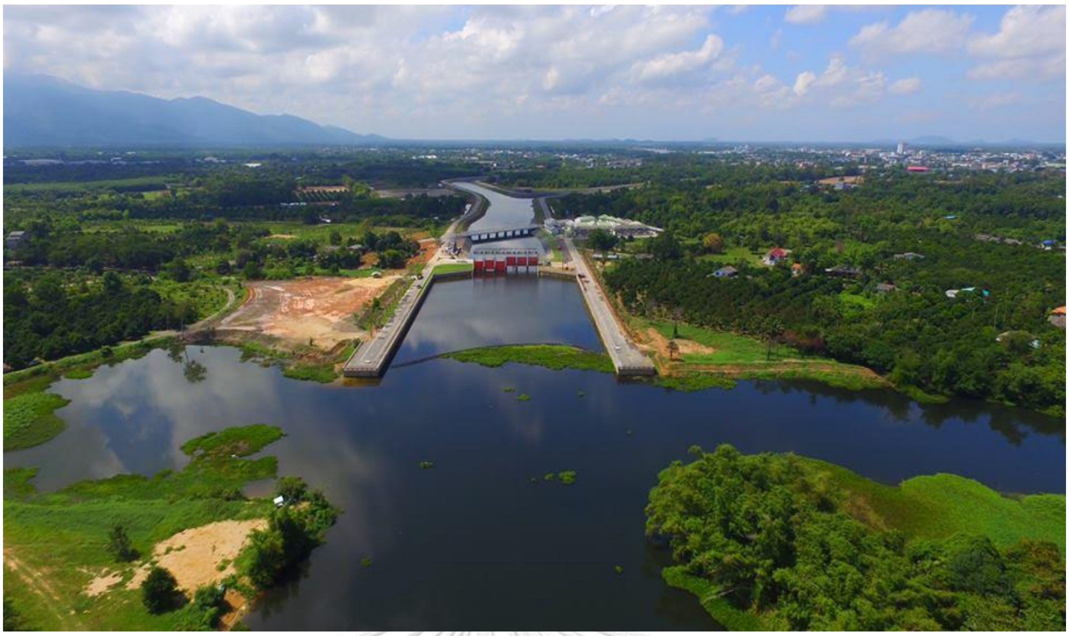

Figure 59 The beginning points of floodway as known as Klong Bhakti Rambhai.
(Source from Royal Irrigation Department)

5.2 Conclusion

In this research, GIS and RS data were carried out to investigate spatial pattern of LULC and to identify change of LULC after 1999, 2006 and 2013 flood in Chanthaburi watershed, Chanthaburi province. Moreover, the purpose of this study was to generated flood vulnerability Chanthaburi watershed, Chanthaburi province, Eastern Thailand.

This study used the temporal Landsat-5 TM, Landsat-7 ETM+ and Landsat-8 OLI imageries covered the Chanthaburi watershed before and after flood in 1999, 2006 and 2013. These images were created the false color composite (Bands R=5, G=4, B=3 for Landsat-5 TM and Landsat-7 ETM+ and Bands R=7, G=5, B=3 for Landsat-8 OLI) for the LULC classification with supervised classification process using Maximum likelihood algorithm. After the classification process, there are 9 LULC categories consist of paddy field, field crops, para rubber, orchard, aquaculture, forest, mangrove, urban and built-up area and water bodies. The result of classification was checked by field investigation and calculated the overall accuracy assessments of LULC classifications before and after 1999, 2006 and 2013 flood, the result shows that the value of overall accuracy of all images classification are more than 85 %, namely 89.2%, 86.8%, 85.1%, 87.4%, 87.0% and 88.6%, respectively, which indicated that this classification was acceptable.

After the classification, the 9 classes of LULC types were reclassified into 4 main classes, namely agricultural land, forest land, urban and built-up land and water bodies. The Change detection of LULC of Chanthaburi watershed after 1999, 2006 and 2013 flood were analyzed by using overlay technique in ArcGIS version 10.2.2. The results revealed that agricultural land was increased after 1999 and 2006 flood, but after 2013 flood, it was decreased due to the urban expansion around sub-urban of Chanthaburi district. However, although the agricultural land was decreased after 2013 flood, some area of agricultural types was increased such as orchard area.

The pattern of LULC revealed that agricultural land, especially, orchard area is a main type of LULC that covers with an area more than 30% of Chanthaburi watershed. It has constantly increased after 1999, 2006 and 2013 flood due to an increased global demand of fruit products such as durian, mangosteen etc. which are the popular fruits and has a higher price than other agricultural product. Besides, the forest land nearby the mountain area was transformed into agricultural land, and water bodies

The urban and built-up area is outstanding in term of increasing rate that has constantly increase since after 1999 flood to 2013 flood, especially in Muang Chanthaburi district. There are many reasons of urban and built-up area increasing such as improved infrastructure, economics changes, the rising in population growth and new building and residence construction. In addition, the agricultural land has shifted to urban and built-up area because the settlements are mostly surrounded by agricultural area consists of paddy field, para rubber and orchard. It can be seen from this study that socioeconomics is the important factor which affect pattern of LULC change

The flood vulnerability map of Chanthaburi watershed was created based on DEM, landform, flood inundation area and LULC. The result of classification will be shown as flood vulnerability map. The result revealed that there are 3 level of flood vulnerability in Chanthaburi watershed, namely high flood vulnerability, low flood vulnerability and non-flood vulnerability. Most of urban area of Muang Chanthaburi district located in area of high flood vulnerability.

Moreover, the urban area of Muang Chanthaburi which located in area of high flood vulnerability because this area is important for economics and residential density is higher than other areas. It indicates that urban and built-up area of Muang Chanthaburi district located at the higher flood vulnerability area than another LULC types, so proper management and flood control structure are necessary because of its vulnerability.

By the way, the flood control structure as known as floodway (Khlong Bhakti Rambhai) was constructed in Chanthaburi watershed for flood impact mitigation in center of the Muang Chanthaburi. This floodway can reduce the impact of a riverine flood, but the urban flood can still occur in the urban area due to urban expansion.

The integration of GIS and RS data provided the spatial data of LULC and flood vulnerability map, all data were used as a tool and guideline for planning in the watershed. Hence, these results suggest a method that can apply to other areas for LULC management and reducing the impact caused by flood hazard.

5.3 Recommendation

5.3.1 Another satellite imagery can apply for this study because Landsat imageries have some limitation such as the recording time and cloud cover, so it difficult to get the image which was immediately recorded after the flood. The satellite which can capture the flood inundation without cloud clover will be a great tool to generate flood hazard area.

5.3.2 There are various method to achieve the flood vulnerability area map, in this study, physical characteristics of area and LULC were applied to analyzed flood vulnerability area. Furthermore, population data, infrastructure data, flood damage in residential property and another.

5.3.3 In recent year, urban flood management become a famous topic for urban study due to high rate urban expansion. The flood vulnerability in the urban zone is a serious problem that government should attend to learn by using GIS and RS data which is an effective tool and reasonable for management and planning.

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APPENDIX

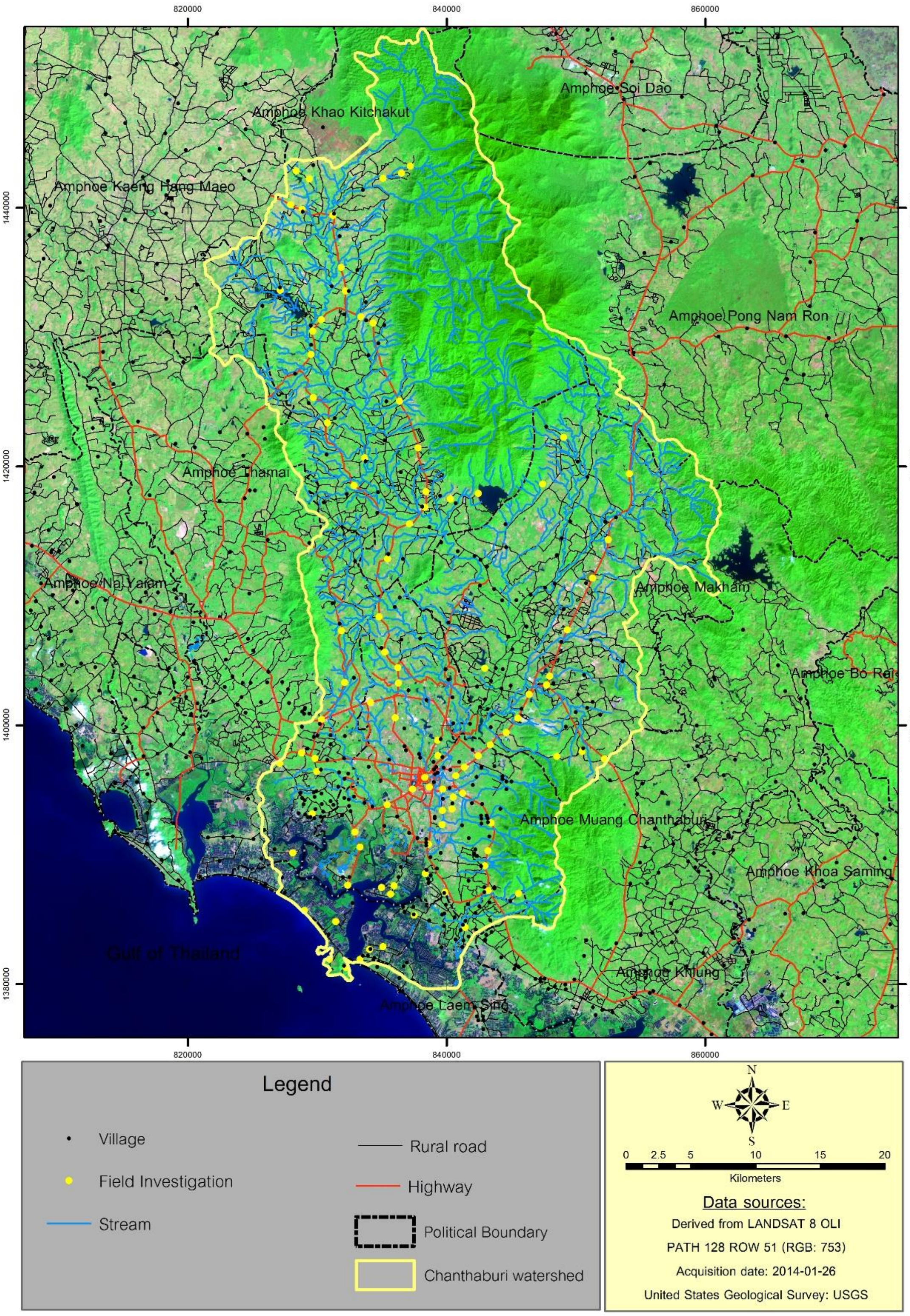
GIS data of field investigation

No.	East	West	LULC Level 1	LULC Name	Notation
1	841236	1394735	U00	Urban and built-up	Klong Toei
2	839691	1395069	A01	Paddy field	Thung Sabap
3	838654	1395215	U00	Urban and built-up	Treerat road
4	840709	1396112	A04	Orchard	
5	841365	1396772	U00	Urban and built-up	
6	842444	1397634	U00	Urban and built-up	
7	843372	1398506	U00	Urban and built-up	Wat Nong Or
8	844606	1399438	A04	Orchard	
9	845511	1400569	A03	Para rubber	
10	846381	1402388	U00	Urban and built-up	
11	847719	1403119	U00	Urban and built-up	Ban Makham School
12	847967	1403792	W00	Water bodies	Nong Taphong
13	849335	1407376	A03	Para rubber	
14	851279	1411387	A02	Field crop	
15	852487	1414361	F01	Forest	
16	854112	1419442	F01	Forest	
17	838318	1395961	U00	Urban and built-up	Wat Khet Nabunyaram
18	837376	1395080	U00	Urban and built-up	Park
19	836015	1400591	U00	Urban and built-up	Ban Kaew
20	836268	1403268	A04	Orchard	
21	836228	1404457	U00	Urban and built-up	Resort
22	835204	1405662	A02	Field crop	Wat Chamsom
23	834764	1408386	U00	Urban and built-up	
24	835433	1412884	U00	Urban and built-up	Chak Thai Municipality Office
25	837125	1415587	U00	Urban and built-up	Ban Hin Loi
26	838315	1416867	U00	Urban and built-up	Ban Krathing
27	840293	1417505	A04	Orchard	
28	842446	1417941	W00	Water bodies	Phluang Dam

No.	East	West	LULC Level 1	LULC Name	Notation
29	838395	1418064	U00	Urban and built-up	Khao Kitchakut Hospital
30	837773	1421449	U00	Urban and built-up	Rajamangala University of Technology
31	836351	1425050	A04	Orchard	
32	834307	1431103	A04	Orchard	
33	833371	1431583	A01	Paddy field	
34	827136	1433643	W00	Water bodies	San Sai Reservoir
35	832186	1433590	A03	Para rubber	
36	831837	1435418	A04	Orchard	
37	831216	1439414	U00	Urban and built-up	Ban ChanKhlem
38	828840	1439897	A02	Field crop	
39	827928	1440251	A03	Para rubber	
40	828379	1442869	W00	Water bodies	Sathon Reservoir
41	829385	1442261	A04	Orchard	
42	837190	1443250	A04	Orchard	
43	836505	1442699	A03	Para rubber	
44	835083	1442291	A03	Para rubber	
45	830313	1431379	U00	Urban and built-up	
46	829638	1430500	U00	Urban and built-up	
47	829507	1428683	A04	Orchard	
48	829700	1425335	A03	Para rubber	
49	830793	1423379	U00	Urban and built-up	
50	833655	1420682	A04	Orchard	
51	832841	1418523	A04	Orchard	
52	834112	1401775	U00	Urban and built-up	Government Office
53	830338	1400446	U00	Urban and built-up	Ban Nern Soong
54	832119	1403321	A03	Para rubber	
55	831874	1407308	A04	Orchard	
56	827102	1397054	U00	Urban and built-up	Downtown of Tha Mai City

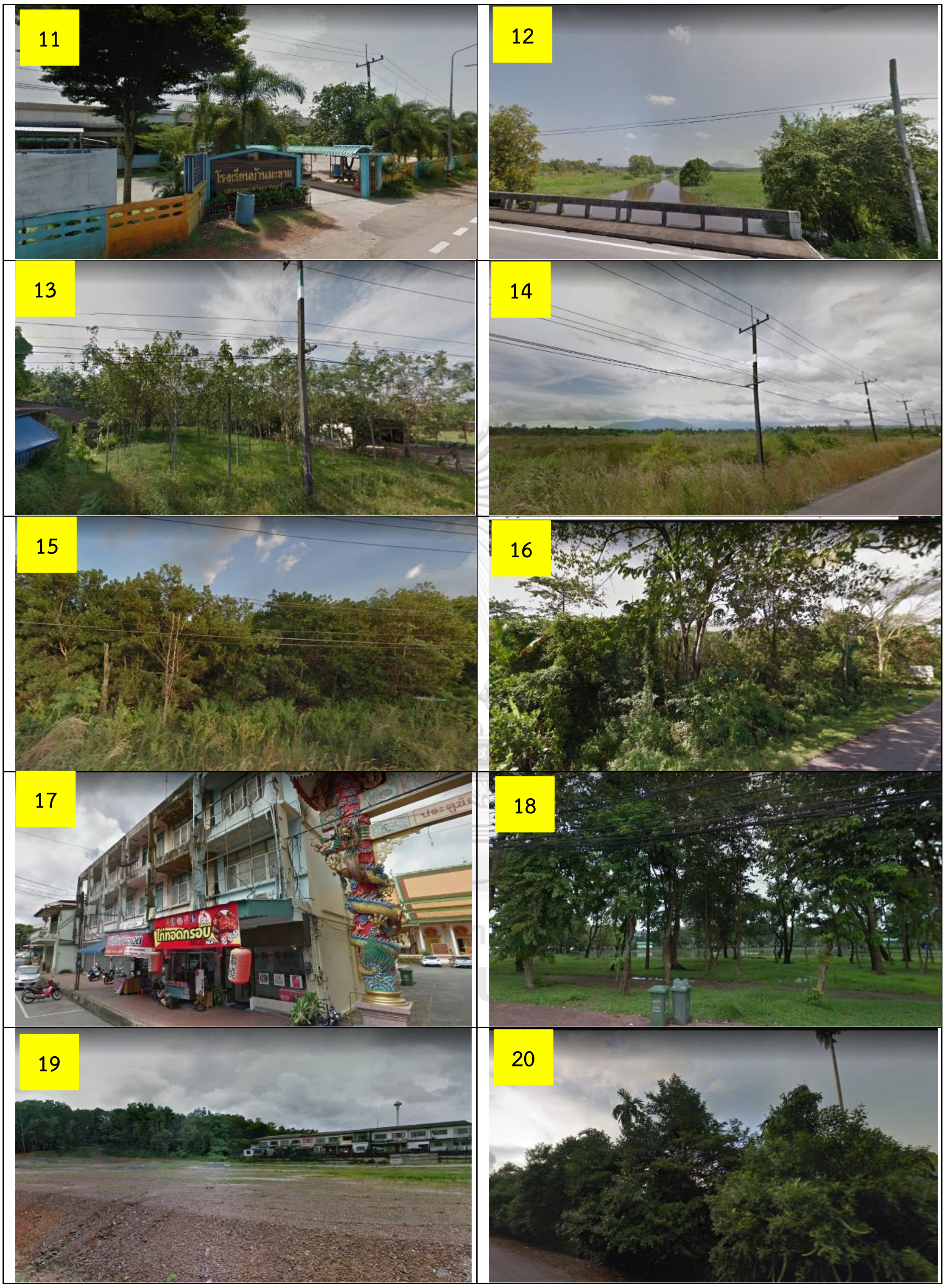
No.	East	West	LULC Level 1	LULC Name	Notation
57	828794	1397864	U00	Urban and built-up	Tha Mai Airport
58	829817	1397446	A04	Orchard	
59	829962	1396424	U00	Urban and built-up	Ban Cham Khor
60	829609	1393161	W00	Water bodies	
61	832905	1391750	F02	Mangrove	
62	833301	1390584	F02	Mangrove	
63	832363	1387632	U00	Urban and built-up	
64	835400	1393854	U00	Urban and built-up	Phra Yeun Park
65	838592	1390813	U00	Urban and built-up	Ban Koh Ta Khian
66	834958	1387454	W00	Water bodies	
67	835664	1386952	A05	Aquacultural	
68	835935	1387604	A02	Field crop	
69	841436	1384381	U00	Urban and built-up	Ban Lang Talad
70	845552	1387009	F00	Forest	Namtok Phlio National Park
71	837494	1385331	U00	Urban and built-up	Ban Klang
72	833298	1381894	U00	Urban and built-up	Laem Sing Bridge
73	832231	1381262	A04	Orchard	
74	830948	1381914	F00	Forest	
75	829006	1385676	W00	Water bodies	
76	831419	1384834	F02	Mangrove	
77	828113	1390139	A05	Aquacultural	
78	852211	1397399	A03	Para rubber	
79	850466	1397971	A03	Para rubber	
80	843426	1392446	A03	Para rubber	
81	843188	1390303	A03	Para rubber	
82	842959	1389140	U00	Urban and built-up	Ban Khombang Lang
83	843210	1387223	U00	Urban and built-up	Ban Nong Khon
84	839310	1398845	W00	Water bodies	Sa Nam Ban Nong Sanguan
85	839316	1397668	U00	Urban and built-up	Yang Weir

No.	East	West	LULC Level 1	LULC Name	Notation
86	842944	1404418	W00	Water bodies	
87	840511	1394461	A05	Aquacultural	Bor Ake fishing park
88	840421	1393524	W00	Water bodies	Klong Bhukti Rambhai
89	839680	1393422	W00	Water bodies	
90	839648	1392319	A01	Paddy field	
91	838347	1388532	U00	Urban and built-up	Ban Nong Bua Lang
92	839880	1387099	U00	Urban and built-up	Ban Nern Pho Bon
93	848503	1397594	F01	Forest	
94	847414	1418652	A03	Para rubber	
95	849046	1422269	A04	Orchard	
96	834056	1382663	A01	Paddy field	
97	835082	1382894	A05	Aquacultural	



Field investigation location

Photographs illustrating locations of the field investigation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VITA

Mr. Chuti Chatewutthiprapa was born in Chanthaburi, Thailand on September 18, 1991. In 2013 he received a Bachelor of Arts degree in Geography with first class honors from Department of Geography, Faculty of Arts, Silpakorn University. After then he entered the Earth Sciences program, Department of Geology, Faculty of Science, Chulalongkorn University for a Master of Science degree study.