การเปลี่ยนแปลงการใช้พื้นที่เนื่องจากการใช้ทรัพยากรธรรมชาติ บริเวณเขาเจ็ดลูกและพื้นที่ใกล้เคียงจังหวัดพิจิตร

นางสาวพัชราภา ลิ่มพงศธร

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
สาขาวิชาโลกศาสตร์ ภาควิชาธรณีวิทยา
คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2547

ISBN 974-17-5170-2

LANDUSE CHANGE DUE TO NATURAL RESOURCES EXPLOITATION IN KHAO CHET LUK AND ADJACENT AREA, CHANGWAT PHICHIT

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A Thesis Submitted in Partial Fulfillment of the Requirements
For the Degree of Master of Science in Earth Science
Department of Geology
Faculty of Science
Chulalongkorn University
Academic Year 2004
ISBN 974-17-5170-2

Thesis Title	Landuse change due to natural resources exploitation in Khao Chet Luk and adjacent area, Changwat Phichit
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พัชราภา ลิ่มพงศธร : การเปลี่ยนแปลงการใช้พื้นที่เนื่องจากการใช้ทรัพยากรธรรมชาติบริเวณเขาเจ็ดลูกและพื้นที่ใกล้เคียงจังหวัดพิจิตร, (LANDUSE CHANGE DUE TO NATURAL RESOURCES EXPLOITATION IN KHAO CHET LUK AND ADJACENT AREA, CHANGWAT PHICHIT) อ. ที่ปรึกษา : ผศ.ดร. นภดล ม่วงน้อยเจริญ, อ.ที่ปรึกษาร่วม : นางสุรีย์ ธีระรังสิกุล 169 หน้า. ISBN 974-17-5170-2

การศึกษาสภาพการเปลี่ยนแปลงการใช้พื้นที่บริเวณเขาเจ็ดลูกและพื้นที่ใกล้เคียงจังหวัดพิจิตร รวมพื้นที่ 677.136 ตร.กม. ระหว่างปี พ.ศ. 2512 ถึง พ.ศ. 2543 สามารถแบ่งลักษณะการใช้พื้นที่ออกเป็น 7 ประเภท ได้แก่ นาข้าว ป่าชุ่มน้ำ ป่าสงวน ทุ่งหญ้าหรือไม้พุ่ม พื้นที่พืชไร่สวนผสม บริเวณที่อยู่อาศัย และ เหมืองทองคำ จากการวิเคราะห์รูปแบบการเปลี่ยนแปลงการใช้ที่ดินโดยระบบสารสนเทศภูมิศาสตร์พบว่า มีการเปลี่ยนแปลงการใช้ที่ดินคิดเป็นร้อยละ 39.58 ของพื้นที่ทั้งหมดโดยการใช้พื้นที่ที่มีการเปลี่ยนแปลงมากที่สุดคือพื้นที่ป่าสงวนซึ่งถูกเปลี่ยนไปเป็นพื้นที่เกษตรกรรมซึ่งเพิ่มขึ้นจากเดิมร้อยละ 63.34 เป็น ร้อยละ 94.08 โดยการเพาะปลูกกระทำอยู่ในพื้นที่ดินที่มีระดับความอุดมสมบูรณ์ปานกลางถึงต่ำ และมีการใช้ที่ดินเหมาะกับสภาพดินอยู่ร้อยละ 77

การศึกษาด้านประชากรเศรษฐกิจและสังคมพบว่าประชากรในพื้นที่ศึกษาตั้งแต่ปี พ.ศ. 2513 ถึง 2543 ไม่ได้เพิ่มขึ้นตามเวลาแต่กลับมีแนวโน้มลดลงเนื่องจากพื้นที่ศึกษามีสภาพแห้งแล้งและอยู่ห่างไกลความเจริญ แต่ในระหว่างปี พ.ศ. 2537 ถึง 2541 มีการค้นพบทองคำและมีการทำเหมืองในพื้นที่ศึกษา ทำให้มีประชากรจำนวนมากเคลื่อนย้ายเข้ามาทำการร่อนทอง หลังจากนั้นจำนวนประชากรก็ลดลงและเริ่มกลับสู่แนวโน้มแบบเดิม

ในการศึกษาครั้งนี้มีการจำลองการใช้ที่ดินในอนาคตโดยยึดหลักว่าเหตุการณ์ในอนาคตจะยังคงเหมือนในปัจจุบัน โดยจะพบว่าพื้นที่นาข้าว, เหมืองทองคำและที่อยู่อาศัยจะเพิ่มขึ้น ขณะที่ประชากรจะมีจำนวนเพิ่มขึ้นด้วย แต่หากว่ามีสถานการณ์ใหม่ๆเกิดขึ้น จำนวนประชากรก็จะแปรผันไปตามสถานการณ์นั้นๆ

ปัญหาสำคัญของพื้นที่ศึกษาคือการขาดแคลนน้ำเนื่องจากไม่มีโครงการชลประทานในพื้นที่ ดังนั้นเกษตรกรจึงต้องพึ่งพาฝนและน้ำบ่อซึ่งมีไม่เพียงพอในฤดูแล้ง และส่งผลกระทบต่อผลผลิตที่ต่ำลง รายได้ลดลงและประชากรลดลงในที่สุด

ภาควิชา ธรณีวิทยา ลายมือชื่อนิสิต ....

สาขาวิชา โลกศาสตร์ ลายมือชื่ออาจารย์ที่ปรึกษา ....

ปีการศึกษา 2547 ลายมือชื่ออาจารย์ที่ปรึกษาร่วม ....

4472346523 : MAJOR EARTH SCIENCE

KEY WORD: LANDUSE CHANGE/ PHICHIT

PATCHARAPA LIMPONGSTORN: LANDUSE CHANGE DUE TO NATURAL RESOURCES EXPLOITATION IN KHAO CHET LUK AND ADJACENT AREA, CHANGWAT PHICHIT. THESIS ADVISOR ASST.PROF.NOPADON MUANGNOICHAROEN, Ph.D., THESIS COADVISOR : MRS. SUREE TEERARUNGSIGUL, 169 pp. ISBN 974-17-5170-2

A 677.136 km^2 area at and around Khao Chet Luk in Changwat Phichit was studied for the landuse change between 2512 B.E. and 2543 B.E. The landuses were classified into 7 types namely paddy field, marsh and swamp, conservation forest, shrub and grassland, mixed crop field, village, and gold mine. The analysis of change pattern of landuse by using geographic information system (GIS) revealed that the greatest change in 2512 B.E. to 2543 B.E. is especially the conservation forest, which was destroyed lavishly for agricultural purpose, which increases from 63.34% to 94.08% of the area, and 39.58% of the total area has been changed in landuse pattern. The laboratory soil test, and soil fertility suggests that the agricultural performance in this area is done on medium to low quality soils where only about 77% of the area is properly used.

The study on population, socials and economics of the area indicates no increasing along time of population from 2513 B.E. to 2545 B.E. Instead, it tends to decrease, probably due to the remoteness and drought nature of this undeveloped area. However between 2537 B.E. and 2541 B.E. the population largely increased due to gold finding and production here. After then the population slightly decreased to return to its previous decreasing trend.

It was noted that the future, if the social and economic conditions remain the same as present, there is a landuse for tendency only paddy field, gold mine and village areas will increase while population also slightly increase. But this trend could be changed if any new situation is occurred.

The serious problem of this area is water shortage as there is no irrigation system. The agriculture must rely only on the rain and limited surface water which always is not enough in dry season and which results as low productivity, low income, and low population finally.

Department ....Geology........ Student's signature ....

Field of study ....Earth Science........ Advisor's signature ....

Academic Year ....2004........ Co-advisor's signature ....

ACKNOWLEDGEMENTS

The author is indebted to a number of persons for their constant support and encouragement toward the successful completion of this study.

The author wishes to express the deepest gratitude to Assistant Professor Dr. Nopadon Muangnoicharoen, advisor, for his suggestions and valuable guidance and encouragement throughout the study. An equal appreciation is expressed to Mrs. Suree Teerarungsigul, her co-advisor.

Special acknowledgement goes to Assistant Professor Veerote Daorerk, Assistant Professor Dr. Somchai Nakapadungrat, and Mr. Worawoot Tantiwanit for their valuable advises, comments, and reading the manuscript.

Sincere thanks are due to Ms. Darinporn Jeampraditkul for her comradeship in everything, to Mrs. Malatee Taiyakupt for her time and willingness and her valuable suggestions about laboratory soil test, to Ms. Sujitra Charoenhirunyingyoj, who helpfully advised the computer programming that used in this study. Their wonderful help is memorable.

Moreover, a great appreciation is directed to personnel of Chatree Gold Mine who support during the field study. Thanks are extended to Mr. Vichian Inmung for the assistance and support about interview local people and reconnaissance the study area.

Profound thanks are expressed to Mr. Atapong Trakulmokthong for the regularity of warm encouragement.

Her respectfulness and love are expressed to her parents, Mr. Paisan Limpongstorn and Mrs. Suwimon Limpongstorn, for their loves, continuous encouragement, financial support, and understanding. Special thanks are for her lovely siblings, Ms. Skawduean Limpongstorn, Ms. Pintong Limpongstorn, and Mr. Pitchasith Limpongstorn, for their closely watch and push her through the study and all best things they did for her until she made a good haul finally.

Sincere thanks are also extended to all her friends for their encouragement and assistance in various aspects throughout the course of the study. Additionally, without mentioning their name, the author's gratitude is truly expressed to all those who generously provide supports for this study until it's complete.

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Glossary of Thai words

Changwat – Province : Administrative area within the country

Amphoe – District : Sub-administrative area within Changwat

Tambon – Tambon : Sub-administrative area within Amphoe

Ban, Moo Ban – Village : A collection of houses and other buildings in a country area that is the smallest unit of local government.

Rai : Size of area. One Rai is 400 square wa or 1,600 square meter

Buddhist Era (B.E.) : The year, 543 years before anno Domini (A.D.) 2543 B.E. is the same as 2000 A.D.

CHAPTER I
INTRODUCTION

1.1 Background

Landuse is a product of human decisions operating within the social, political and legal frameworks (Mather, 1986). Nowadays, we always use the land lavishly, wastefully, and carelessly. The population growth and economic development, especially during the last generation or two, make us realize that a good land, conveniently located to our needs, is scarce. While air, water, and wildlife have mobility, land is stationary. This simple reality allows land resources to be easily claimed and developed for either private or public gain. Thoughtful persons are much disturbed at the reckless exploitation of the land.

As the population increases and level of affluences rises, that makes greater demands from the land until the limit of the area's ability to supply is reached. Uncontrolled population growth causes disaster since it induces both environmental and ecological destruction through excessive deforestation, urbanization, agricultural development, overgrazing etc. In the other words, the improper development has accelerated towards a crisis of famine, as a result of extreme consumption of natural resources.

To understand a landuse change as an element of environmental change, it is necessarily to specify the links between the human systems which generate changes in landuse and the physical systems that are affected by the resulting changes in landuse.

The present study is in an area which is rural and non-irrigational, and has received less attention. Until recently, gold deposits were discovered that brings this area to be a gold mineral economic region of Phichit–Phetchabun-Phitsanulok gold deposit area. At least two important gold deposits were found in this area, one at Khao Phanompha that caused a huge gold rush in 1994 (2537 B.E.), and the other at Khao

Mo-Khao Pong where Akara Mining Limited presently holds a concession. The gold deposit concession at Khao Phanompha was later granted to the Phichit Provincial Administrative Organization.

Finding gold had converted parts of a fairly good agricultural land into wasteland full of fox holes and pits. It also resulted in sudden economic jump and interplayed to employment in mining and the related services with a larger income than from agriculture. Therefore, the landuse pattern had changed widely that causes the environmental impact such as soil erosion, dust pollution, trespassing on national forest, loss of vegetation, development of transportation, leaching of contaminants into water, and increasing of waste products.

Comparison of the change of landuse pattern from the past to the present will explain the change in the environment together with the social, and cultural changes. And a precise consideration of some data can be predicted to the future change.

In this study, many Thai words are used and necessary to explain for the understanding in this report.

1.2 Location and administration of the study area

The study area is at the boundary between central and northern Thailand, covering an area of 677.136 square kilometers (km^2) or 423,210 rais. It lies between Latitudes 16° 07’ 49” N to 16°30’ 27” N and Longitudes 100°30’ 27” E to 100°44’ 22” E, being covered in the topographic maps, scale 1:50,000, Sheets 5141 III (Amphoe Thap Khlo) and 5141 IV (Amphoe Wang Sai Phun). It consists of parts of Amphoe Wang Sai Phun, Amphoe Thap Khlo, Amphoe Taphan Hin, and Amphoe Muang Phichit of Changwat Phichit, Amphoe Chon Daen and Amphoe Wang Pong of Changwat Phetchabun, and Amphoe Noen Maprang of Changwat Phitsanulok. The administrative districts are further subdivided into 16 Tambons. This area is about 380 kilometers from Bangkok and could be reached via 2 potential routes from Bangkok. The first route is

Phahonyothin Highway no.1 – Asian road (Highway no.32) – Highway no.117 – Highway no.115. The alternative route is Phahonyothin Highway no.1) – Asian road (Highway no.32) – Highway no.11 – Highway no.111. Figure 1.1 illustrates the location and topography of the area while the administrative areal portions are shown in Figures 1.2, 1.3 and Table 1.1.

1.3 Objectives of the study

The objective of this study is to collect and evaluate basic environment earth-scientific information which might be the controlling factors of the changing of the landuse pattern. The landuse change will be compared with the natural resource exploitation in a period of about 30 years, from the years 2512 B.E. till 2543 B.E. Then a prediction of the tendency of the future landuse pattern into the year 2550 B.E. is attempted.

1.4 Methodology

The methods of study are as shown in Figure 1.4. The explanation of the methods is as followed.

1.4.1 Basic background data

The basic background data were collected from the published articles and maps. The most recent condition was verified in the field visit which also included some interview of the local people. The details are as following.

1.4.1.1 Published data

The published data in the period of 30 years are collected from various maps. These include the topography, soil distribution, land usage and infrastructure, land covering, etc., some of which has indicated the change through time. The published reports also give the socio-economic background of the study area.

The socio-economic data were from the reports and official census of the National Statistical Office. These information were best compared to the topographic maps, i.e. modified the data into a uniform and comparable digital pattern. The correctness was later checked by a reconnaissance throughout the study area.

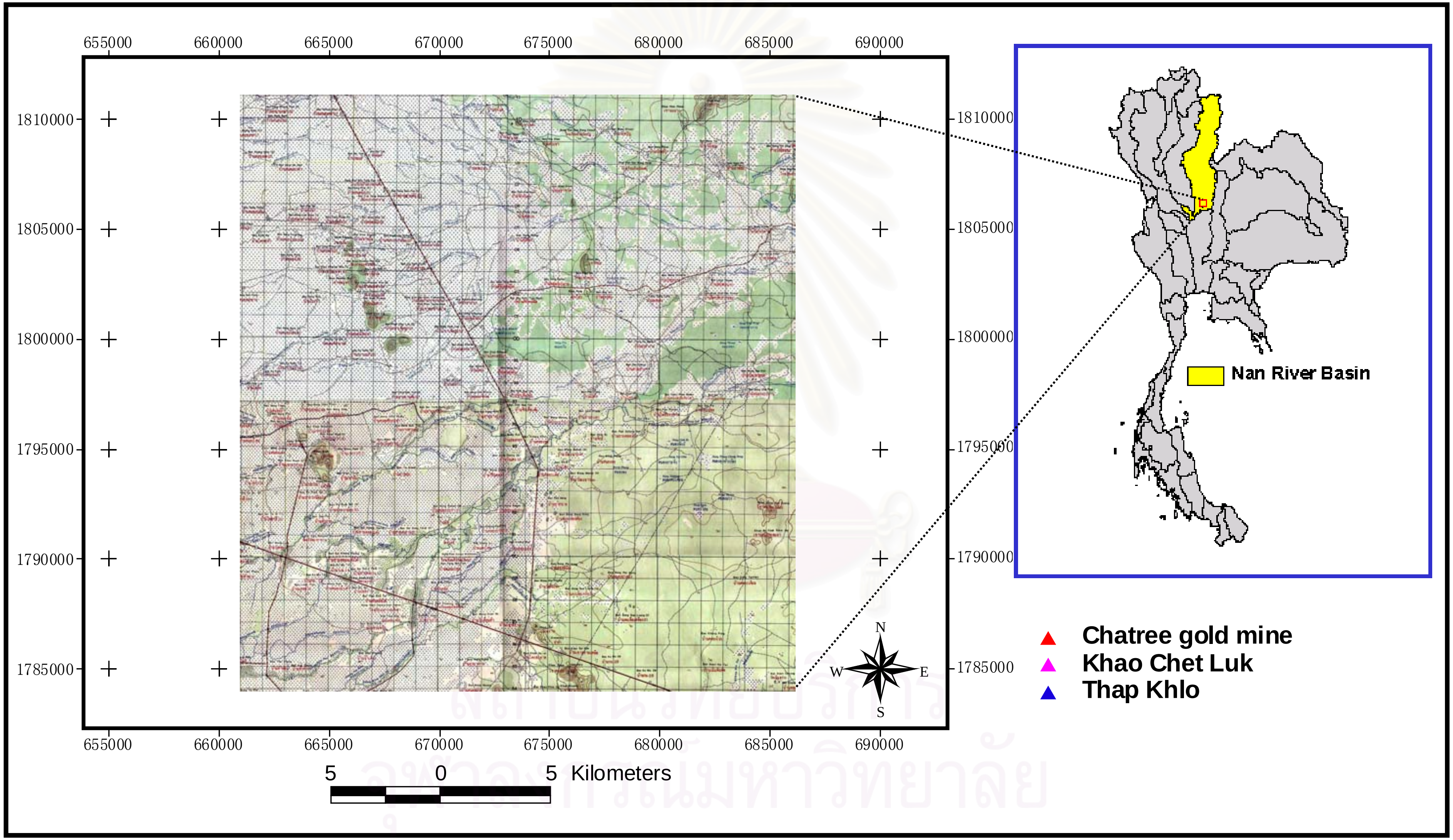


Figure 1.1. Topographic map of the study area. The map is prepared from the 1:50,000 topographic map sheets 5141 III (southern part) and 5141 IV (northern part).

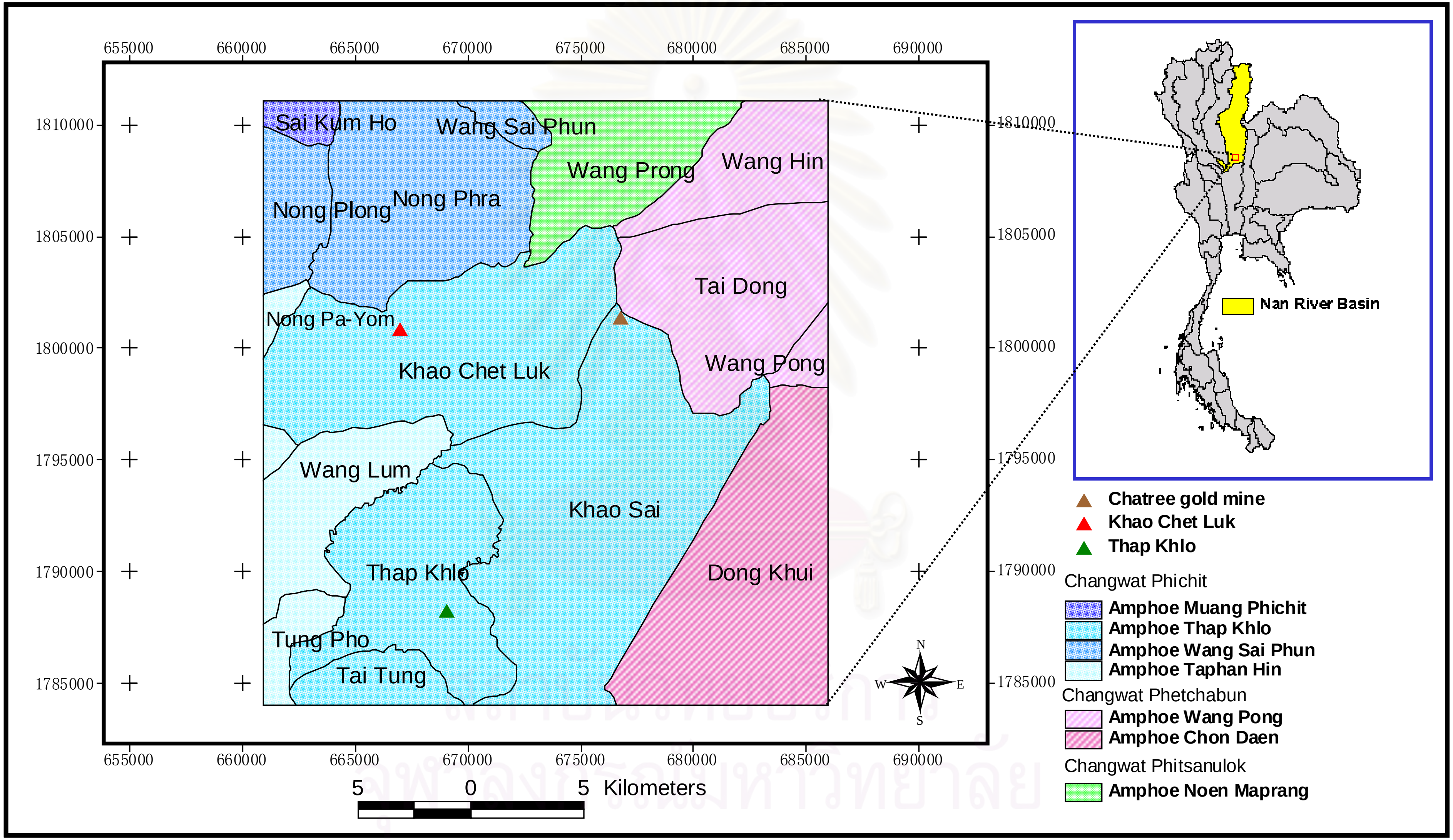


Figure 1.2. Administrative districts (Amphoe) and sub-districts (Tambon) in the study area.

The reports are the statistical reports of Changwat Phichit, years 1996, 1997, 1998, 2001, 2002, and 2003, of Changwat Phetchabun, years 1997, 1998, 2001, 2002, and 2003, of Changwat Phitsanulok, years 1997, 1998, 2001, and 2003.

There are also reports on the population and housing census done by the National Statistical Office which give further socio-economic data. These are the census reports on the population and housing of Changwat Phichit, years 1970, 1980, 1990, and 2001, of Changwat Phetchabun years 1970, 1980, 1990, and 2001, and of Changwat Phitsanulok, years 1970, 1990, and 2001.

Table 1.1. Composition of the administrative areas in this study.

Amphoe (Changwat)	Administrative Area (km^2)	Area in present study (km^2)	Percentage of administrative area studied	Percentage in study area
Muang Phichit (Phichit)	704.025	6.026	0.86%	0.89%
Taphan Hin (Phichit)	4,620.412	46.372	10.04%	6.85%
Wang Sai Phun (Phichit)	272.467	101.964	37.42%	15.06%
Thap Khlo (Phichit)	404.319	298.118	73.73%	44.03%
Wang Pong (Phetchabun)	505.062	107.916	21.37%	15.93%
Chon Daen (Phetchabun)	1,151.517	82.898	7.2%	12.24%
Noen Maprang (Phitsanulok)	1,100.455	33.842	3.075%	5%
Total		677.136		100%

Note: Percentage of areas derived from a GIS analysis done in this study.

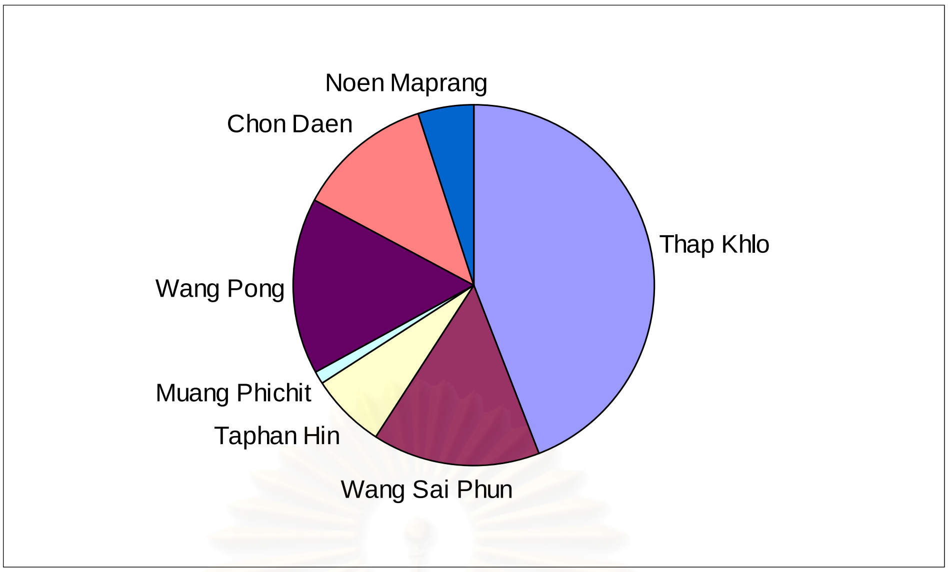


Figure 1.3. Proportion of the administrative areas in this study.

- The topographic maps, 1:50,000 scale, Series L7017, sheets 5141 III (Khao Sai, updated until 2512 B.E. and Amphoe Thap Khlo updated until 2538 B.E.) and 5141 IV (Wang Sai Phun, updated until 2512 B.E. and Amphoe Wang Sai Phun, updated until 2531 B.E.), of the years 2512 B.E. and 2531 B.E. are from the Royal Thai Survey Department. The maps provide information of the topography (drainage system), which does not obviously change within a short period of time (2512 B.E. till 2545 B.E.). The other information including the types of landuse (agricultural, living) and concerning infrastructures illustrated in the maps of different periods, thus, indicating the changing through time.
- The landuse map in 2531 B.E. from the Department of Land Development can be compared with the 2531 topographic base map 1:50,000 above. The change of the landuse pattern between 2512 B.E. till 2531 B.E. was thus inferred from the change observed in the topographic maps mentioned above.
- The landuse and soil maps in 2543 B.E. are from the Department of Land Development. These maps were used to observe change of landuse between 2531 B.E. to 2543 B.E.
- The groundwater map in 2544 B.E. is from Department of Water Resources.
- The meteorological data between 2529 B.E. and 2545 B.E. are from the Department of Meteorological. These data are used in supporting the study of land suitability.

The field check of the area revealed the most recent areal information of the physical environment data and the present landuse condition. The field study also includes the interviewing of the local residents. The present landuse and land cover had been compared to the topographic maps of 2543 B.E. to understand all change or the stableness of these conditions. The interview was about the social, cultural and economic conditions here.

The soil and water samples were also collected for analytical purposes for this study and other concurrent works of Jeampraditkul (2005) and Chuanchoey (2004). The details of the studies are in the following chapters.

1.4.1 Laboratorial works

Only the soil analysis be reported thoroughly in this present report. This is meant to determine the agricultural value of the land through an evaluation of soil fertility. Other laboratorial study details are shown in the other works, however the results of study will be shared as needed.

In this study, 11 soil samples were collected for such purpose. The determination of soil fertility is based on the following properties.

1.4.2.1 Physical properties: These are the soil texture, the acidity/alkalinity (pH), percentage of organic matter, conductivity, and percentage of salinity.

1.4.2.2 Chemical properties: These are the total exchangeable bases (Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}), micronutrients (Fe, Mn, Cu, and Zn), sulfate (So_4^{2-}), nitrate (NO_3^{-}), and ammonia.

1.4.2 Data management

Data collected from different sources were compiled, reviewed and chosen for the suitable interval of time to compare for the landuse pattern. The map data were rearranged into the comparable pattern and were computerized by means of scanning, grid mapping using Envi 3.2 Software, and digitizing, then inserting tables for spatial data and attribute data respectively. To transform the map data into spatial data in this study, the GIS software programs Arcview 3.2a and Surfer 7.0, were used. The advantages of the programs are that they can collect, analyze, and display digital data, with the geographical coordinate grid composing of graphic data and attribute data.

About the socio-economic conditions in the study area, it was noticed during the field visit that the Buddhist temples could reasonably be used as the indicators for such purpose. By interviewing as well as noticing of the people habit of merit-making and the supporting of the local temples on their structural buildings, a good estimation of the number of local residents, both registered and non-registered, as well as the income of the people surroundings the temples could be done. Also, it was noted that Akara Mining Company, being considered itself as a local association, follows this pattern of resident behavior by joining in the merit-making ceremonies and financially supporting few surrounding temples too.

The population in the study area is problematic as the census is normally done according to the administration boundary, not readily available to specific area like this study area. The population are from population and housing census year 2513 B.E., 2523 B.E., 2533 B.E., and 2543 B.E. and statistical report of Changwat Phichit, Phetchabun, and Phitsanulok in year 2515 B.E., 2524 B.E., 2536 B.E., 2537 B.E., 2538 B.E., 2539 B.E., 2540 B.E., 2541 B.E., 2542 B.E., 2544 B.E., 2545 B.E., and 2546 B.E. The adjustment of the population data must be designed to be according to the study area, and also to include the non-registered population, whom the census could not cover. Other statistical data are also available from National Statistical Office.

The analysis of the collected data by using GIS system is further used to evaluate the landuse change pattern. Evaluation of the landuse change pattern by using an overlaying and intersecting method and to project the future landuse tendency in 2550 B.E. was done by using an equation suggested by Sayan Manmano (2533) and to project the population further into 2560 B.E., by a method suggested by Henry and Heinke (1996). Furthermore, the information of soils and suitable plants are used for making a suitable landuse map by comparing with the 2543 B.E. landuse map.

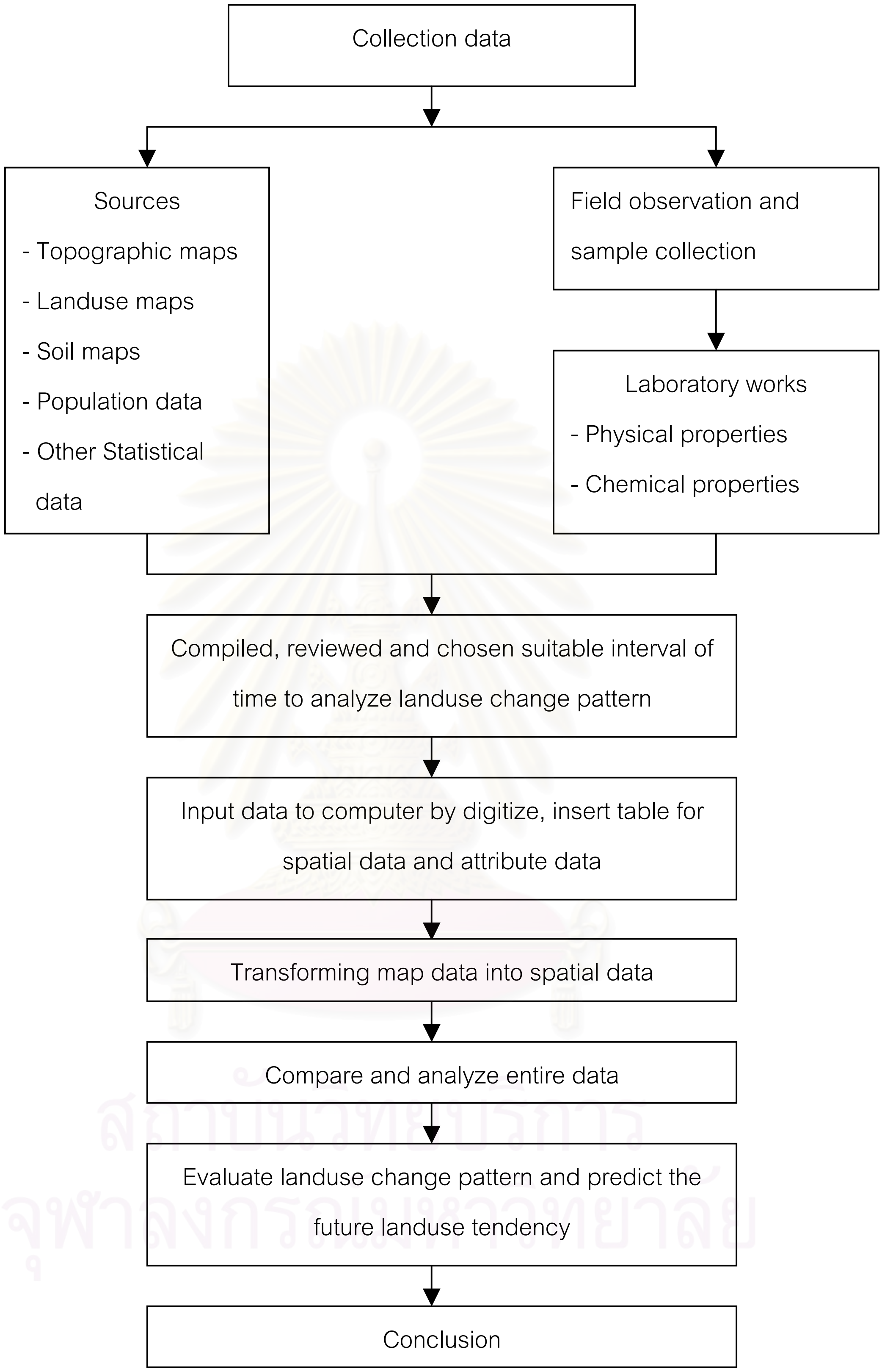


Figure 1.4. Study methodology.

1.5 Previous investigations

A few previous works of similar nature of study, though no areal relationship, were reviewed. They are as following.

Porntip Tungsripong (2541) studied the land cover and landuse change in Khlong Yan Basin, Changwat Suratthani and Changwat Ranong, southern Thailand, and found the relationship between the land cover and landuse change with the stream flow. Most of the decrease of forest area was change into rubber plantation, rice field, other agricultural activity and urban area. The rubber plantation especially occupied 21.85 percent of watershed area. Average annual rainfall and streamflow tend to decreased so, the percent of annual rainfall that change to streamflow also decreased and resulted in shift of timing of peak flow to November.

Prachan Meebun (2539) studied the landuse change in Songkhla Lake Basin during 2525 B.E. - 2537 B.E. aiming to analyze the change in landuse. He found that the change of landuse in all five watershed classes of the Songkhla Lake Basin did not show any consistent trend. Therefore, it appeared necessary to define a proper direction on landuse of the basin based on the potential of each area according to soil and water conservation principles so that it would enhance the sustainable use and development of the basin in the future.

Sayan Manmano (2533) studied the landuse in a 1.5 km^2 plot Bang Buatong municipal area of Changwat Nonthaburi between 2523 B.E. and 2530 B.E. that is 1.5 km^2 and found that there were a slight change of the landuse pattern during that period especially in the residential uses as caused by the population expansion from the crowded Bangkok metropolis, the landuse change was noted as the residential area had increased by 0.0937 km^2or 6.25% of all area.

Walaya Srisung-ngam (2541) identified the spatial distribution and change pattern of recreation landuse in Hua Hin municipality of Changwat Prachuab Khirikhan from 1986 to 1996. The study showed that the landuse pattern in an area of 54,750 rai, approximately 12 per cent of total municipal area, in the past ten years, had been changed. The change was primarily an increasing in the utilization of recreational and commercial landuse.

Somchit Limsawatphol (2538) had used a Geographic Information Systems (GIS) technique to study the landuse and the related problems, the factors that may determine or constrain to the landuses, analysis of potentials and trends as well as recommendation on landuse planning in Changwat Trat. The research revealed that the diversity and richness of natural resources were the basic factors for an economic development. In the past, the natural resources have been utilized for such activities as agriculture. Later, mining was the most important cause of landuse changes and had affected other landuses, and also had an impact on the socio-economic problems, in particular soil, water, and forest resources.

Prachumporn Niratsayakul (2542) compared a landuse change on Sakae Krung Basin, central Thailand, using the data from satellite image in 1990 and 1997 and soil property and suitability for agricultural practices. The result showed that the encroachment of agriculture land into the forest area, which had improper slope for agricultural practices. The expansion of agricultural land increased the total amount of water consumption within the basin since agriculture sector normally consumed more water than any other sectors.

Yaowalak Chokthavorn (2543) studied and compared the characteristics of non-registered population that have activities in the inner city, the urban fringe and the suburb of Bangkok metropolis; and the condition of each area which had so many activities for support them. The research showed no different characteristics of the non-registered population in all areas, with the age ranging between 14 and 59 year old, and with the monthly earning from working in private companies or doing any labour work between 5,000 and 10,000 baht.

1.6 Physical Environmental Characteristics of the Study Area

1.6.1 Land surface

1.6.1.1 Morphology of land surface

The elevation in the study area ranges from 25 to 250 meters above the mean sea level (MSL). The land is generally an undulating to flat terrain, inclining roughly from east to west. Furthermore, small isolated hills or group of hills are found as Khao Mo, Khao Pong, Khao Phanompha, and Khao Chet Luk. The elevation map and contour map as derived from the contour lines by using a triangulated irregular network (TIN) method is shown in Figure 1.5 for slope map and in Figure 1.6 for contour map. Furthermore, a three dimensional elevation model in the study area is shown in Figure 1.7.

1.6.1.2 Drainage system

The study area is in the eastern part of Nan River basin. Here the small tributaries of Nan River flow from Phetchabun Range further to the east. The important streams in Amphoe Thap Klo are Rongkok, Wangdaeng, Wanghinpleng, Wangngew, Khlongmuang and Saiyangrung. Most streams are dry in November through February or March. Only in the rainy season, the stream water flows, commonly with flash floods after a heavy raining. These streams flow westward into the important tributary, Boosabong River in Amphoe Wang Sai Phun, and some other streams in Amphoe Thap Khlo and Taphan Hin to the southwest of the study area. The drainage system of the study area is shown in Figure 1.8.

1.6.2 Geology

The study area is situated in the easternmost edge of the central lowland Chaophraya basin. From Noy Chinpongsanon et al. (2531) and Department of Mineral Resources (2545), the unconsolidated Quarternary sediments underly most of the area except to the east, where the Permo-Triassic volcanic rocks expose on the hills. The rock units are described below, from older to younger, and a geologic map of the study area is shown in Figure 1.9.

1. C1: Carboniferous Limestone, the oldest rocks, are grey to grayish black in color. The rocks are found continuously in small hills off the eastern limit of the study area, and expose occasionally at the pond floor to the south.

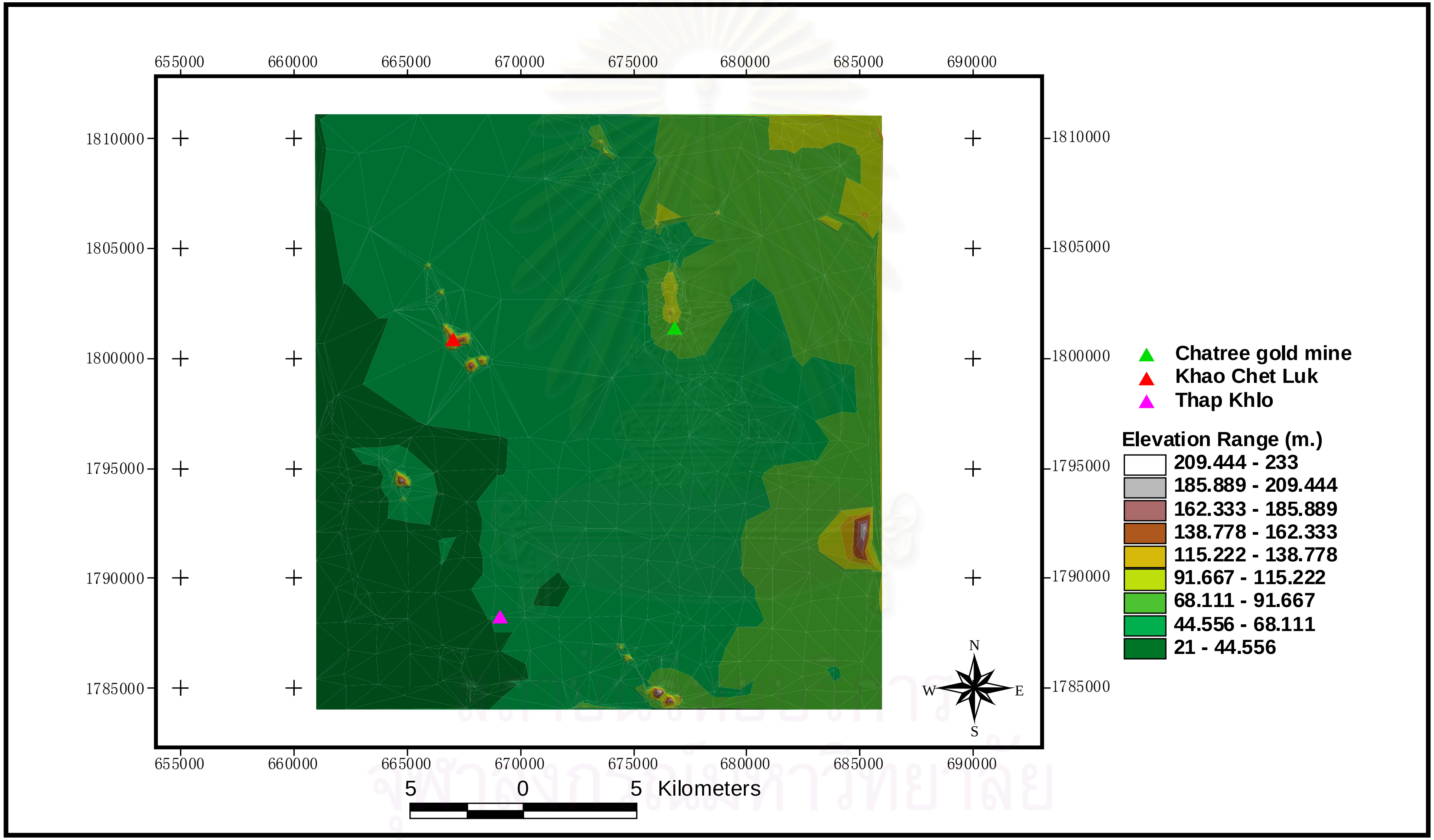


Figure 1.5. Elevation map of the study area as made by triangulated irregular network (TIN) method.

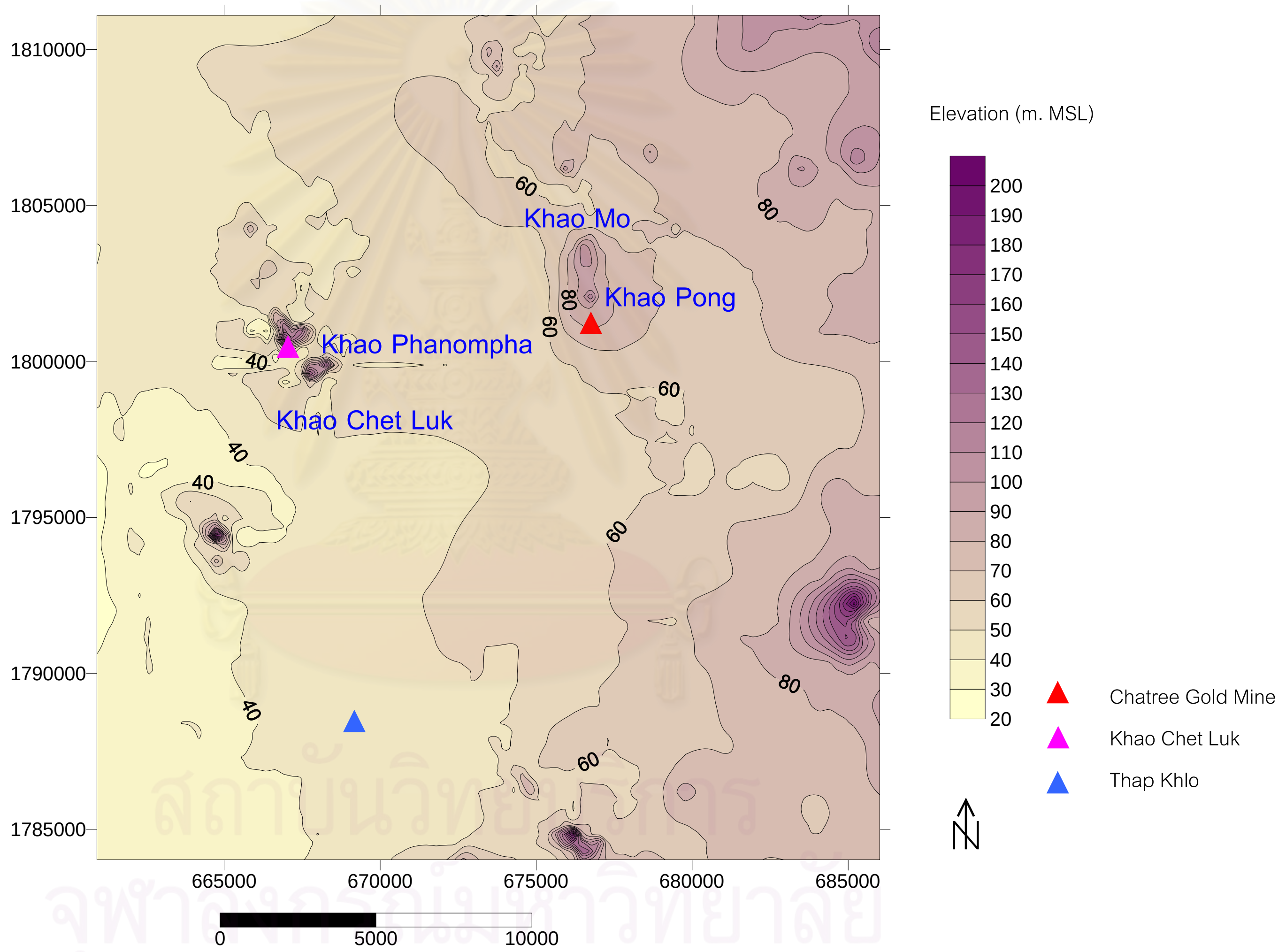


Figure 1.6. Contour map of the study area.

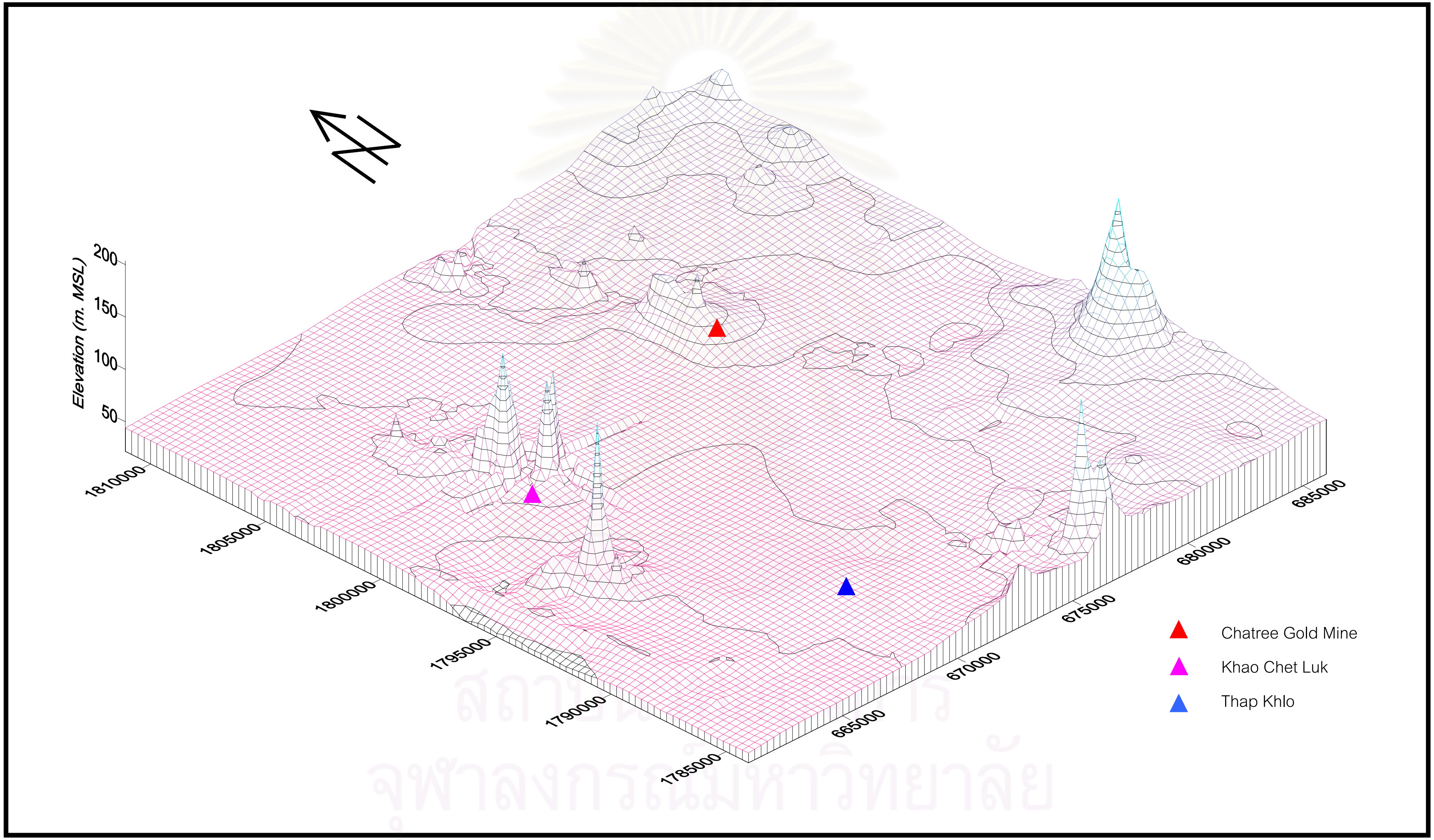


Figure 1.7. Three dimensional morphologic model of study area. The vertical exaggeration of the land surface is shown in a bar-scale.

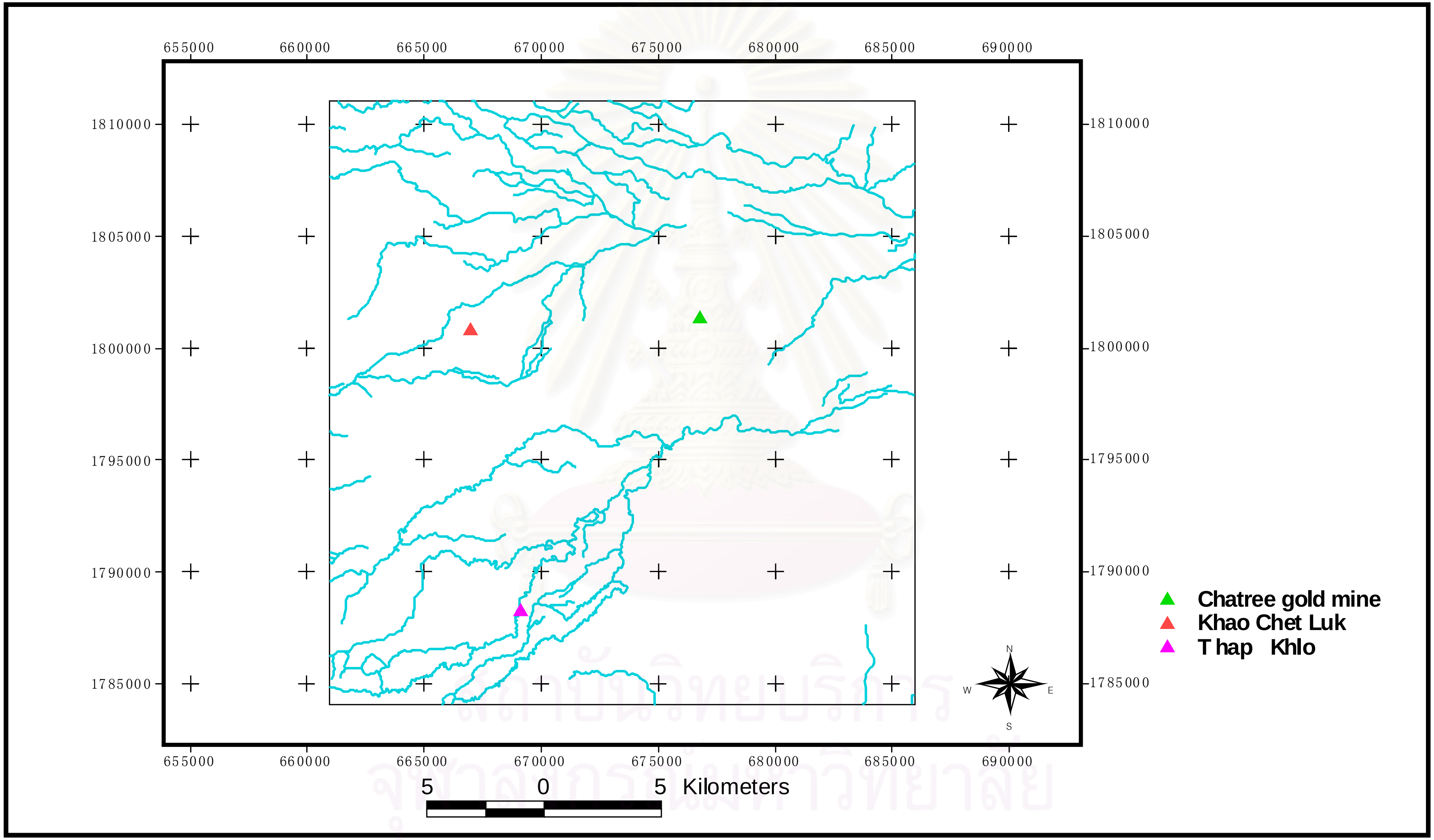


Figure 1.8. Drainage system in the study area. The streams flow from east to west.

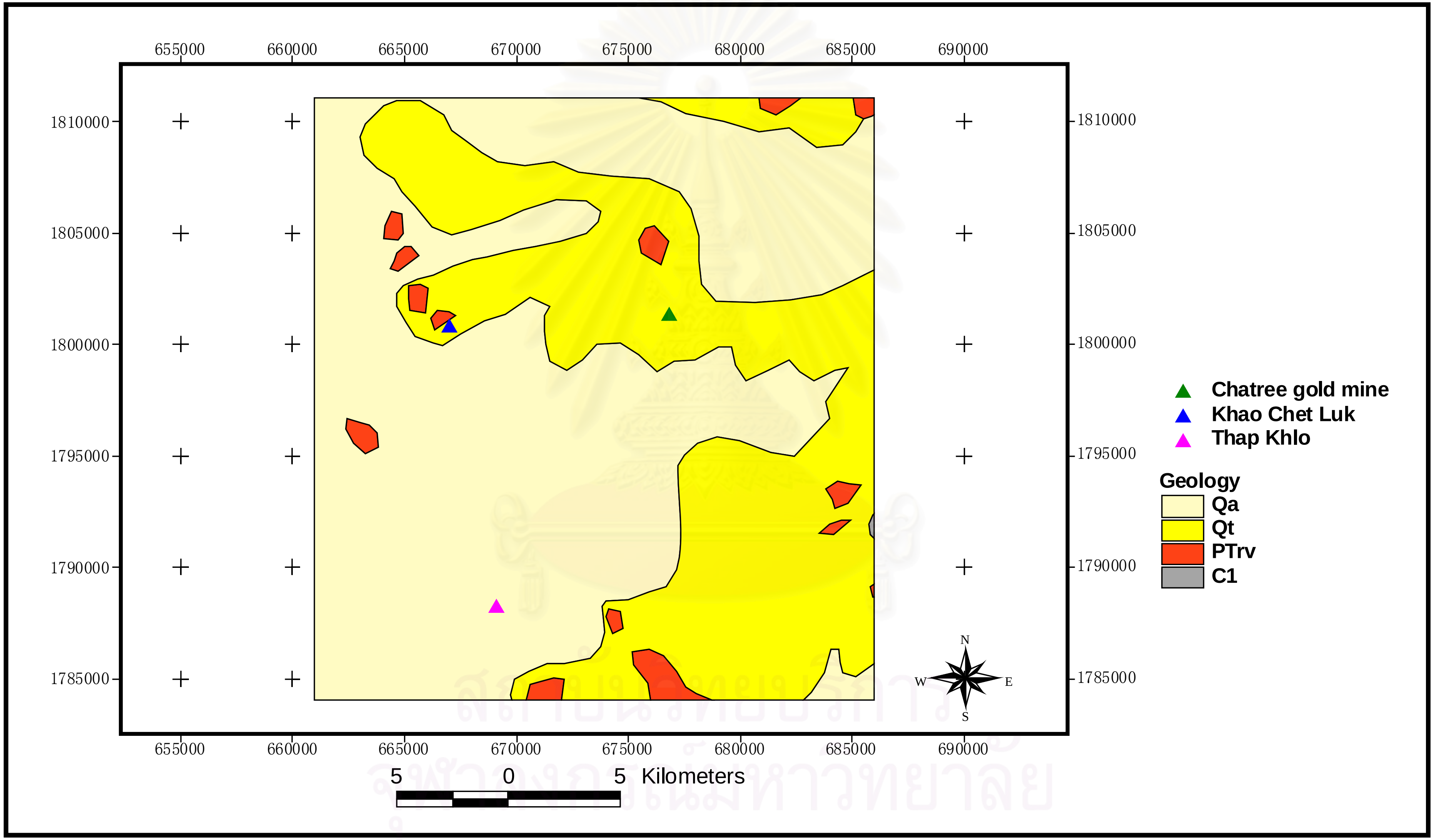


Figure 1.9. Geologic map of the study area. The map was modified from that of Department of Mineral Resources (2545).

2. PTrv: Permo-Triassic volcanic rocks are primarily found to the west and at the central part of the study area on the isolated hills. The rocks are tuffs, agglomerate, phyllite, and andesite.

3. Quarternary unit: consisting of unconsolidated sediment units as following.

- Qt: Terrace, talus, and colluvial deposits are spreading to the east of Qa, through the eastern part of the study area where the land is flat to gently undulating. The difference in elevation of the high and low terraces is about 10 to 20 meters. The sediments in these deposits consist of Pleistocene gravels, silt, clay, and laterite, and have age between 1.18 and 0.01 million years. The thickness of this sedimentary unit is about 250 meters.
- Qa: Alluvial deposit is found to the west of the study area. The area that is underlain by this unit is generally flat. The Holocene fluvial deposits are composed of gravels, sand, silt, and clay, with an age of less than10,000 years.

1.6.3 Climate

The study area receives an influence from the northeast monsoon and southwest monsoon. The climate is divided into 3 seasons, summer, rainy, and winter. Mid February to mid May is summer. The highest recorded temperature is 43.3 °C (2506 B.E.), with an average of 29.28 °C. Early summer is normally dry and there might be some rains from mid April on. The rainy season begins from mid May to the end of October. It is the time of southwest monsoon from the Indian Ocean which blows into the area. The highest recorded temperature is 41.6 °C (2535 B.E.), with an average of 27.72 °C. From mid November to mid February is the winter. The highest recorded temperature is 39.8 °C (2513 B.E.), with an average of 24.6 °C. the northeast monsoon normally brings dryness and coldness from mainland China into the area.

The climatic data were collected from the nearby meteorological stations of the Meteorological Department, namely Nan, Uttaradit, Phetchabun, Wichian buri, and Phichit from 2529 B.E. to 2545 B.E.

The annual average rainfall from 2529 B.E. to 2545 B.E. was collected and analyzed by Jeampraditkul (2005) as shown in Table 1.2 and Figure 1.10. The average maximum rainfall from 2529 B.E. to 2545 B.E. is 210.78 mm. in September and minimum 1.78 mm. in January.

1.6.4 Natural resources

1.6.4.1 Soil resources

Twenty-five soil groups are found in the study area. The detail explanation is in the following chapter.

1.6.4.2 Mineral resources

The mineral resources in the study area are essentially the gold deposits. Two important gold findings are recorded in the area. One is the Chatree gold deposit in Khao Mo-Khao Pong in Amphoe Thap Khlo and Amphoe Wang Pong, and the other at Khao Phanompha, Amphoe Wang Sai Phun. The primary gold mineralization is found in the quartz veins in the Permo-Triassic volcanic units, mainly as the invisible native gold. The secondary gold is the visible one which is found in the colluvial deposit of Khao Phanompha. Figure 1.11 shows the two gold deposits and gold panning at Khao Phanompha.

Chatree gold project of Akara Mining Co.,Ltd., at Khao Mo-Khao Pong comprises two open pits, Tawan and Chantra. The ore is transported to a processing plant to be crushed and milled, then followed by Carbon-In-Leach technology to extract gold. The annual average gold production rate will be 65,000 ounces and the annual average silver by production rate will be 160,000 ounces while the project life will be approximately 20 years (S.P.S Consulting Service, 1999).

At Khao Phanompha which is a hill in the hill-group at Khao Chet Luk, Amphoe Thap Khlo of Changwat Phichit, locating to the westernmost portion of the study area, the Department of Mineral Resources reported the gold deposits in 1999 as both the primary and secondary kinds. The primary deposits are from the gold-bearing quartz veins in the Permo-Triassic pyroclastic and volcanic sequences and the secondary kind is the placer gold, perhaps released from the primary source to be scattered in the eluvial soils. The placer gold is found only to the east of the hill-group

Table 1.2. Average annual rainfall in study area between 2529 B.E. and 2545 B.E. (from Jeampraditkul, 2005).

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Rainfall (mm.)	1.76	8.3	32.02	58.41	154.18	116.34	135.49	210.27	210.78	105.65	20.63	5.12

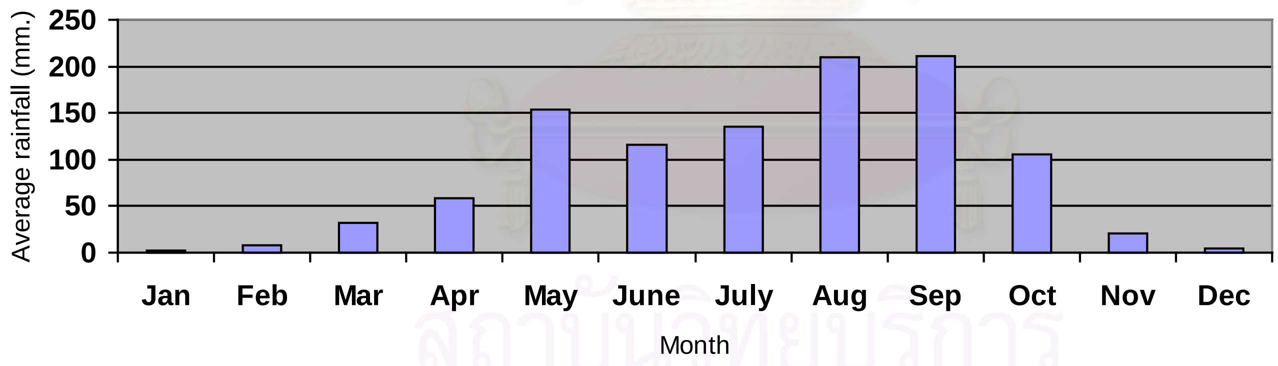


Figure 1.10. Average annual rainfall in study area from 2529 B.E. to 2545 B.E. (from Jeampraditkul, 2005).

covering an area of 0.0483 km^2, to a depth of approximately 2 meters from the ground surface, with 4.2 grams per cubic meter gold concentration. The recoverable gold could be over 360 kilograms. (Department of Mineral Resources, 2545)

(A)

(B)

(C)

Figure 1.11. Gold deposits and mining in the study area. (A) Tawan pit at Chatree gold deposit, (B) Khao Phanompha gold deposit, and (C) gold panning at Khao Phanompha.

1.6.4.3 Groundwater

Noy Chinpongsanon et al. (2531), Layne (Thailand) Limited (2001a, 2001b), and Atop Technology Company Limited (2001) studied the groundwater in this area. They classified the aquifer type according to the associated characteristics i.e. geomorphology, sources of water, water quantity, water quality, and the depth of the aquifers. Thus they recognized 3 aquifers, namely Qlt, Vc, and Pcms.

1. Qlt: it is found in the west of the area where the terrain is rather flat from north to south. The lithology of the aquifer mainly consists of clay with some of gravels and sand. The water yield of this aquifer could be up to 50 gallons per minute, and the quality is good.

2. Vc: The host rocks consist of rhyolite, andesite and agglomerate that are normally found on small hills scattering over the east of the area. The water is found in the fractures and pore spaces. The pumping rate is 5-15 gallons per minute or no yield at all.

3. Pcms: The water is found in the east of the study area along the boundary of Changwat Phetchabun. The source rocks consist of sandy rocks, shale and phyllite. The water here is kept only in the rock fractures and pore spaces like in Vc aquifer. The pumping rate is 20-50 gallon per minute, or no yield at all.

Charoen Piencharoen (2522) summarized that the high potential of the groundwater resources for agriculture must have a pumping rate of more than 34m^3/hr. or 150 gallons per minute. So, the groundwater in this area is of low potential for agricultural usage.

The aquifer type, groundwater expected yield and groundwater quality map of the study area are shown in Figures 1.12, 1.13 and 1.14.

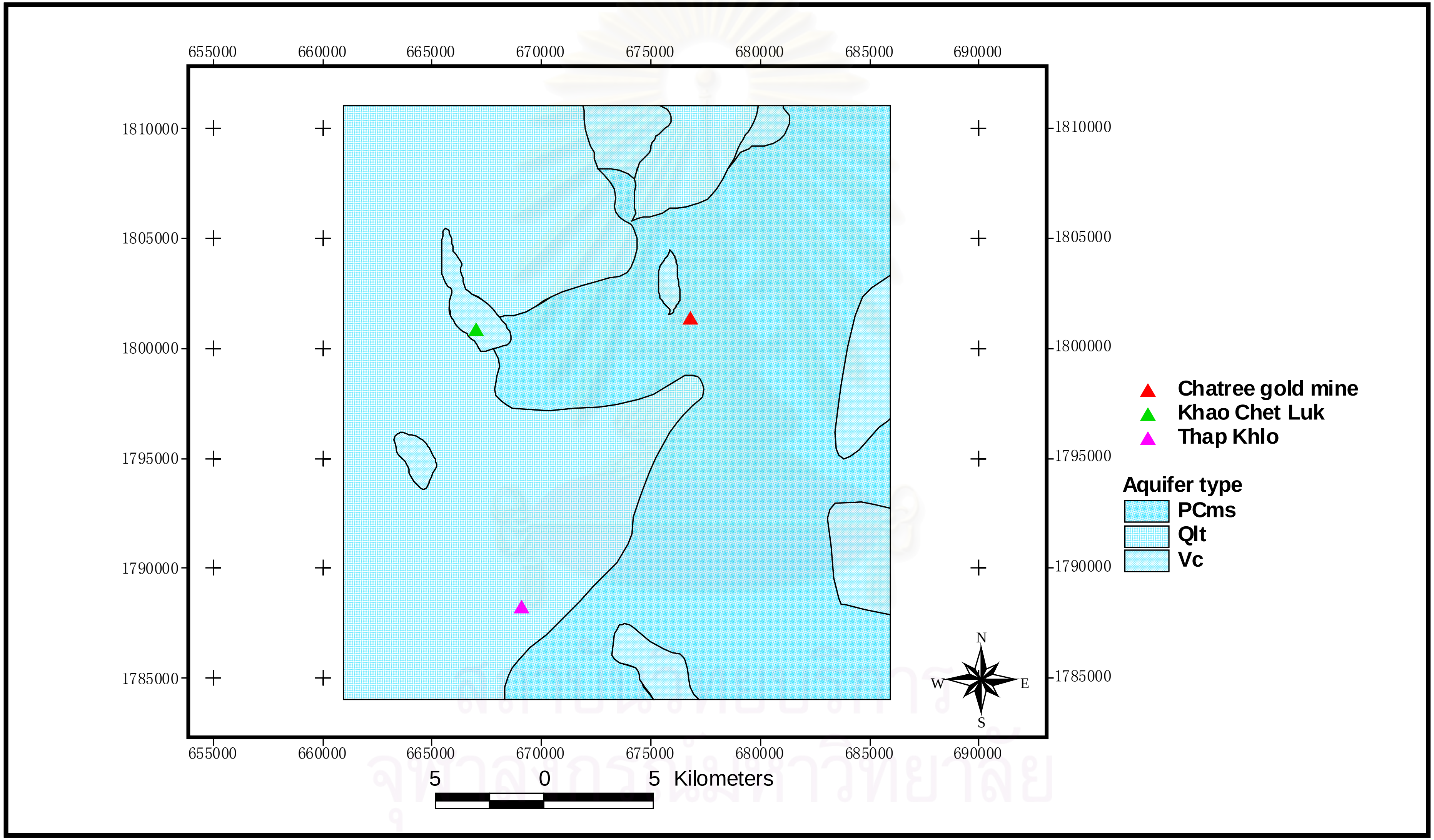


Figure 1.12. Aquifer type map of the study area [from Layne (Thailand) Limited, 2001a, 2001b and Atop Technology Company Limited, 2001].

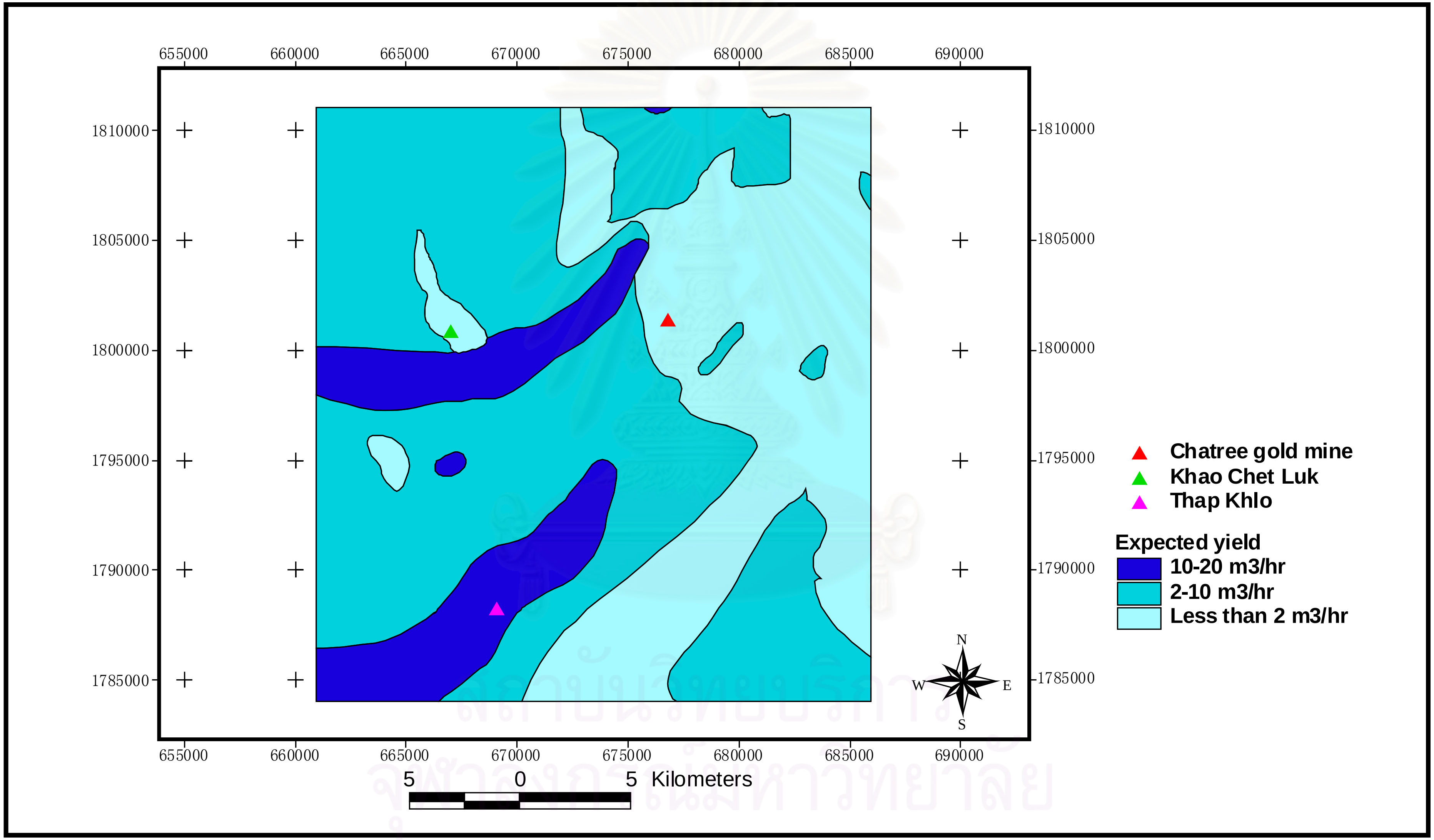


Figure 1.13. Groundwater expected yield map of the study area [from Layne (Thailand) Limited, 2001a, 2001b and Atop Technology Company Limited, 2001].

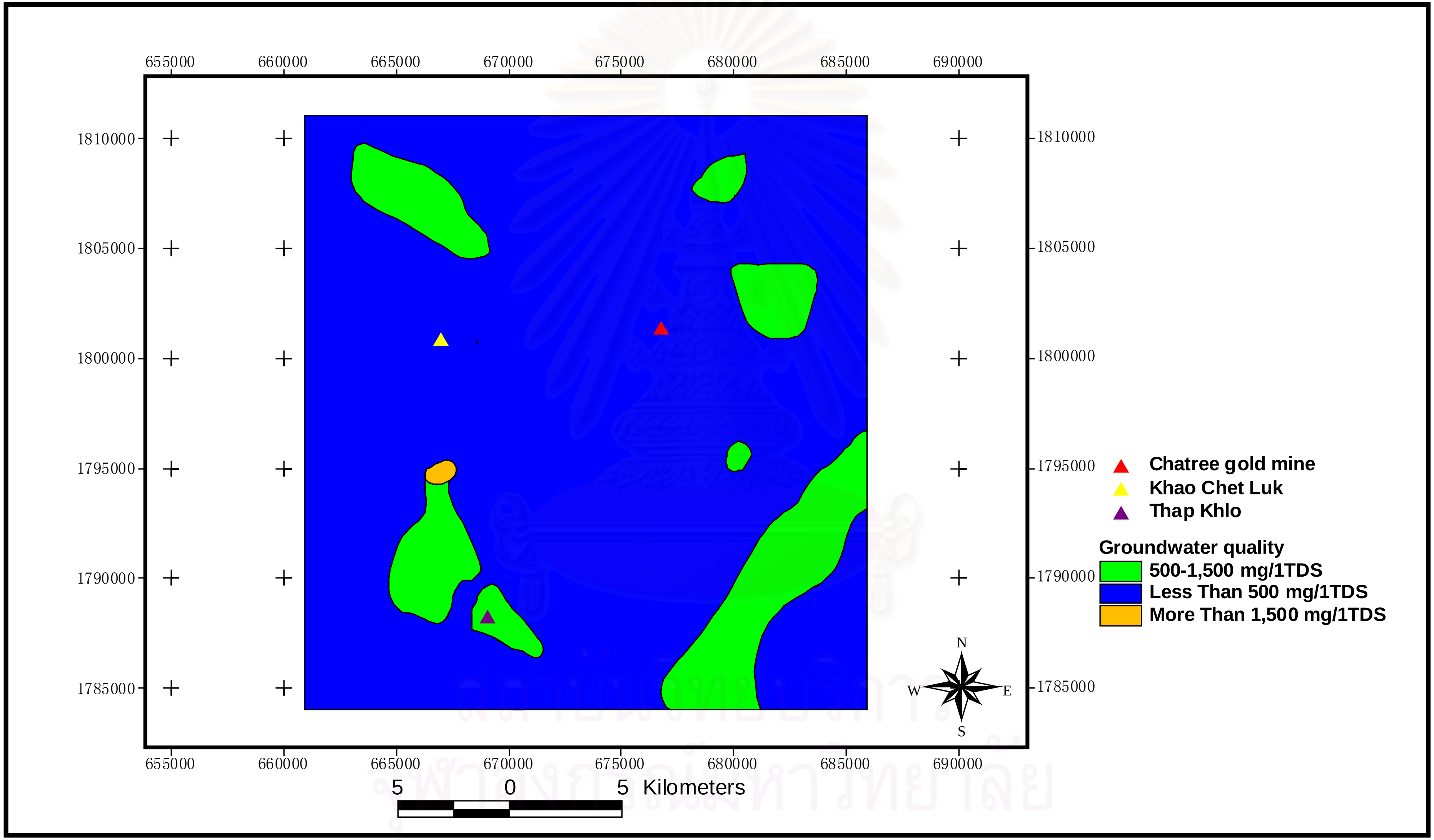


Figure 1.14. Groundwater quality map [from Layne (Thailand) Limited, 2001a, 2001b and Atop Technology Company Limited, 2001].

The groundwater level in some wells in the study area is different between rainy and dry season as shown in Figure 1.15. Here the water level is up to 4.4 meter different from the rainy to dry seasons.

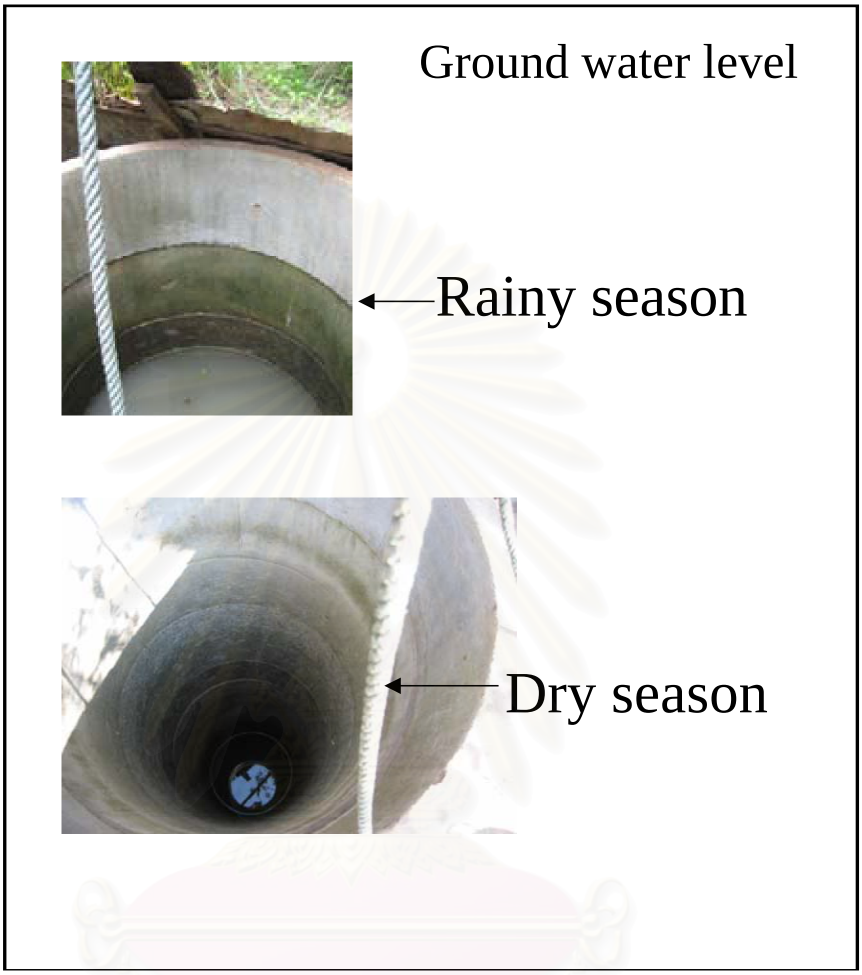


Figure 1.15. Water level in rainy and dry season. The location of the well is at Tambon Khao Sai, Changwat Phichit.

Jeampraditkul (2005) analyzed the groundwater flow direction from measured groundwater level data and found that it flew from east to west, or more precisely northwest-southwest, just like the surface water flowage direction. The groundwater flow direction is shown in Figure 1.16.

Chuanchoey (2004) also investigated some chemical properties of 11 groundwater samples in this study area. The water samples were from the same locations where soil samples were collected in the present study. The results of her study can be summarized as following.

1. All physical properties and chemical qualities of most samples are within the recommended ranges of the potable water (Notification of the Ministry of Industry, No. 4, B.E. 2521 (1978), issued under the Groundwater Act B.E. 2520 (1977), published in the Royal Gazette, Vol. 95, Part 66, date June 27, B.E. 2521 (1978).

2. Two locations in the southernmost part of study area have the higher Mg, Ca, Na, and SO_4^{2-} content than the other locations in the same study.

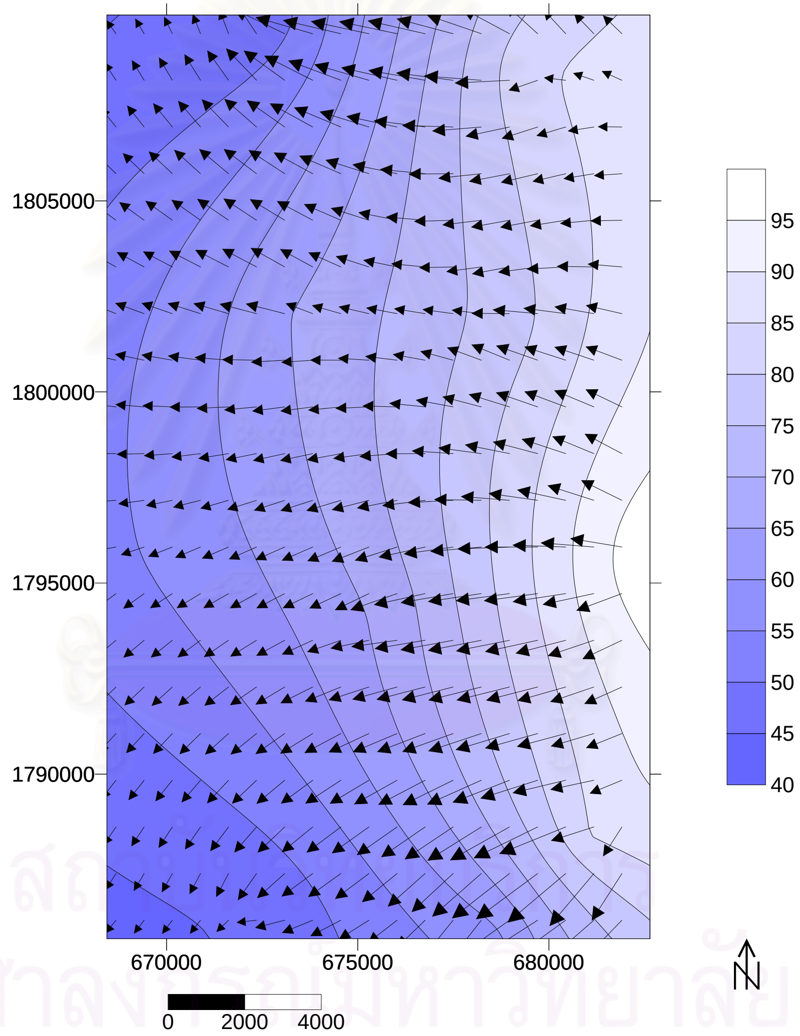


Figure 1.16. Groundwater flow direction in the study area (from Jeampraditkul, 2005).

CHAPTER II

CONCEPTS OF LAND AND LANDUSE

In this chapter, the land and landuse concepts which are the most concerned in the study are listed in the following sequence: land, soil, landuse, population, and interactions between landuse, human, agriculture, soil, and ecology. The concept of the Geographic Information System (GIS), a recent technology used in a landuse consideration, is also discussed.

2.1 Land resources

2.1.1 Definition of land

Land is defined as an area of soil in natural state which in many ways will be used and thought about in terms of landuse utilitarian. Such area also includes the mountain, stream, swamp, canal, river, sea, sand, island, and beach land (Chaliew Chaengprai, 2530).

The physical ingredients of environment to associate the land are climate, topography, soil, surface water, vegetation, and other items with the natural origin and human made (Mackenzie and Mackenzie, 1995)

2.1.2 General land characteristics

Dashni Emphan (2531) classified the general land characteristics into 4 items. These are immobility, finiteness, physical characteristics (such as topography, soil, soil surface structures, mineral composition, and climate) and alternatives and combined uses.

2.2 Soil resources

2.2.1 Soil definition

Soil is a natural material which is derived from rock weathering and mixed with organic matter, and thinly covers the land surface. Thus it is a mixture of solid minerals, organic matter, water, and air with unique proportion depending on the soil type. The soil holds up plants growth and sustainment (Chaliew Chaengprai, 2530).

Keller (2000) stated that soils might be defined in two ways. The soil scientists define soil as solid earth material that has been altered by physical, chemical, and organic processes, such that it can support rooted plant life, while the engineers define soil as any solid earth material that can be removed without blasting. Both definitions are important in the environmental studies.

Botkin and Keller (2003) noted that soils can be defined as earth materials modified over time by physical, chemical, and biological processes such that, in addition to supporting rooted-plant life, they are altered from the original parent material into a series of horizons that are subparallel to the surface.

Chhatwal (1997) gave a definition that soil is a body in nature, composing of organized, unconsolidated mineral and organic material on the immediate surface of the earth that serves as a natural medium for the growth of land plants, and that the soil is the consequence of the parent material from which it is formed, and of the environmental factors including climate, micro- and macro-organisms, topography, and relief acting over a period of time.

2.2.2 Function of soil

Chhatwal (1997) suggested that in a relationship to a plant growth, under the most natural horticultural and agronomic circumstances, soil has the following functions

1. It provides anchorage and support to enable plants to stand erect and absorb solar radiation. It also provide support for the foot and vehicle traffic in connection with husbandry of crops.

2. It provides water to plant root systems.

3. It furnishes plant nutrients at the adequate rates and levels.

4. It permits the flow of gases to provide oxygen for respiring root systems.

5. It expedites the flow of heat to subsurface layers and provides a physical chemical regime for regulation of toxins.

2.2.3 Soil fertility

Soil fertility is referred to the capacity of a soil to supply the nutrients necessarily for plant growth when other factors, such as availability of water and climate, are also favorable (Botkin and Keller, 2003).

2.2.4 Soil textures

The soil textures that have influence on vegetation can be listed as following.

1. Influence to tillage easiness: The sandy soil is easier to tillage than clay.
2. Influence to soil fertility: Clay has more nutrients carrying capacity than the sandy soil.
3. Influence to porosity: Clay is dense and firm while the sandy soil is crumble.
4. Influence to capacity of water holding: Clay has more capacity of water holding than sandy soil.

2.3 Landuse

2.3.1 Landuse definition

A landuse marks the human activities on the land which are directly related to that land (Clawson and Stewart, 1965).

Meyer and Turner (1994) noted that a human employment of the land and its resultant change may involve either a shift to a different use or an intensification of the existing use.

Somchit Limsawatphol (2538) gave a definition of the land use as a human activity and utilization of land resources for satisfaction and high benefit.

Conclusively, thus, the landuse is for human needs such as agriculture, commerce, industry and residence. Due to the land in an area with difference in properties and proportions, these factors are the land productivity and suitability indicators. So, using land of each type brings about land productivity potential and soil ruin. To use the land to the highest benefit, the land must meet its potential, population and support capability because erroneous usage will reduce soil quality that later brings to a lower soil potential. And as soil is the natural resources that have size, location, and usage, the users hence should carefully think about landuse utility and effects.

2.3.2 Suitable landuse

Landuse can be done in many ways but these must be the right uses with high efficiency. If the land is used in its best way, human will get sustainable benefit from that land.

Kasem Chankaew (2525) suggested that the proportion of suitable landuse for Thailand should be as forest 50%, agricultural land 35%, town, village and industry 5%, marsh, canal, river, idle land, and publicland 5%, and road 5%.

2.3.3 Factors that control different landuse

Dashni Emphan (2531) suggested the factors that control different land usage as following.

1. Physical factors that compose of the effective support capacity, namely, land physical characteristics such as topography and slope, soil properties, soil fertility, irrigation, rain, water, and climate. The

physical characteristics limitation marks the indicators in landuse support.

2. Social factors are the population, habitation, education technology, landuse technology, complexity of social composition and landuse organization, and people's opinion and recognition.

3. Economic factors that are considered in landuse are the productive cost which includes the stable cost and variable cost, the productive income, market, and labor cost and availability.

From the above factors generally, the landuse can be divided into 5 types as below.

1. Urban lands as the residential area, commercial zone, industrial zone, area for transportation, and administrative and educational areas.

2. Agricultural lands as the annuals and perennials planting areas including the vegetable farm, orchard, field crop area, rice field, ranch, and shifting cultivation.

3. Forests as the natural forest area which is further divided by its type such as Dipterocarp deciduous forest, mixed deciduous forest, seasonal rain forest, lower montane forest, bamboo forest, and the large-scale plantation and human-grown forest.

4. Surface water bodies as the river, marsh, swamp, canal, and lake.

5. Idle land as the area that has lost its land covering which includes the abandoned agricultural lands.

2.4 Population

The population definitely has an effect on the landuse. The change of population, especially the population growth, leads to change in land usage. Henry and Heinke (1996) explained that a population growth is often characterized as exponential, that is, it increases (or decreases) by a fixed percentage of existing total number over a unit period of time. Mathematically, this can be expressed as

$$P = P_0e^{rt}$$

P = Future size of the population

P_0 = Current size of the population

t = Number of years for the extrapolation

r = Assumed constant growth rate for each of the years (as a function)

e = Base of natural logarithms

2.5 Interactions between landuse, human, agriculture, soil, and ecology

The history of agriculture can be viewed as the series of human attempts to overcome environmental limitation and problems. It is also a history in which each new solution has created new environmental problems. A surprisingly large percentage of the world's land area is in an agricultural usage, approximately 11% of the total area of the whole world (Botkin and Keller, 2003). An urbanization or suburbanization increase that unmistakenly means the increasing population demands more resources as well as more innovations (Keller, 2000). Some of the best agricultural land will be converted for the other uses while the agricultural land will be decreased to its marginal limit. And when one does farming, he would create the abnormal ecological conditions and novel ecosystems. Moreover, agriculture depends heavily on the soil quality, but may lead to a decline in that quality. For these interactions, it is apparent that man creates landuse change. If the land is changed into its suitable boundary such as using land according to the suitable soil, and the suitable social and economic purposes, man will always get a high benefit from that land in a long run. But if human allow an endless evolution, it will change the type, quantity, ingredient proportion, structure, and action of ecological system (Dashni Emphan, 2531). Moreover, these interactions are not the only factors that control landuse, the infrastructures, water, resources economic system, etc. which are developed during times also control landuse.

2.6 Geographic Information System (GIS)

Keller (2000) defined GIS as a form of technology capable of storing, retrieving, transforming, and displaying spatial environmental data. The spatial data used in the GIS may be points, lines, or areas. Following are examples of the GIS spatial data: temple or elevation is a point, streams or roads are line, and landuse or soil type is a polygon (area). It is important to recognize that GIS is more than a simple way to categorize and store data. The system has the ability to manipulate data and create a new product as well.

GIS has four essential elements as following.

1. Data acquisition: Collecting from the maps and so forth.
2. Data processing and management: Recording data from the maps and other sources in a systematic way. This process involves the creation of a computer database where all the data are stored and accurately located.
3. Data manipulation and analysis: This is the part of the GIS that will develop new information, for example, using the topographic and geologic maps, the geologic data may be combined and overlain with data on landform to evaluate a slope stability.
4. Generation of products: This is the stage in GIS work that produces the desired output. The output may include a land capability map, statistical analysis of environmental variables, or natural hazard map.

So in this study, GIS is the important instrument to collect, process, and analyze the landuse data. It is used to create database, register study area by Envi 3.2 Program, invert and display other maps into digital form, and analyze landuse change pattern by overlay method using Arcview 3.2a Program. Furthermore, the analyzed results were displayed in forms of map by using Arcview 3.2a and Surfer 7.0 Program.

CHAPTER III

SOILS IN THE STUDY AREA

As the study area is noted to be a non-irrigated terrain, the crops thus depend almost entirely on the rainwater, with a very limited usage of shallow groundwater in the open ponds. The properness and productivity of the agricultural activity is thus based primarily on the soil characteristics. A special interest is thus conducted on the soil condition as followed.

3.1 Soil resources

Noy Chinpongsanon et al. (2531) noted that this area was covered by fine grained with subordinate coarse grained soils, with poor drainage system. The suitability of this area is moderately to poorly for rice growing. In the dry season, the land was moderately suitable for less water-required crops such as sesame. Water resource development should be occurred in this area, the land would only be moderately to poorly suitable for vegetation and short-lifed seasonal crops such as mung bean (green bean), peanut, soy bean, sweet corn, and melon.

3.1.1 Soil group description

Of 62 soil groups found all over Thailand, 25 groups are found in the study area as shown in Figure 3.1. The soil group properties are shown in Table 3.1. These properties include the texture, soil depth, drainage, fertility, pH, with a suitability for economic plants and landuses, and problems concerning these soils.

A soil texture was studied by the Department of Land Development in 2543 to be classified into 6 types, namely clay, sandy clay loam, sandy loam, sandy soil, mountainous soil, and lateritic soil. The soil texture map is shown in Figure 3.2.

A GIS technique was employed onto the soil groups in the study area to calculate each soil group area, as based on the data of the Department of Land Development (2543b). The results are as following.

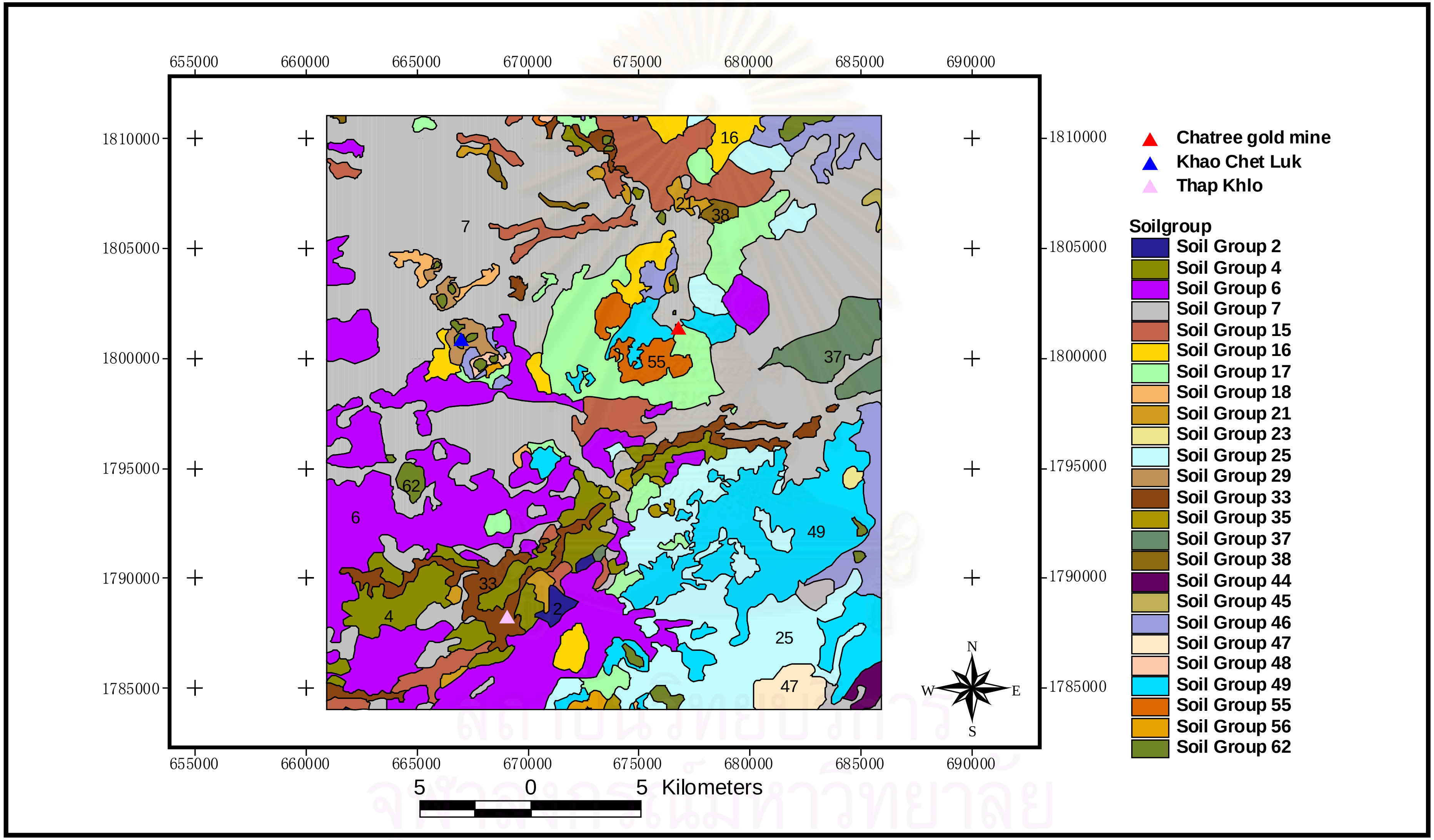


Figure 3.1. Soil groups in the study area (from Department of Land Development, 2543b).

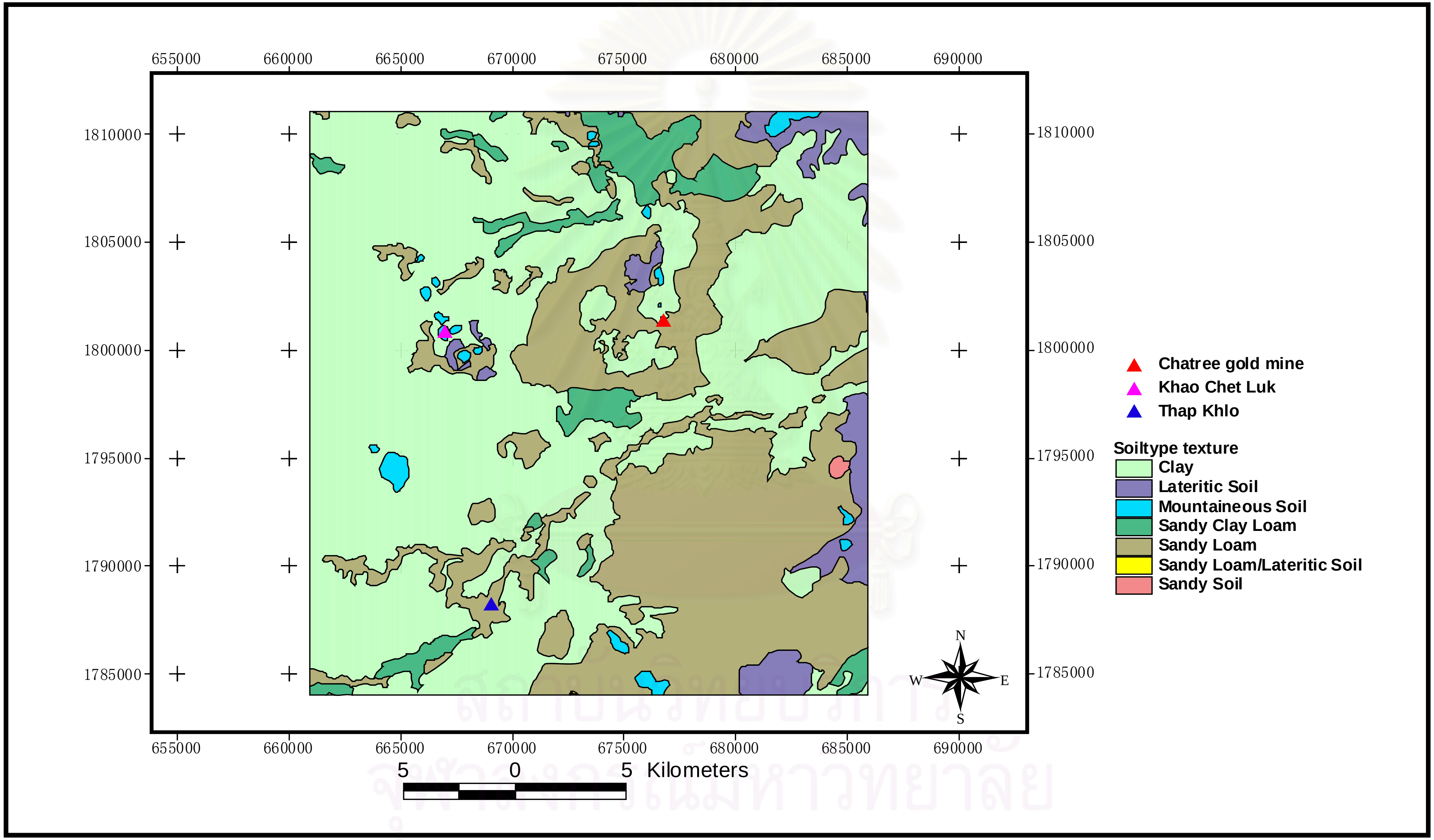


Figure 3.2. Soil texture distribution in the study area (From an analysis of soil group map in Figure 3.1).

Table 3.1. Soil group properties in study area, with economic plants, and soil problems.

Soil Groups	Area (km^2)	Texture	Soil depth	Drainage	Fertility	pH	Suitability	Problems
2	1.925	Clay	Deep	Bad	Medium	4.5 to 5.5	Rice	High acidity
4	29.479	Clay		Quite bad-bad	Medium	5.5 to 6.5	Rice	Water detained for 4 to 5 months
6	105.090	Clay	Very deep	Bad	Low-quite low	4.5 to 5.5	Rice	Low fertility, high acidity
7	233.258	Clay	Deep	Quite bad	Medium	6.0 to 7.0	Rice	Water detained for 3 to 5 months
15	34.438	Sandy clay loam	Very deep	Quite bad	Quite low-medium	6.0 to 7.5	Rice	
16	14.072	Sandy loam	Very deep	Bad	Low-quite low	5.0 to 6.0	Rice	Low fertility
17	41.217	Sandy loam	Very deep	Quite bad	Low	4.5 to 5.5	Rice	Sandy soil, low fertility
18	2.604	Sandy loam	Deep	Bad	Low	6.0 to 7.0	Rice	Risk to be starved

Table 3.1. (cont.).

Soil Groups	Area	Texture	Soil depth	Drainage	Fertility	pH	Suitability	Problems
21	4.657	Sandy loam	Deep	Medium good-quite bad	Medium	5.5 to 7.5	Rice	Water detained for 2 to 3 months
23	0.657	Sandy soil	Deep	Bad-very bad	Low	6.0 to 7.0	Rice	Sandy soil
25	61.225	Sandy loam	Shallow	Quite bad	Low	4.5 to 6.0	Rice	Too much laterite, low water holding capacity
29	3.525	Clay	Deep	Good	Low	4.5 to 5.5	Field crops and Plantation	Deep groundwater
33	19.854	Sandy loam	Very good	Good-medium good	Medium	6.5 to 7.5	Field crops and Plantation	Risk to be starved
35	1.862	Sandy loam	Deep	Good	Low	4.5 to 5.5	Field crops	Sandy soil
37	12.555	Sandy loam	Deep	Medium good	Low	4.5 to 5.5	Field crops	Low fertility

Table 3.1. (cont.).

Soil Groups	Area	Texture	Soil depth	Drainage	Fertility	pH	Suitability	Problems
38	2.626	Sandy loam	Deep	Medium good	Medium	5.0 to 7.0	Field crops	Sandy soil
44	0.213	Sandy clay loam	Deep	Very good	Very low	5.5 to 7.0	Cassava	Very sandy
45	0.632	Lateritic soil	Very shallow	Good	Low	4.5 to 5.5	Cassava, coffee	Shallow soil
46	21.05	Lateritic soil	Shallow	Good	Low	4.5 to 7.0	Field crops	Too much laterite
47	5.47	Lateritic soil	Shallow	Good	Low-medium	5.0 to 7.5	Field crops	High erosion
48	0.904	Sandy loam	Very shallow		Low	5.0 to 7.0	Field crops	High erosion
49	62.542	Sandy loam	Shallow-very shallow	Good	Low	5.0 to 6.5	Field crops	Too much laterite
55	7.004	Clay	Medium deep	Good-medium good	Medium	6.0 to 7.5	Field crops	High erosion
56	1.39	Sandy loam	Medium deep	Good	Low	5.0 to 6.0	Field crops	High erosion

Table 3.1. (cont.).

Soil Groups	Area	Texture	Soil depth	Drainage	Fertility	pH	Suitability	Problems
62	6.967	Mountainous soil	Its properties and fertility depend on parent rocks that have rubble and rocks scatter mostly.				Field crops and coffee	High erosion
Total	677.136							

Note: Modified by GIS method from the data of Department of Land Development (2543b).

Soil Group 2: This soil group covers an area of 1.925 km^2. It is of clay texture, deep soil, bad drainage, medium fertility, and pH is 4.5 to 5.5. Its problem is high acidity. The suitable economic plant for this soil group is rice.

Soil Group 4: This soil group covers an area of 29.479 km^2. It is of clay texture, quite bad to bad drainage, medium fertility, and pH is 5.5 to 6.5. Its problem is detainment of water for 4 to 5 months. The suitable economic plant for this soil group is rice.

Soil Group 6: This soil group covers an area of 105.09 km^2. It is of clay texture, very deep soil, bad drainage, low to quite low fertility and pH is 4.5 to 5.5. Its problems are low fertility and high acidity. The suitable economic plant for this soil group is rice.

Soil Group 7: This soil group covers an area of 233.258 km^2 which was the largest area. It is of clay texture, deep soil, quite bad drainage, medium fertility, and pH is 6.0 to 7.0. Its problem is detainment of water for 3 to 5 months. The suitable economic plant for this soil groups is rice.

Soil Group 15: This soil group covers an area of 34.438 km^2. It is of sandy clay loam texture, very deep soil, quite bad drainage, quite low to medium fertility, and pH is 6.0 to 7.5. The suitable economic plant for this soil group is rice.

Soil Group 16: This soil group covers an area of 14.072 km^2. It is of sandy loam texture, very deep soil, bad drainage, low to quite low fertility, and pH is 5.0 to 6.0. The suitable economic plant for this soil group is rice.

Soil Group 17: This soil group covers an area of 41.217 km^2. It is of sandy loam texture, very deep soil, quite bad drainage, low fertility, and pH is 4.5 to 5.5. Its problems are low fertility and too much sand in soil. The suitable economic plant for this soil group is rice.

Soil Group 18: This soil group covers an area of 2.604 km^2. It is of sandy loam texture, deep soil, bad drainage, low fertility, and pH is 6.0 to 7.0. Its problem is it risks to be starved of water. The suitable economic plant for this soil group is rice.

Soil Group 21: This soil group covers an area of 4.657 km^2. It is of sandy loam texture, deep soil, medium good to quite bad drainage, medium fertility, and pH is 5.5 to 7.5. Its problem is detainment of water for 2 to 3 months. The suitable economic plants are rice.

Soil Group 23: This soil group covers an area of 0.657 km^2. It is of sandy texture, deep soil, bad to very bad drainage, low fertility, and pH is 6.0 to 7.0. Its problem is that there is too much sand in soil. The suitable economic plants are rice.

Soil Group 25: This soil group covers an area of 61.225 km^2. It is of sandy loam texture, shallow soil, quite bad drainage, low fertility, and pH is 4.5 to 6.0. Its problems are that there is too much laterite and low capacity to keep water. The suitable economic plants for this soil group are rice.

Soil Group 29: This soil group covers an area of 3.525 km^2. It is of clay texture, deep soil, good drainage, low fertility, and pH is 4.5 to 5.5. Its problem is the depth of groundwater and it risks to be of low humidity because of deep ground water. The suitable economic plants for this soil group is field crops and plantation.

Soil Group 33: This soil group covers an area of 19.854 km^2. It is of sandy loam texture, very deep soil, good to medium good drainage, medium fertility, and pH is 6.5 to 7.5. Its problem is that it risks to be of insufficient water. It suits for kinds of many plants.

Soil Group 35: This soil group covers an area of 1.862 km^2. It is of sandy loam texture, deep soil, good drainage, low fertility, and pH is 4.5 to 5.5. Its problem is that there is too much sand in soil. The suitable landuses for this soil group are for mixed crop fields.

Soil Group 37: This soil group covers an area of 12.555 km^2. It is of sandy loam texture, deep soil, medium good drainage, low fertility, and pH is 4.5 to 5.5. Its problem is low fertility. The suitable landuse for this soil group is for field crops.

Soil Group 38: This soil group covers an area of 2.626 km^2. It is of sandy loam, deep soil, medium good drainage, medium fertility, and pH is 5.0 to 7.0. Its problem is that there is too much sand in soil. The suitable economic plants for this soil group are field crops.

Soil Group 44: This soil group covers an area of 0.213 km^2, the smallest in the whole area. It is of sandy clay loam texture, deep soil, very good drainage, very low fertility, and pH is 5.5 to 7.0. Its problem is that there is too much sand in soil. The suitable economic plants for this soil group are cassava.

Soil Group 45: This soil group covers an area of 0.632 km^2. It is of lateritic and very shallow soil, good drainage, low fertility, and pH is 4.5 to 5.5. Its problem is that it situates in a slope area so that it is shallow soil and highly risks an erosion. The suitable economic plants for this soil group are rubber tree, coffee, and cashew nut.

Soil Group 46: This soil group covers an area of 21.05 km^2. It is of lateritic and shallow soil, good drainage, low fertility, and pH is 4.5 to 7.0. Its problem is too much laterite in soil. The suitable landuse for this soil group is for field crops.

Soil Group 47: This soil group covers an area of 5.47 km^2. It is of lateritic and shallow soil, good drainage, low to medium fertility, and pH is 5.0 to 7.5. Its problem is that it highly risks for erosion in a slope area. The suitable economic plants for this soil group are field crops.

Soil Group 48: This soil group covers an area of 0.904 km^2. It is of sandy loam texture, very shallow soil, low fertility, and pH is 5.0 to 7.0. Its problems are that it highly risks for erosion in a slope area and too much laterite in soil. The suitable economic plants for this soil group are field crops.

Soil Group 49: This soil group covers an area of 62.542 km^2. It is of sandy loam texture, shallow to very shallow soil, good drainage, low fertility, and pH is 5.0 to 6.5. Its problem is that there is too much laterite in soil and low fertility. The suitable economic plants for this soil group are corn and cashew nut.

Soil Group 55: This soil group covers an area of 7.004 km^2. It is of clay texture, medium deep soil, good to medium good drainage, medium fertility, and pH is 6.0 to 7.5. Its problem is that it highly risks for erosion in a slope area. The suitable economic plants are for mixed crop fields.

Soil Group 56: This soil group covers an area of 1.39 km^2. It is of sandy loam texture, medium deep soil, good drainage, low fertility, and pH is 5.0 to 6.0. Its problems are that it highly risks for erosion in a slope area and low fertility. The suitable economic plants for this soil group are the field crops.

Soil Group 62: This soil group covers an area of 6.967 km^2. It is of hill-slope soil. Its properties and fertility depend on the parent rocks that have rubble and fractured rocks scatter throughoutly. Its problem is that it highly risks for erosion in a slope area. The suitable economic plants for this soil group are field crops and coffee.

3.1.2 Soil suitability

The soils in the study area are mostly clay and sandy loam. Clay covers the largest area, 380.281 km^2. The major soil groups of clay are Groups 2, 4, 6, 7, 29, and 55. The clay is poorly drained, with medium to low fertility and is suitable for growing rice. Soil Groups 2, 4, 6, and 7 are suitable for growing rice but their problems are high acidity, low fertility, and poorly drained. Soil Group 29, probably derived from fluviatile sediments or various weathered rocks, is of fine texture. The group is thick and has suitability for all field crops and fruits. Soil Group 55 is suitable for mixed crop fields but it is prone to erosion.

Sandy loam, which cannot keep water, covers 225.508 km^2. The soil groups of this kind are Groups 16, 17, 18, 21, 25, 33, 35, 37, 38, 48, 49, and 56. Soil Group 17,18, and 25 are suitable for growing rice but their texture which is very permeable risks a low humidity and is low fertile. Soil Groups 16 and 21 are also suitable for rice but they cannot drain properly and water is usually detained in the soil in rainy season. Soil Groups 33, 35, 37, and 38 are suitable for field crops, pasture, and some fruits plants such as tamarind, mango and jack-fruit. The soil units are thick with moderately good draining and moderate fertility but they risk being low humidity with plenty of sand. Soil Groups 48, 49, and 56 have low fertility and are prone to erosion so they are suitable for pastureland and some field crops.

The lateritic soil spreads over the area, covering 27.152 km^2. The major soil groups of this soil are Groups 45, 46, and 47. The soil is low fertile and thin, and is not suitable for growing rice because laterite obstructs the root system, so it is suitable for grassland and rubber plantation.

In the steep slope and hilly areas, Soil Group 62 is found being either deep and thick or thin unit. The group covers 6.967 km^2. Its texture and fertility is different from place to place up to their parent rocks. The soil is not suitable for any agricultural usage.

Soil groups that are of sandy clay loam texture cover 36.571 km^2. they are Soil Groups 15 and 44. The soil group that is of sandy soil texture and covered 0.657 km^2 is Soil Group 23.

3.1.3 Soil quality analysis

There are 16 chemicals elements which are essential for plant growth. These are C, H, and O from CO_2 in the air and H_2O in humidity. These 3 elements are for about 90% of plant requirement. The other 13 elements are N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, B, Mo, and Cl that come from soils except N which partly comes from N_2 in the air.

Naturally the soils from a new afforestation have plenty of the last 13 elements but when the crops have been grown repeatly in one area, the essential elements are absorbed and used up that results as a loss of nutrition until insufficiently and leads to a low productivity. N, P, and K are the most wanted for growth thus the depleting of these elements is common.

In this study, 11 soil samples (Figure 3.3) were collected to analyze for their quality to be used as the base-data to determine the soil fertility and for other purposes. The parameters of soil quality analyzed in the study area consist of physical properties i.e. the soil texture, the power of hydrogen ion (pH) or acidity/alkalinity, the percentage of organic matter, the conductivity, and the salinity, and chemical properties that are total exchangeable bases (Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}), micronutrients (Fe, Mn, Cu, and Zn), So_4^{2-}, NO_3^{-}, ammonia, and phosphorus. The Analytical results are shown in Table 3.9, while the procedures of soil test and the related information are shown in the appendix.

3.1.3.1 Soil physical properties

The soil physical properties are the soil texture, structures, density, porosity, color, and water holding capacity. An important physical property for the agricultural purposes is the soil texture.

A.) Soil texture: Soil texture analysis was done using a hydrometry method for analyzing the soil particle quantities (diameter not larger than 2 mm.) and then using a triangular diagram as shown in Figure 3.4 to identify the soil texture types. If the soil has an organic component it must first has to be removed by using hydrogen peroxide. The soil texture includes the sorting and plasticity. These properties depend on the particle size, proportion of different sizes, and its ability to absorb water. The soil that has a high sand ratio is termed coarse textural while that with a high clayey ratio, fine textural (Tassani Attanan and Jongrak Chancharoensuk, 2542). Normally, the soil textures are classified into 6 groups as following.

1. Sandy soil (including sand and loamy sand). The major component is sand (more than 70% sand, clay less than 15%).

2. Sandy loam. It has a high sandy ratio of about 40 to 80%.

3. Loam. This soil has an equal quantity of sand and silt while the clay ratio is about 7 to 27%.

4. Silt loam. This soil has a silty ratio about 50 to 88%.

5. Clay loam. This soil has the clay particle of about 27 to 40%, same as that for the sand particle.

6. Clay soil. This soil has more than 40% of clay particle.

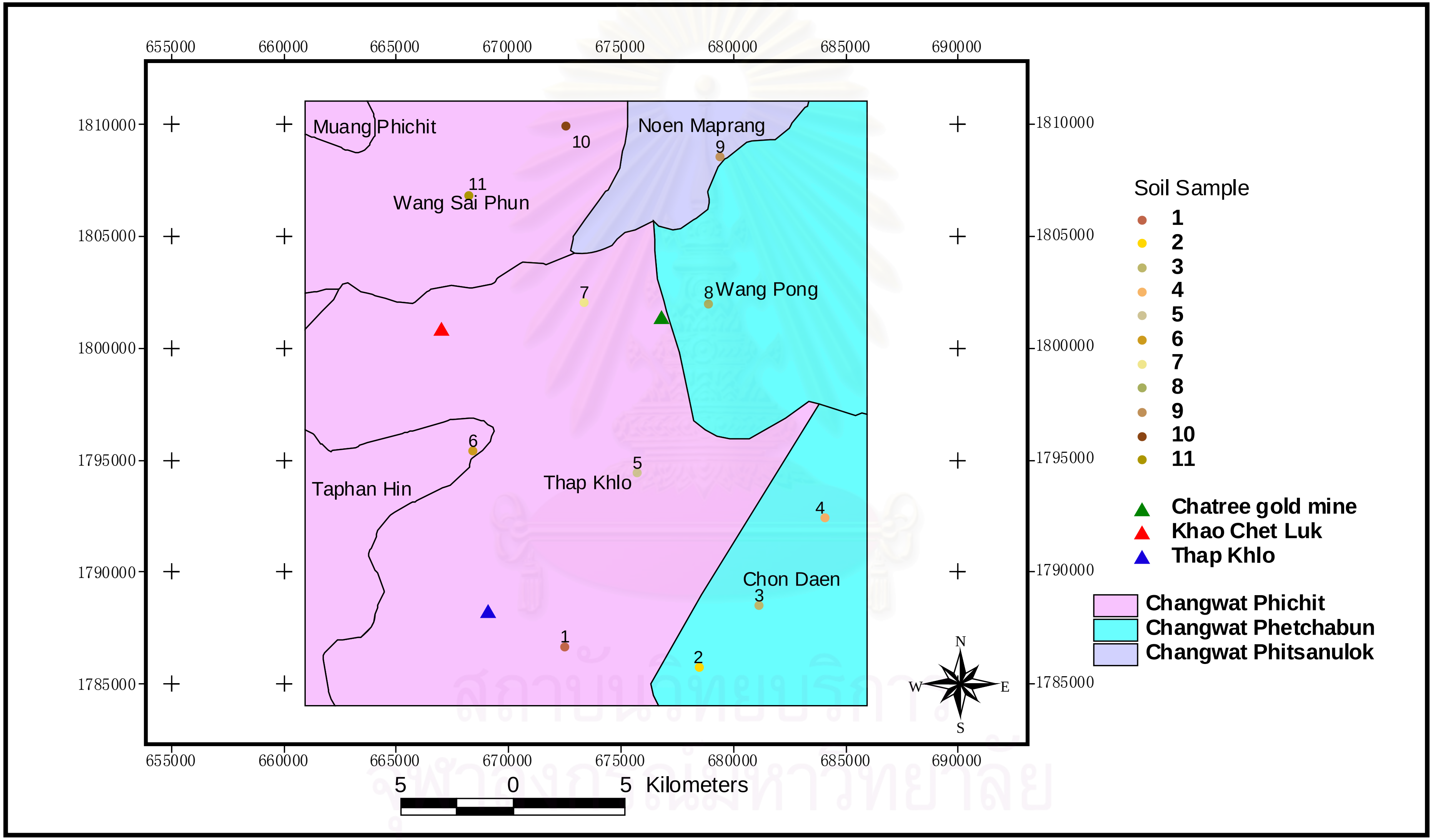


Figure 3.3. Locations of soil samples in the study area.

Table 3.2. Results of soil properties analysis.

	1	2	3	4	5	6	7	8	9	10	11
Grid reference E	672508	678457	681136	684089	675727	668368	673365	678898	679409	672556	668230
Grid reference N	1786608	1785665	1788445	1792383	1794395	1795351	1801996	1801962	1808495	1809877	1806813
pH-$CaCl_2$ method	6.8	7.2	7.4	6.3	6.9	4.8	5.8	6.2	5.6	4.9	7.5
pH-H_2O method	7.25	7.57	7.96	7.10	7.40	5.34	6.64	7.32	6.44	5.27	7.70
pH in field	6.8	7	7	7	7	6.6	7	7	7	6.8	7
Conductivity(ms/cm)	0.425	0.638	0.322	0.514	0.558	0.302	0.269	0.561	0.330	1.108	0.441
Salinity	0.032%	0.045%	0.025%	0.037%	0.04%	0.024%	0.022%	0.04%	0.026%	0.075%	0.033%
Texture	SL	SCL	SCL	SL	SL	SL	SL	SL	SL	CL	SCL
Organic matter	1.7%	3.1%	2.2%	4.8%	3.8%	1.3%	1.4%	2.8%	1.1%	2.5%	1.3%
T.E.B. (meq/100g)	11.64	50.39	8.24	6.28	6.07	6.56	6.39	12.43	10.13	14.94	45.12
Ca (ppm.)	2000	9400	1020	3200	3200	800	800	1520	1320	1800	8000
Mg (ppm.)	42	130	130	280	230	140	100	260	280	370	320
K (ppm.)	60	70	180	240	300	60	140	320	60	280	290
Na (ppm.)	108.025	215.625	122.875	123.05	108.75	120.175	90.15	100.975	101.175	153.575	109.825
P (ppm.)	98	26	28	86	700	25	83	112	7	94	136
Fe (ppm.)	46.32	6.866	10.608	69.16	8.89	41.75	26.705	42.64	32.54	99.48	7.782
Cu (ppm.)	1.382	1.488	0.748	1.302	0.476	0.732	0.59	0.812	0.884	2.324	1.13
Mn (ppm.)	67.56	28.5	27.98	66.96	35.82	6.66	41.02	49.08	25.28	61.98	25.86
Zn (ppm.)	1.728	0.384	3.82	8.68	4.795	0.412	2.99	4.52	0.696	3.96	0.724
N (ppm.)	2.4	1.12	1.74	2.16	2.42	0.92	2.12	2.98	2.02	6.06	1.15
Nitrate (ppm.)	0.5	0.6	1	0	1.2	0	1.4	1.3	0.8	3.4	0.7
Ammonia (ppm.)	1.9	0.52	0.74	2.16	1.22	0.92	0.72	1.68	1.22	2.66	1.08
Sulfate (ppm.)	16	8	6	14	14	6	10	16	6	8	10

Note: SL = Sandy Loam, SCL = Sandy Clay Loam, CL = Clay Loam

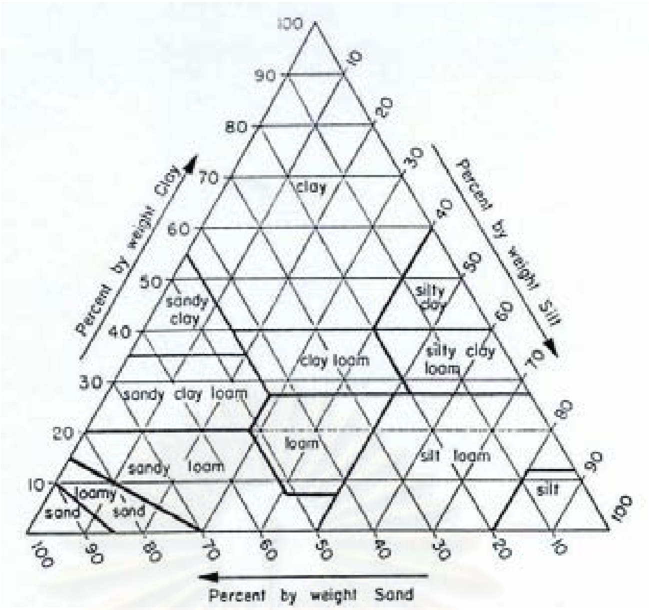


Figure 3.4. Triangular diagram of the soil texture types (from Narong Chinbutr and Chakrapong Jermsiri, 2536).

B.) Soil pH

The soil pH depends on the soil qualities such as the type and amount of mineral contents, organic matter, and salinity. Soil pH which identifies acidity and alkalinity of soil, has an effect on many chemical compounds which are dissolved in soil. It also affects the clay mineral ion bonds and is related to a base saturation percentage of soil.

United States Department of Agriculture (1951) classified pH rate into 10 ranges as shown in Table 3.3.

Table 3.3. pH rating.

Ranges	Rating	Ranges	Rating
<4.5	Extremely acid	6.6 to 7.3	Near neutral
4.5 to 5.0	Very strongly acid	7.4 to 7.8	Slightly alkali
5.1 to 5.5	Strongly acid	7.9 to 8.4	Moderately alkali
5.6 to 6.0	Moderately acid	8.5 to 9.0	Strongly alkali
6.1 to 6.5	Slightly acid	>9.0	Extremely alkali

Sources: United States Department of Agriculture (1951).

Soil pH is the first factor in soil fertility determination. It controls the nutrient levels in soil for plant usage because dissolving of soil nutrients depends on pH. Many crops would grow satisfactorily in solution whose pH range from 4 to 8. Normally if pH is low, problems will increase, such as in the acid soil ($pH<5.5$), Al, Fe, and Mn react with phosphorus to become less soluble so phosphorus could be of no use for plants.

The strong alkali soils ($pH>8.5$) also have problems. Many plants suffer from phosphate and minor element deficiencies if the pH value rises much above 8. At pH 8.4 the concentration of essential ions is too low for plant to obtain an adequate supply nutrition because the nutrients are in an insoluble form that the roots cannot take in enough of them for the plant requirements (Russell, 1961). For some nutrients such as sodium, if pH is too high, it means a high sodium content condition which is unsuitable for plants while nitrogen will easy be dissipated by evaporation. Figure 3.5 shows the pH influences for soil nutrients and fungi activities.

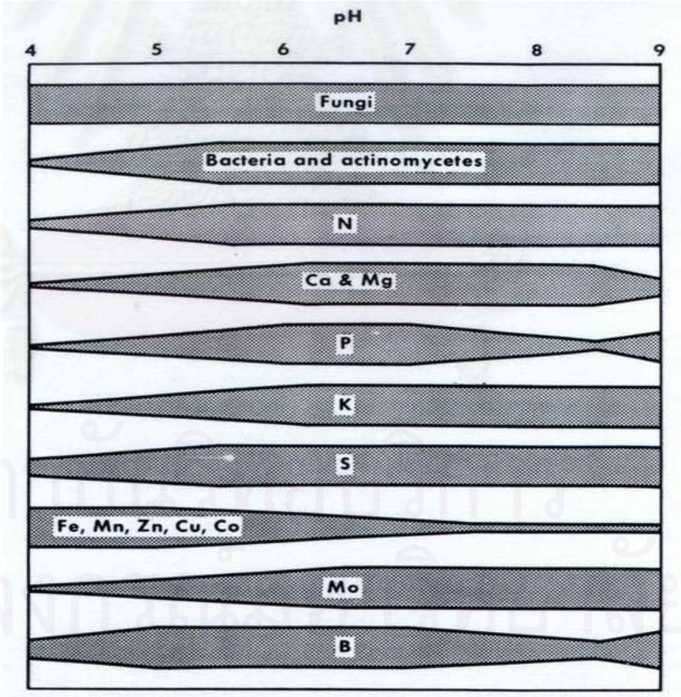


Figure 3.5. Ranges of pH which have influences on soil nutrients and fungi activities. (from Buckman and Brady, 1969).

Laboratorial soil pH test in this study was done using a pocket pH meter in two methods, water and $CaCl_2$. In the field investigation, the pH value was also measured using a soil-pH/humidity tester which is a fast method though not accurate.

Relations between Farm Produce and Soil pH

To make the soil ideal for absorbing fertilizers it is necessary to neutralize the soil by compounding neutralizer agents such as lime, etc. However, should lime or other property be sprayed in for a too large quantity, it causes what we call ”dearth of manganese” with an end result that the soil itself entirely loses its proper property as “soil fertilizer”.

In case of spraying lime on the soil, it is most advisable that the soil's hydrogen ion, or pH be detected first to determine the appropriate quantity of lime needed for neutralization. To this end it is recommended to use this soil simple pH tester, for on-the-spot pH detection use. Users never fail to be satisfied with the results.

By neutralization it means that the soil is made into a condition of pH 7 in terms of hydrogen ion content, but pH 7 does not always mean the best condition. The optimum pH index is more or less different according to produce involved, and the respective optimum pH indexes by produce are as per the following tabulation:

Table 3.4. List of Optimum pH Index for some farm produces.

pH 7-8	Barley, Spinach, Sugar Beet, Ground-Nuts, Onion, etc.
6-7.5	Rye, Wheat, Peas, Sweet Potato, Turnip, Clover, Egg-Plant, Burdock, Tobacco, etc.
5.5-7	Soya Bean, Rape(cole), Red Bean, Radish, Carrot, Tomato, Corn, etc.
5-6.5	Rice –Plant, Dry-Land Rice, Potato, Taro, etc.

To judge if the proper quantity of lime has been sprayed for neutralization, detection is required to be made about a week after the lime spraying. Volume of the lime to be sprayed for neutralization varies according to quality of the soil involved.

Table 3.5. The quantity of lime needed to be raise, by one unit pH index of soil toward Alkali side or Alkalization (10,700 square feet (990 square meters or ¼ acre).

Nature of soil	In case of Weak Humus	In case of Medium Humus	In case of Rich Humus
Sandy Soil	64 kgs. (140 lbs)	64 kgs. (140 lbs)	64 kgs. (140 lbs)
Minute Soil	95 kgs. (210lbs)	188 kgs. (415lbs)	290 kgs. (640lbs)
Sand Soil	188 kgs. (415 lbs)	315 kgs. (700 lbs)	450 kgs. (100 lbs)
Medium Soil	315 kgs. (700 lbs)	375 kgs. (825 lbs)	469 kgs. (1,030 lbs)
Sticky Soil	375 kgs. (825 lbs)	469 kgs. (1,030 lbs)	533 kgs. (1,170 lbs)
Humus soil in case humus volume is 15% up: Abt. 450 kgs. (1,000 lbs) – 900 kgs. (2,000 lbs)			

Example:

Supposing that the soil reaction is at pH 4 and is of a sandy nature, which is low in humus, to elevate the pH to 6.5, the quantity of lime needed, according to tabulation above, (pH 6.5 – pH 4 = 2.5) is 2.5 to make the soil alkali.

This mean, in term of practical figures, that the quantity of lime needed to neutralize the soil, measuring 10,700 square feet (990 square meters or ¼ acre), 10cm deep, is 188 kgs. (415 lbs.) x 2.5 = 470 kgs. (1,038 lbs.)

C.) Organic matter

The organic matter is a complex component of soil. It is important to soil fertility as it is a source of phosphorus, nitrogen, and micronutrients. Furthermore, it has more water holding capacity than most inorganic particles, and also helps retaining the porosity and aggregate stability of soils. So, suitable quantity of organic matter makes a better fertility in soil.

United States Department of Agriculture (1951) classified the organic matter rate into 7 ranges as shown in Table 3.6.

Table 3.6. Organic matter rating.

Ranges	Rating
<0.5%	Very low
0.5% to 1.0%	Low
1.1% to 1.5%	Moderately low
1.5% to 2.5%	Medium
2.6% to 3.5%	Moderately high
3.6% to 4.5%	High
>4.5%	Very high

Sources: United States Department of Agriculture (1951).

In this study, an analysis of organic matter percentage was done using the Walkley-Black method, which is titration method. The results are shown further on.

D.) Conductivity

The dissolved chemical element forms a solution in water which conducts electricity. The conductivity depends on temperature and salt quantity. Therefore, conductivity is used for finding soil salinity. In this study a pocket conductivity meter is used for measure and its results are mS/cm unit. The study results are shown further on.

E.) Salinity

A saline soil is the soil that has a conductivity over 4 mS/cm at 25°C, with dissolved Na more than half of total dissolved cations, and pH<8.5. (Tassani Attanan and Jongrak Chancharoensuk, 2542). It makes the soil to be low in organic matter, affecting in less dissolvability of P, Na, K, and Ca, thus decreasing the dissolved nutritions for plants.

The salinity analysis in this study was done using a saturation extract method by filling water into soil until saturated, and using a conductivity-meter to measure the value. The conductivity of saturation extract can classify of salinity rate in Table 3.7.

Table 3.7. Conductivity and percentage of salt rating, and harm for plants.

Conductivity of saturation extract (mS/cm) at 25°C	% salt at saturation extract	Salinity group	Harm for plants
0 to 2	0% to 0.1%	Nonsaline	No harm
2 to 4	0.1% to 0.3%	Very slightly saline	Harm only to highly sensitive plants
4 to 8	0.3% to 0.5%	Low salinity	Harm for many plants
8 to 15	0.5% to 1.0%	Moderately saline	Only some plants can grow e.g. wheat, grape, and olive
8 to 16	>1.0%	Strongly saline	Only plants that stand the highly saline soil can grow e.g. barley, sugar beet, and date
>16		Very strongly saline	Only mangrove swamp plants can grow

Sources: Supot Totrakul (2526)

3.1.3.2 Soil chemical properties

The soil chemical properties in this study are some properties such as the total exchangeable bases (Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}), micronutrients (Fe, Mn, Cu, and Zn), So_4^{2-}, NO_3^{-}, and ammonia.

A.) Total exchangeable bases (T.E.B.)

The total exchangeable bases are the elements in rows IA and IIA in the periodic table which consist of metal elements that are alkali and alkaline earth. They are Li, Na, K, Rb, Cs, Fr and Be, Mg, Ca, Sr, Ba, and Ra. But in natural condition, only Ca, Mg, K, and Na are occurred in high quantity while the others may be occurred in a very small amount. The quantity of total exchangeable bases thus includes the total amount of Ca, Mg, K, and Na in me/100g unit (milliequivalent per soil 100 g). These cations which are absorbed on the clay surface, reduce the acidity in soil. When it is hydrolysed, it becomes OH^-.

Analysis of the total exchangeable bases in this study was done on a basic cation, NH_4^+, which replaces other cations on the clay surface. The analysis of the basic cations which is replaced by NH_4^+ is done using an atomic absorption spectrophotometer. The total exchangeable bases are from the summation of each ppm cation divided by their milliequivalent which is different for different elements, i.e. 11, 12, 19, and 20 for Na, Mg, K, and Ca respectively. United States Department of Agriculture (1951) classified the Ca, Mg, and K rates as shown in Table 3.8.

Table3.8. Ca, Mg, and K rating.

Ca Range	Mg Range	K Range	Rating
<400 ppm	<40 ppm	<60 ppm	Low
400 to 600 ppm	40 to 90 ppm	>60 to 90 ppm	Medium
>600 ppm	>90 ppm	>90 to >120 ppm	High

Sources: United States Department of Agriculture (1951).

B.) Micronutrients

The micronutrients e.g. Fe, Mn, Cu, Zn are the transition elements being necessarily for plants growth only for a certain amount (as trace elements). These 4 elements have received an interest because many soils have problems if the quantities are not suitable. The reason is that the micronutrients are soluble in a low pH condition. In a very low pH condition, i.e. in acid soils, however the amount of soluble micronutrients could be so high that they become toxic to plants. On the other hand, the high pH soils may contain less soluble micronutrients until they are insufficient for a proper growing of plants.

In this study, DTPA (diethylene triamine pentaacetic acid) was used for analyzing all 4 micronutrients. The DTPA soil solutions were analyzed in an atomic absorption spectrophotometer. Their results in ppm. are shown further below.

United States Department of Agriculture (1951) classified the sufficient quantity levels for some micronutrients as shown in Table 3.9.

Table 3.9. Sufficient quantities level for Fe, Mn, and Zn.

Rating	Fe	Mn	Zn
Low	<15 ppm	<5 ppm	<5 ppm
Sufficient	15 to 40 ppm	5 to 30 ppm	5 to 30 ppm
High	>40 ppm	>30	>30 ppm

Sources: United States Department of Agriculture (1951).

C.) Sulfate

Most plants use sulfur in the form of sulfate (SO_4^{2-}). Sulfate is the most stable form in soil with a good air ventilation condition. In a water confined condition, sulfur will change to sulfide form (S^{2-}) and sulfur is unusable for plants.

In this study, an extraction solution is used. This is acetate-acetic solution which was analyzed in a spectrophotometer by using Sulfa Ver 4 method. The study results are shown further below.

D.) Available nitrogen

Naturally, Nitrogen is the most found in the organic matter but the plants cannot extract that for uses. The plants can only use nitrogen in the forms of ammonium and nitrate compounds. These compounds are obtained from the decomposition of the organic materials. But the quantity of the usable nitrogen compounds in soils is changing all the time due to the washing-out, plant usage, changing temperature, soil humidity and ventilation, so the determination of the usable nitrogen quantity must be done on the amount of existing organic materials and of the total nitrogen.

United States Department of Agriculture (1951) classified nitrate rate in Table 3.10.

Table 3.10. Nitrate rating.

Ranges	Rate
0 to 39 ppm	Low
40 to 99 ppm	Acceptable

Sources: United States Department of Agriculture (1951).

In this study, an ammonium analysis was done using Nessler method in a spectrophotometer and the analysis of nitrate was done using cadmium reduction method by using Nitra Ver 5 nitrate reagent which was analyzed in a spectrophotometer.

E.) Available phosphorus

Available phosphorus is an important nutrient for plant growth. Naturally, phosphorus in the soil derives from inorganic phosphorus from fluorapatite decomposition, which the mineral itself is nondissolvable. Only the phosphorus in the form of $H_2PO_4^-$ and HPO_4^- especially in Ca compounds that plants can use.

The other source of available phosphorus is the decomposed organic materials. The problems of phosphorus in soils for plant growth are from many reasons. They are as following.

- In sufficient initial amount of phosphorus in soils due to less phosphorus sources.

- Phosphorus exists in an insoluble form such as in the cases of no decomposition of sources.

- Phosphorus reacts to form an insoluble compound with some elements e.g., Fe, Al, Mn, especially in a low pH condition.

Phosphorus may form an insoluble compound with Ca at a very high pH condition also. Thus to determine the amount of useful available phosphorus, one must consider the sources of phosphorus together with the rate of decomposition and the pH condition.

The United States Department of Agriculture (1951) classified the phosphorus rate into 7 ranges as shown in Table 3.11.

Table 3.11. Phosphorus rating.

Ranges	Rating
<3 ppm	Very low
3 to 6 ppm	Low
6 to 10 ppm	Moderately low
10 to 15 ppm	Medium
15 to 25 ppm	Moderately high
25 to 45 ppm	High
>45 ppm	Very high

Sources: United States Department of Agriculture (1951).

3.1.4 Soil quality analysis results

The collective soil study results are shown as following.

3.1.4.1 Soil physical properties

A.) Soil texture

The soil texture observed in study area is noted to be sandy loam as seen in 7 samples or 63.63% of all samples, sandy clay loam in 3 samples or 27.28%, and clay loam in 1 sample or 9.09% respectively.

B.) Soil pH

Figure 3.6 shows the distribution of pH values which was analyzed by $CaCl_2$ method in soils in the study area. The pH values vary from 4.8 to 7.5, or from very strongly acidic to slightly alkaline. The area where the pH value is more or less neutral (pH 6.6 to 7.2) is located in the northwest while the central west of study area is of the acid soils. The alkali soils are in northwestern and southeastern parts of study area. Thus, the suitable pH value for plants is in the middle part of the study area.

C.) Organic matter

Figure 3.7 shows the distribution of the percentage of organic matter in the study area. It varies from 1.1% to 4.8% that is classified as moderately low to moderately high. Seven soil samples or 63.63% of all samples, have a moderately low value, 3 samples medium, 1 sample moderately high, and 1 sample very high. The highest percentage of organic matter is located in the central east of the study area and the lowest is in the north.

D.) Conductivity

Figure 3.8 shows the distribution of the conductivity values in the study area. The range of conductivity value is from 0.269 to 1.108 ms/cm. The highest value is in the north of study area in Amphoe Wang Sai Phun and the lowest value is scattered in Amphoe Chon Daen, Noen Maprang, and Thap Khlo in the northeastern, central and southeastern parts respectively.

E.) Salinity

The salinity values of all samples in the study area are between 0 to 0.1%. They were all classified as non-saline and are of no harm to plants. The percentage of salinity value contour map in study area is shown in Figure 3.9. It could be simply noted that the salinity distribution conforms that of the conductivity.

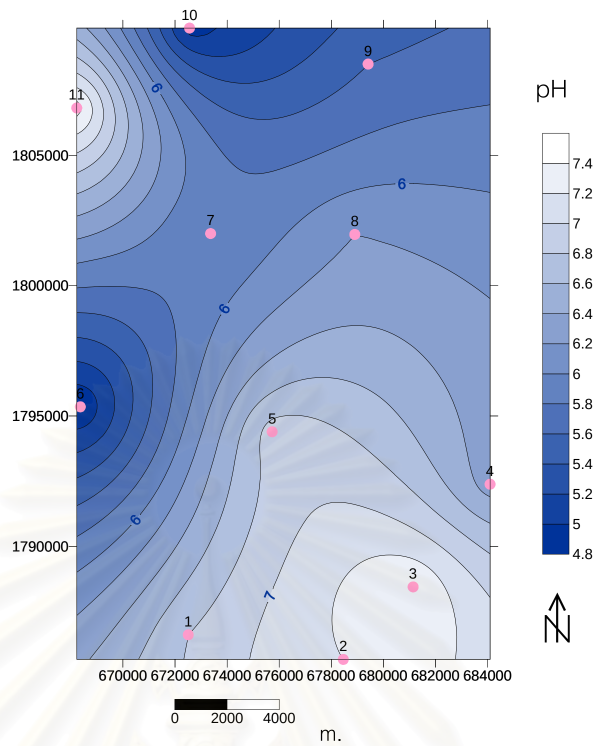


Figure 3.6. Distribution of pH values in the study area.

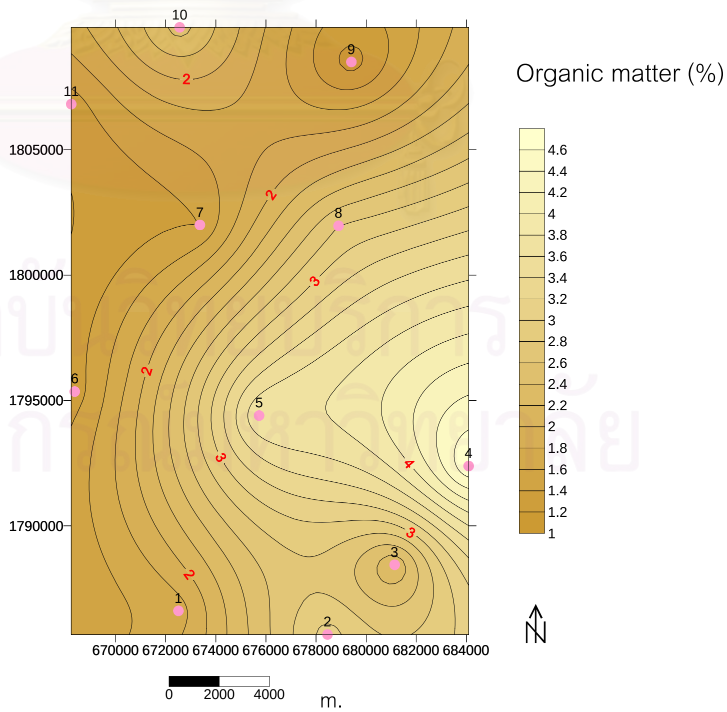


Figure 3.7. Percentage of organic matter in the study area.

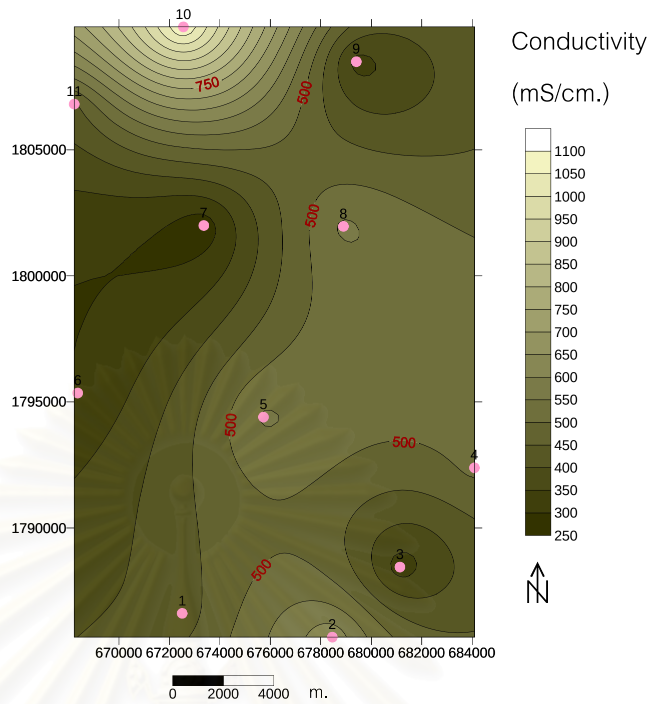


Figure 3.8. Conductivity value in the study area.

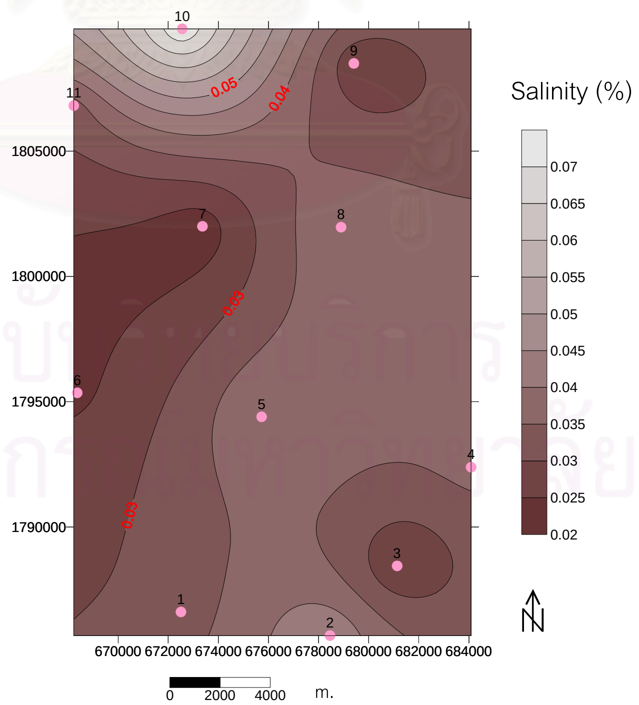


Figure 3.9. Percentage of salinity value in the study area.

3.1.4.2 Soil chemical properties

A.) Total exchangeable bases

Figure 3.10 shows the values of the total exchangeable bases (T.E.B.) in the study area. The range of the values is from 6.07 to 50.39 meq/100g. The highest value is in south in Amphoe Chon Daen and in the northwest in Amphoe Noen Maprang while the lowest value is in the middle of study area in Amphoe Thap Khlo.

Of the chemical elements of T.E.B., it was noted that Ca, Mg, and K concentrations are in a high range. Their concentrations in the study area are as following.

Ca : Figure 3.11 shows the distribution of Ca concentration of soil in the study area. The Ca concentration varies from 800 to 9400 ppm. that are considered to be of a high content (>600 ppm.). All of samples are in this range. The distribution of the Ca concentration follows that of T.E.B.

Mg : Figure 3.12 shows the distribution of Mg concentration in the soils in the study area. The Mg concentration varies from 42 to 370 ppm. that are medium to high content. Almost all samples, 10 samples or 90.91% of 11 samples, are of high content (>90 ppm.) and 1 sample is medium content (40 to 90 ppm.).

K : Figure 3.13 shows the distribution of K concentration in the soils in the study area. The K concentration varies from 60 to 320 ppm. that are low to very high content. Almost samples, 7 samples or 63.63% are of very high content (>120 ppm.). They are in the middle of study area. Only 1 sample is of medium content (60 to 90 ppm.) and 3 samples are of low content (30 to 60 ppm.) that in southwest of study area.

Na : Figure 3.14 shows the distribution of Na concentration in the soils in the study area. The range of concentration is from about 90 to 216 ppm. The highest content is in the south of the study area in Amphoe Chon Daen while the lowest content is in the middle of study area.

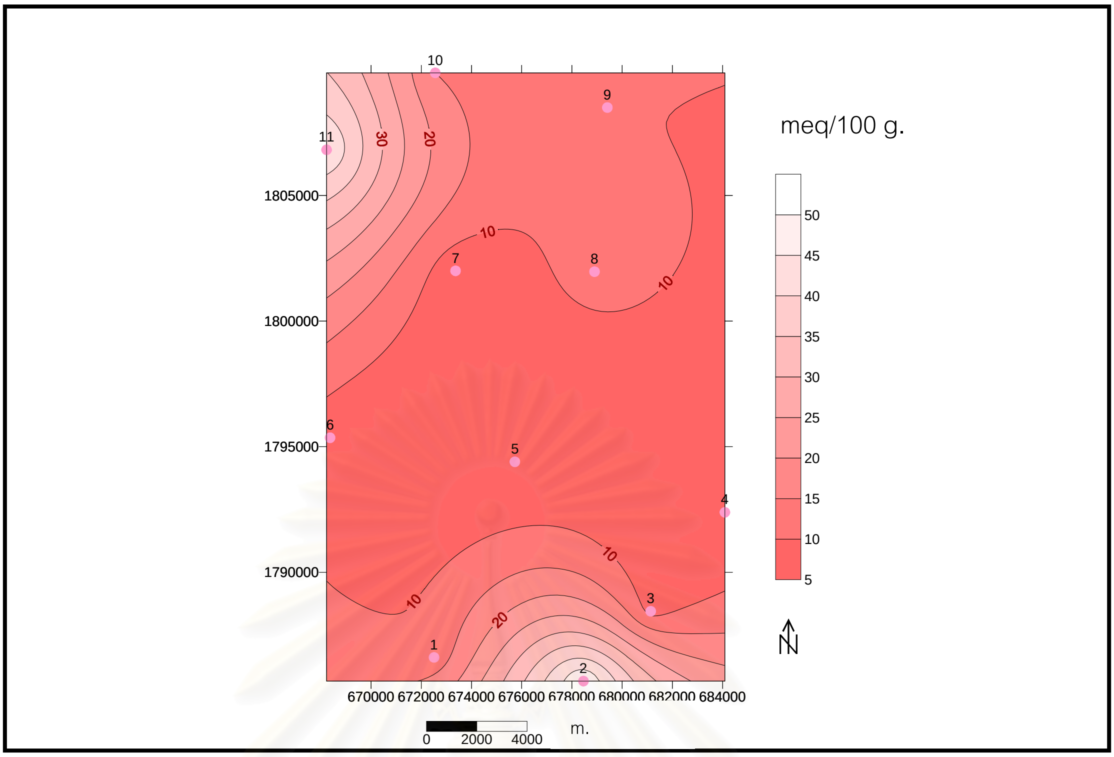


Figure 3.10. Total exchangeable bases value in the study area.

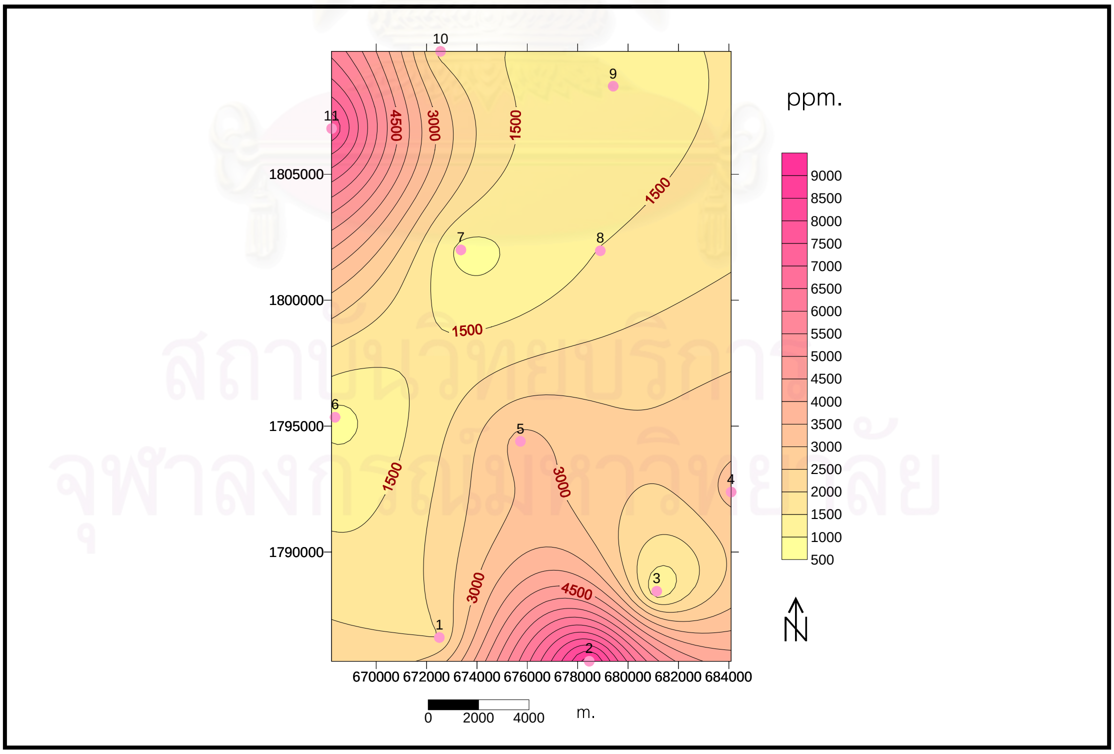


Figure 3.11. Ca concentration in the study area.

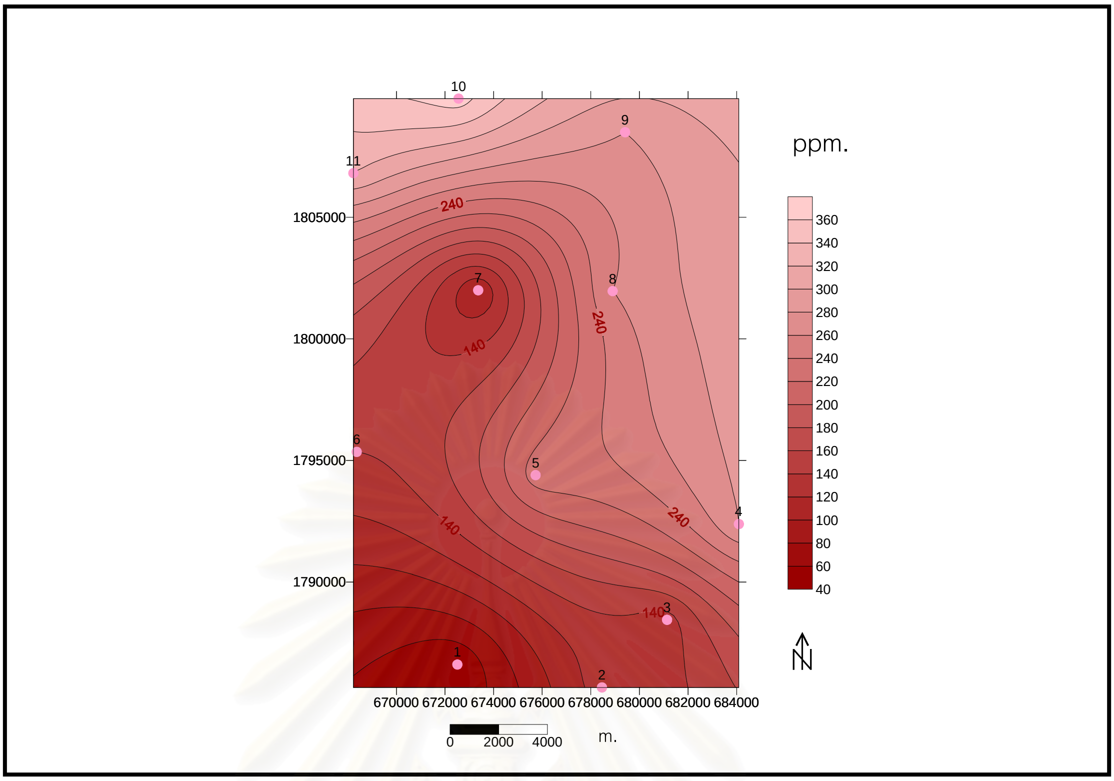


Figure 3.12. Mg concentration in the study area.

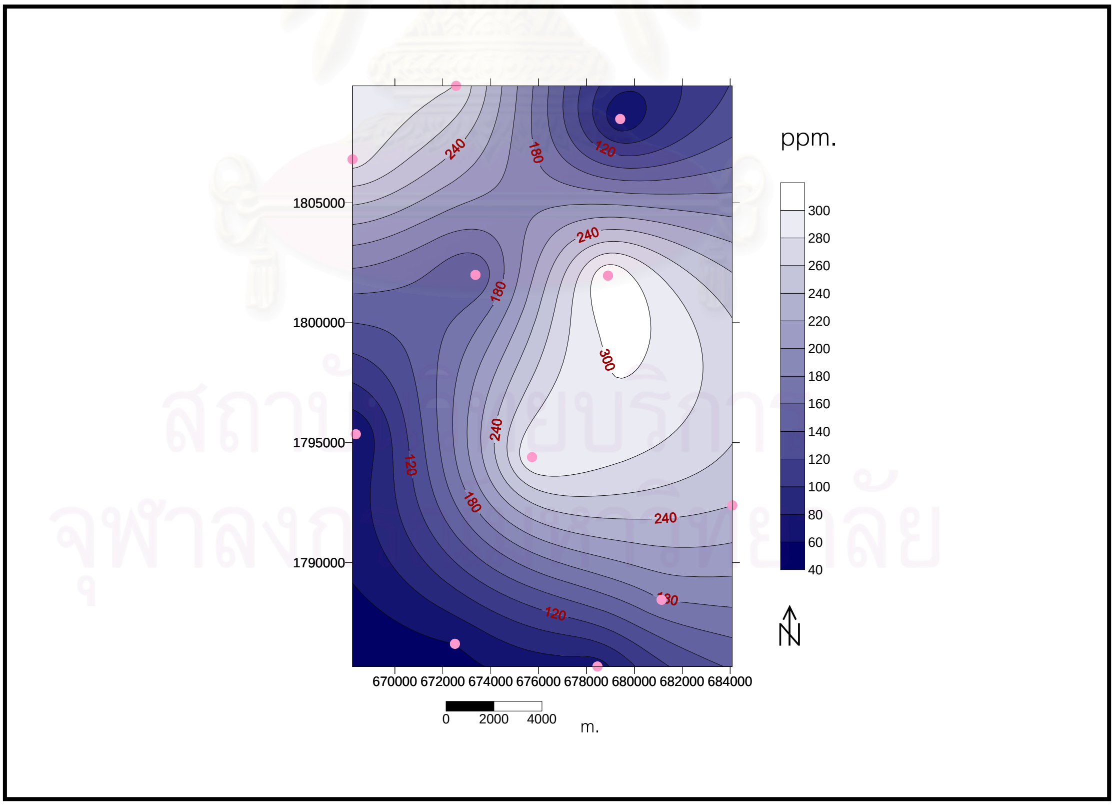


Figure 3.13. K concentration in the study area.

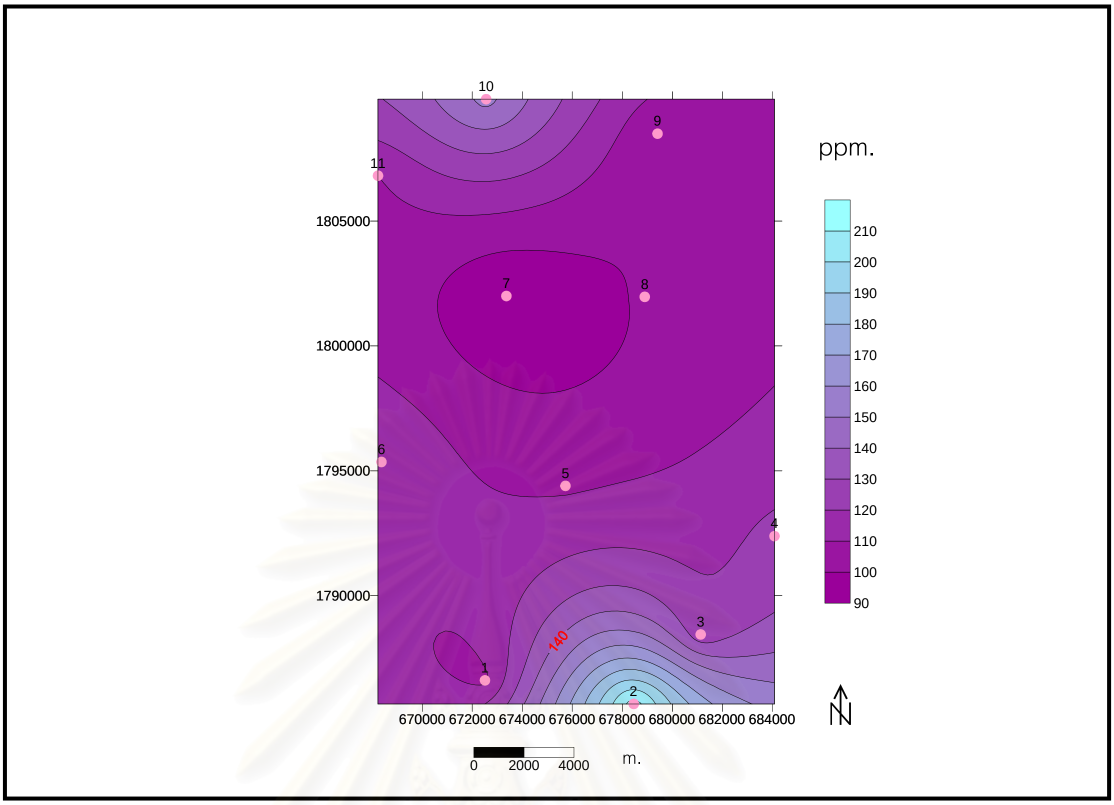


Figure 3.14. Na concentration in the study area.

B.) Micronutrients

Four elements were analyzed as micronutrients in this study. The study results are as following.

Fe : Figure 3.15 shows the distribution of Fe concentration in the soils in the study area. The Fe concentration varies from about 7 to 100 ppm. that are of low to high content. Five samples or 45.46% of 11 samples, are of high content (>40 ppm.) and are located to the borders of area. Two samples are of sufficient quantity (for plants) content, and are at the north and middle of the area while 4 samples or 36.36% are of low content and are found to the south to northwest of the study area.

Mn : Figure 3.16 shows the distribution of Mn concentration in the soils in the study area. The Mn concentration varies from about 6 to 67 ppm. that are sufficient quantity to high content. Five samples are sufficient quantity content that are located in the south, west, and north of study area.

Zn : Figure 3.17 shows the distribution of Zn concentration in the soils in the study area. The Zn concentration varies from 0.384 to 8.68 ppm. that are of low to sufficient quantity content. Almost all samples, 10 samples or 90.91% are of low content and are located in the middle to west of study area. One sample, or 9.09% is of sufficient quantity content, and is located in the east of study area.

Cu : Figure 3.18 shows the distribution of Cu concentration in the soils in the study area. The Cu concentration varies from 0.476 to 2.324. The lowest content is in the middle of the study area while the highest content is in the north and south of the study area.

C.) Sulfate

Figure 3.19 shows the distribution of sulfate concentration in the soils in the study area. The sulfate concentration varies from 6 to 16 ppm. The lowest content is in the north to west and south of the study area while the highest content is in the middle to southwest of the study area.

D.) Available Nitrogen

The available nitrogen concentration was considered as the nitrate and ammonia.

Figure 3.20 shows the distribution of available nitrogen concentration in the soils in the study area. It varies from 0.92 to 6.06 ppm. The highest content is in the north of the study area while the lowest is in the west to the south of the study area.

Nitrate : Figure 3.21 shows the distribution of nitrate concentration in the soils in the study area. The nitrate concentration varies from 0 to 3.4 ppm. that are of low content. All of samples are in this range. The highest value is in the north of the study area while the lowest value is in the east and the west of the study area.

Ammonia : Figure 3.22 shows the distribution of ammonia concentration in the soils in the study area. The ammonia concentration varies from 0.52 to 2.66 ppm. The highest content is in the north of the study area while the lowest content is in the south of the study area.

E.) Available Phosphorus

Figure 3.23 shows the distribution of phosphorus concentration of study area. The phosphorus concentration varies from 7 to 700 ppm. that are of moderately low to very high content. Almost samples, 7 samples or 63.63% are of very high content (>45 ppm.), and are located in the middle of the study area and concentration are lower out of from its radius.

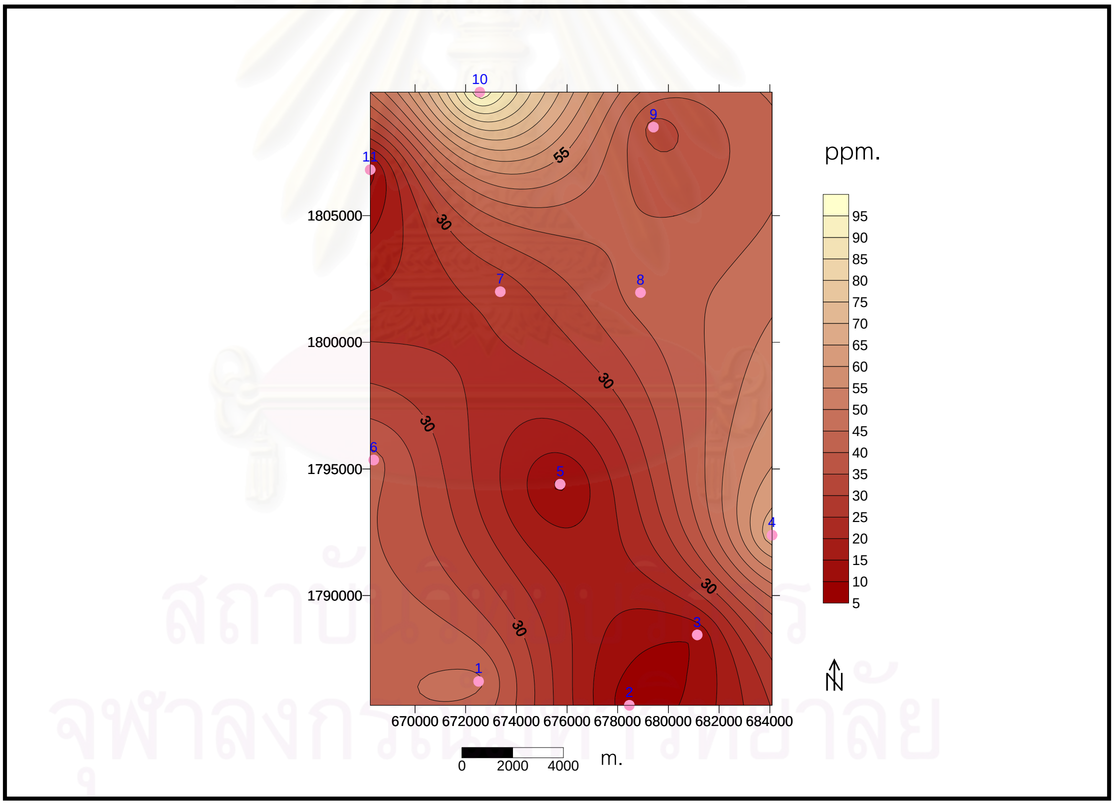


Figure 3.15. Fe concentration in the study area.

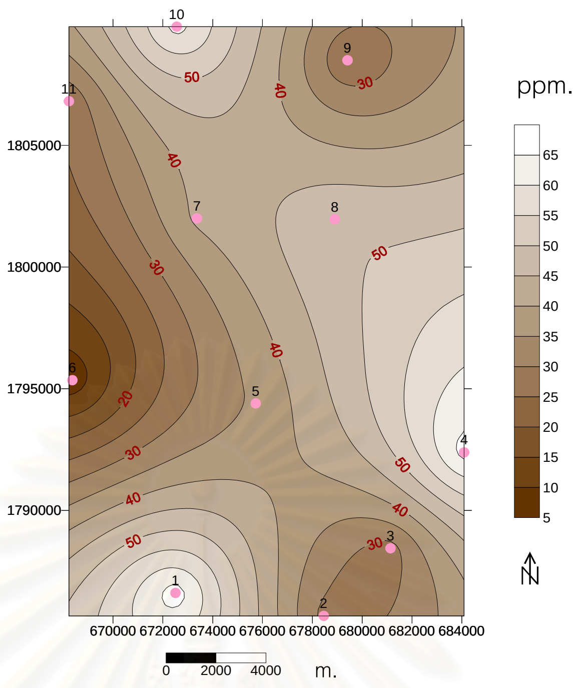


Figure 3.16. Mn concentration in the study area.

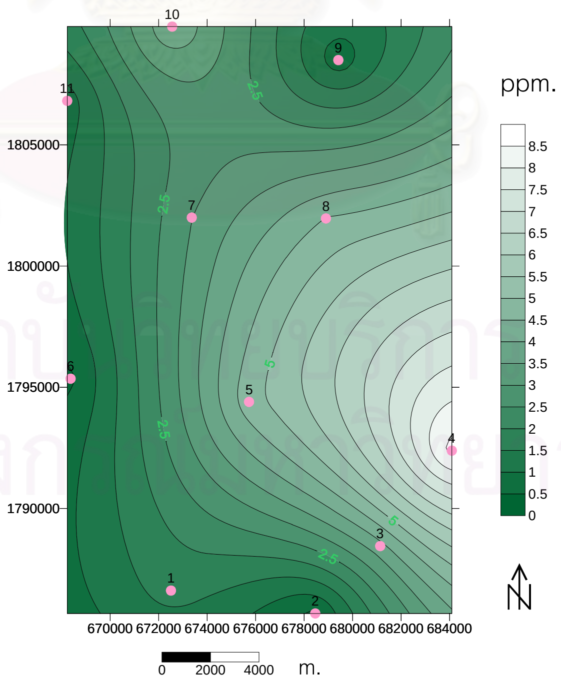


Figure 3.17. Zn concentration in the study area.

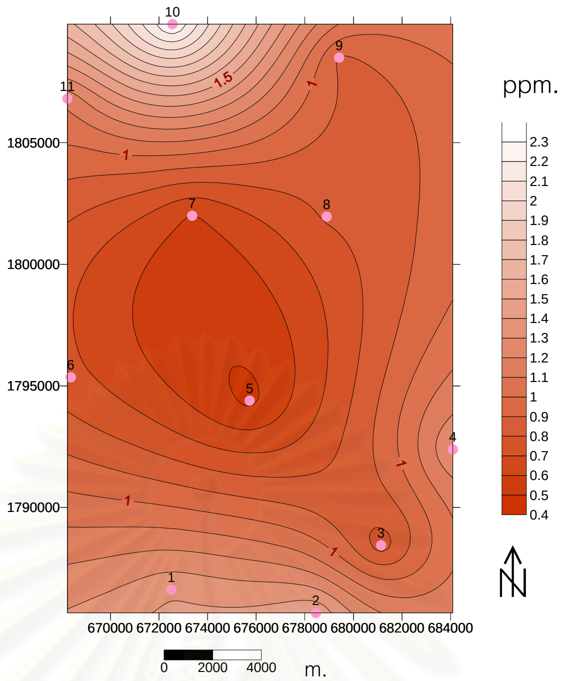


Figure 3.18. Cu concentration in the study area.

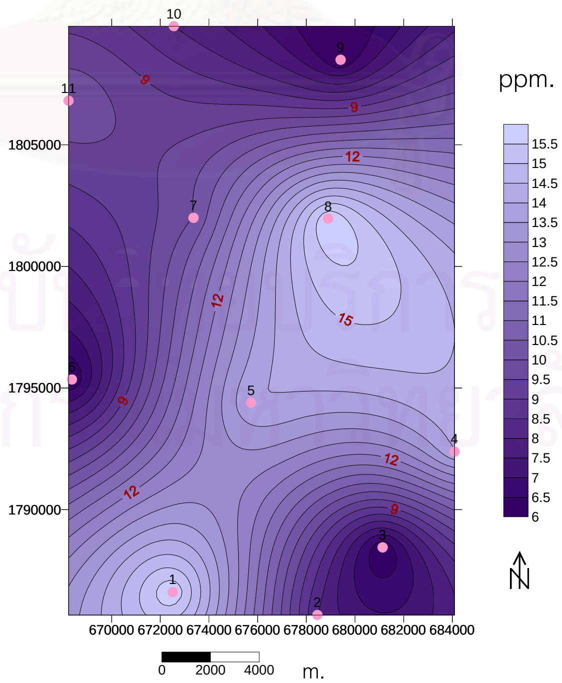


Figure 3.19. Sulfate concentration in the study area.

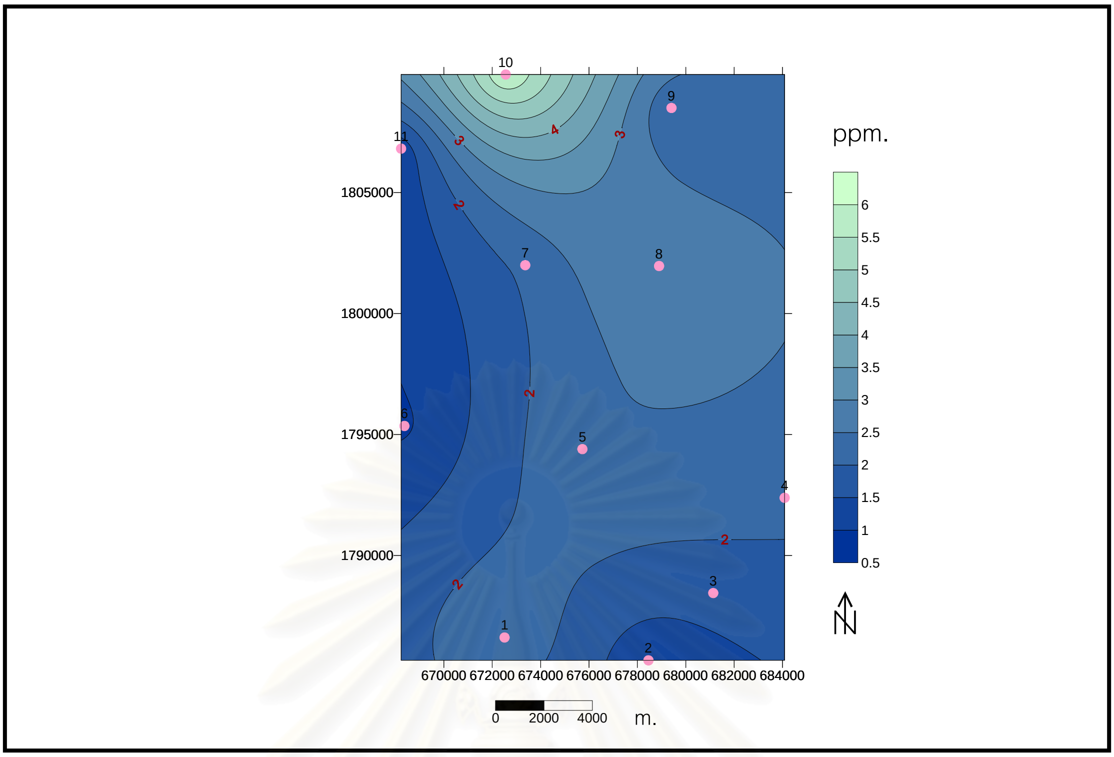


Figure 3.20. Nitrogen concentration in the study area.

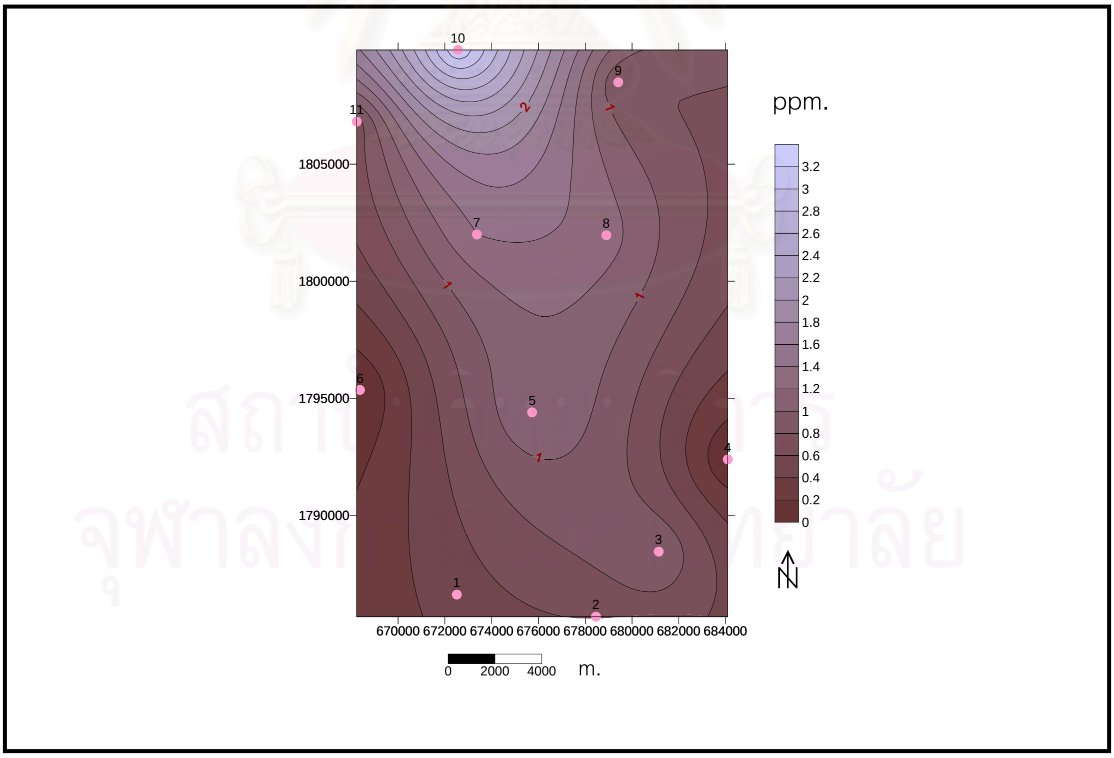


Figure 3.21. Nitrate concentration in the study area.

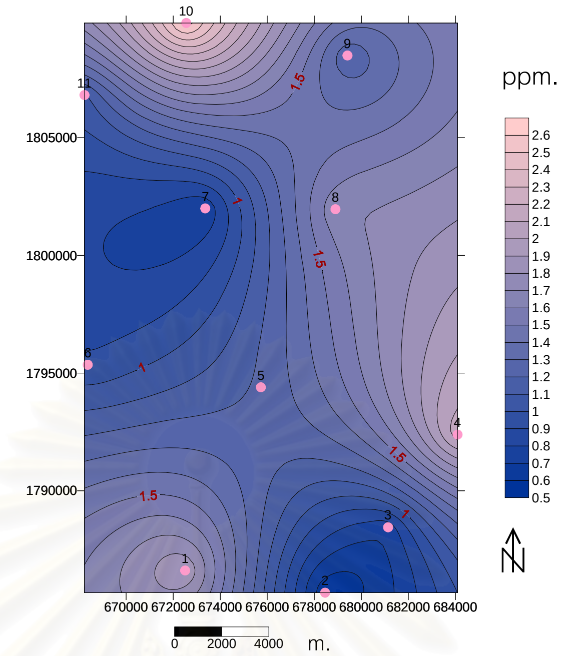


Figure 3.22. Ammonia concentration in the study area.

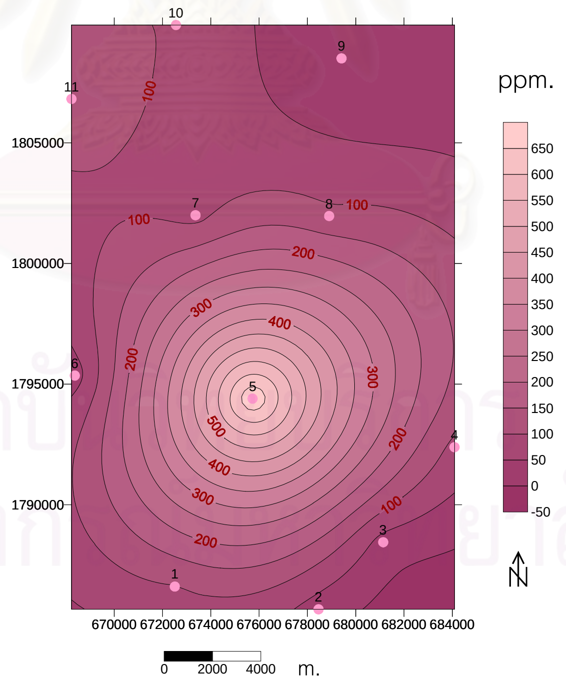


Figure 3.23. Phosphorus concentration in the study area.

3.2 Land suitability and soil capability

A piece of land can be used for many purposes. However as many usages could be conflicting with one another, generally only one usage could be applied onto that land at a time. But there are the chances that a piece of land could become a multipurpose land. The physical environment of the land is a factor which determines-, or ideally determines-, the suitable usage. This physical environment includes the rock and soil types and condition, mineral resources, groundwater, degree of slope inclination and their stability, drainage and surface water, areal precipitation, wind condition, vegetation cover, location, and geological structures (faults, folds). Some usages may not depend on the physical environmental factors to a significant extent, but the others, such as agriculture, may be sensitive to many factors (Cargo and Mallory, 1997).

The soil suitability and landuse were studied by using the 2543 soil map of Department of Land Development's. The suitability of the soil groups for plants was compared by overlaying technique of the 2543 landuse map of Department of Land Development's that is a correlation of the landuses on to the distribution of the suitable soils. Of course, if some areas can be converted to a more suitable use, it will certainly increase the productivity and income, and also helps reserving soil.

As already mentioned (Figure 3.1), 25 soil groups are found in the study area. It was noted that 34.5% of the study area was covered by Soil Group 7, 15.5%, 9.2%, 9.0%, and 4.4% by Soil Groups 6, 49, 25, and 4 respectively while the rest 27.4% of the area was covered by the rest 20 soil groups. Their suitability on the agricultural purposes and the actual land usage in 2543 is discussed below. The map of soil suitability for plants growing is shown in Figure 3.24.

Soil Groups 2 and 6; The suitable economic plants for these groups is rice, i.e. it is suitable to grow rice in the rainy season, and other field crops later if there is enough water in the dry season. In 2543 these soil groups was used for growing rice.

Soil Group 4; The areas which have this soil group are suitable to grow rice in the rainy season and other field crops in the dry season. In 2543 this soil group was used for growing rice mostly.

Soil Group 7; This soil group is more suitable to grow rice than other field crops. In 2543 this soil group in the north of the study area was used for growing rice and in the west was used for growing corn.

Soil Groups 15, 16, 17, and 18; These soil groups are more suitable to grow rice than field crops, but if there is enough water in the dry season, it can growth the field crops as well. The 2543 landuse of these soil groups in the study area was mostly to grow rice with subordinate corn.

Soil Group 21; This soil group is suitable to grow rice in the rainy season and field crops in the dry season. The 2543 landuse of this soil group in the study area was only to grow rice in the north and the south of the study area.

Soil Group 23; This soil group is not suitable to grow rice nor field crops because it is sandy soil. The 2543 landuse of this soil group in the study area was to grow corn and dipterocarp deciduous forest.

Soil Group 25; This soil group is very thin and have many pebbles. It is suitable to grow rice in the rainy season and field crops that have short root system in the dry season. The 2543 landuse of this soil group in the study area was to grow rice and corn.

Soil Group 29; This soil group is found in the undulating terraces and hillsides with the slope 3 to 25%. It is more suitable to grow field crops than rice because its texture is clayey that is hard to keep water for rice. The 2543 landuse of this soil group in the study area was to grow corn with subordinate rice and forest.

Soil Group 33; This soil group is found in the areas that have slope 2 to 12%. It is suitable for many kinds of plants. Landuse of this soil group in 2543 was for growing forest, corn, rice, grassland, village, and mixed crop fields.

Soil Group 35; This soil group is suitable to grow mixed crop field and grassland but the 2543 landuse in the study area was to grow rice.

Soil Group 37; This soil group is not suitable to grow rice nor other field crops but it is suitable for grassland. In 2543 this soil group was used for grassland, cornfield, forest, and village.

Soil Group 38; This soil group is suitable to field crops but the 2543 landuse in the study area was to grow rice.

Soil Groups 44, and 46; These soil groups are suitable for grassland but the 2543 landuse of these soil groups were use for cornfield, rice field, and forest.

Soil Group 45; this soil group is suitable to grow rubber plantation, cashew nut and grassland. The 2543 landuse of this soil group in the study area was to grow rice.

Soil Group 47; this soil group is not suitable to grow any plants but in 2543,the landuse in the study area was use for growing corn.

Soil Group 48; this soil group is suitable for grassland and not suitable to grow rice. The 2543 landuse of this soil group in the study area was use for disturbed forest and cornfield.

Soil Group 49; this soil group is not suitable to grow all of plants because it is very thin soil. The 2543 landuse of this soil group in the study area was use for growing rice, corn, disturbed forest, and grassland.

Soil Group 55; this soil group is suitable to grow field crops and grassland. The 2543 landuse of this soil group in the study area was to grow corn.

Soil Group 56; this soil group is suitable to grow field crops that is depend on its slope. In 2543 this soil group in the study area was used for forest.

Soil Group 62; this soil group is suitable for forest because it is mountainous area. In 2543 this soil group in the study area was used for disturbed forest, rice field, corn, and grassland.

According to Table 3.1, the suitable land in the study area is mostly for the rice field as the soils is the most suitable for this plant.

By determining the above data, it was noted that the suitable landuse was about 521.314 km^2 or 77% of the study area. This was 392.092 km^2 in Changwat Phichit, 105.654 km^2 in Changwat Phetchabun, and 23.568 km^2 in Changwat Phitsanulok. The unsuitable landuse was noted to be totally 155.822 km^2, 60.387 km^2 in Changwat Phichit, 85.161 km^2 in Changwat Phetchabun, and 10.274 km^2 in Changwat Phitsanulok. The suitability landuse is shown in Figure 3.25.

In Changwat Phetchabun, the unsuitable landuses were mostly in Amphoe Chon Daen where the soils are suitable for rice. But in 2543 the landuse was for mixed crop fields and grassland. A similar unsuitable landuse was observed in Amphoe Wang Pong, where the suitable landuse was also for rice. In 2543 the landuse was for mixed crop fields and grassland. Another unsuitable landuse was observed in Amphoe Noen Maprang, Changwat Phitsanulok, where the suitable landuse was for rice field. But in 2543 the landuse was for mixed crop fields.

In Changwat Phichit, more unsuitable landuse was observed in Amphoe Thap Khlo, where the suitable landuse was only for grassland, not for any plants. But in 2543 the landuse was for mixed crop fields. Similarly, an unsuitable landuse was observed in Amphoe Taphan Hin, where the suitable landuse was for forest and rice field. But in 2543 the landuse was for village. Also in Amphoe Wang Sai Phun and Amphoe Muang Phichit, a similar unsuitable landuse was observed as the suitable landuse was for grassland and mixed crop field. But in 2543 the landuse was for rice field.

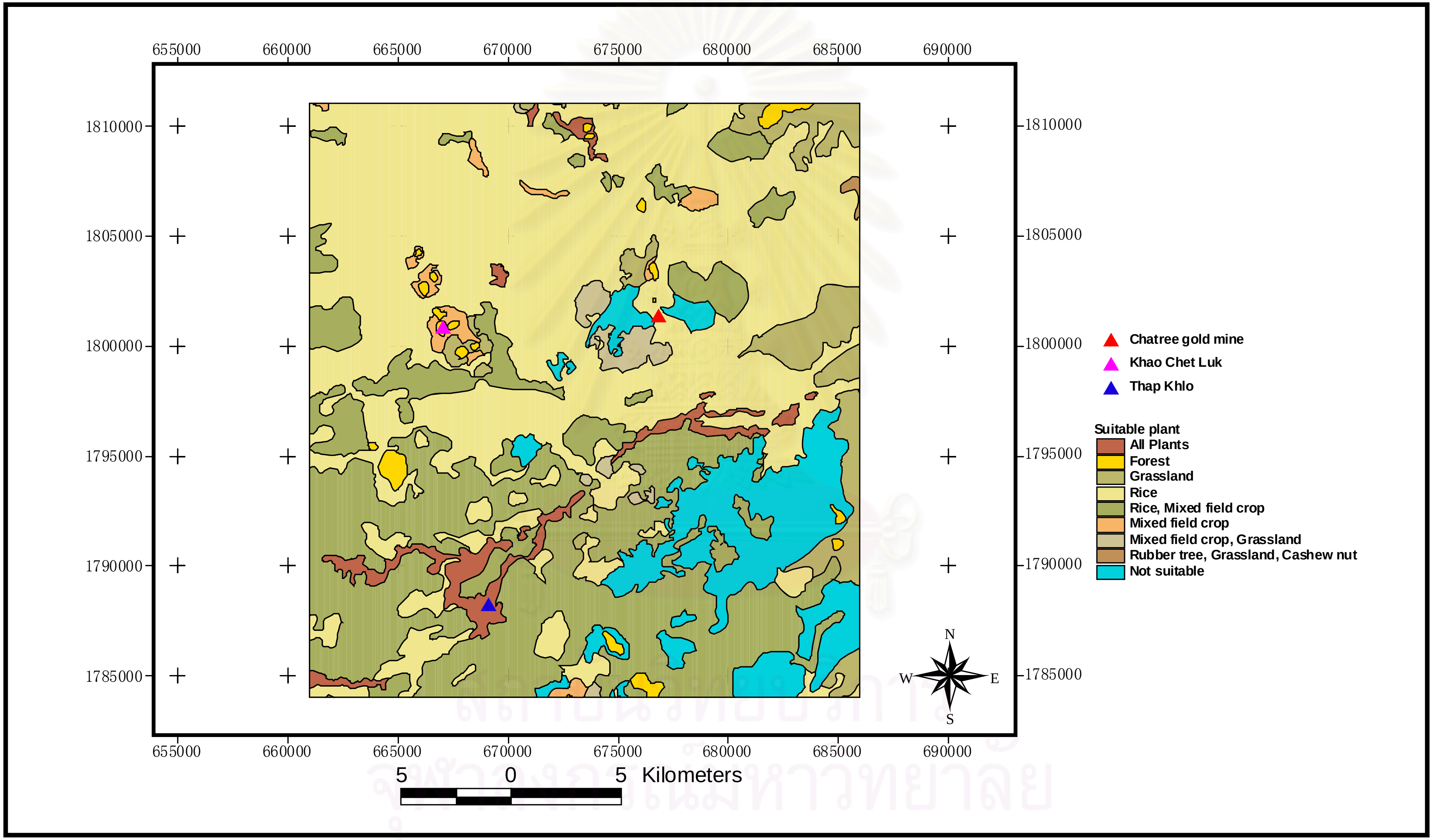


Figure 3.24. Ideally suitable plants for specific soil groups.

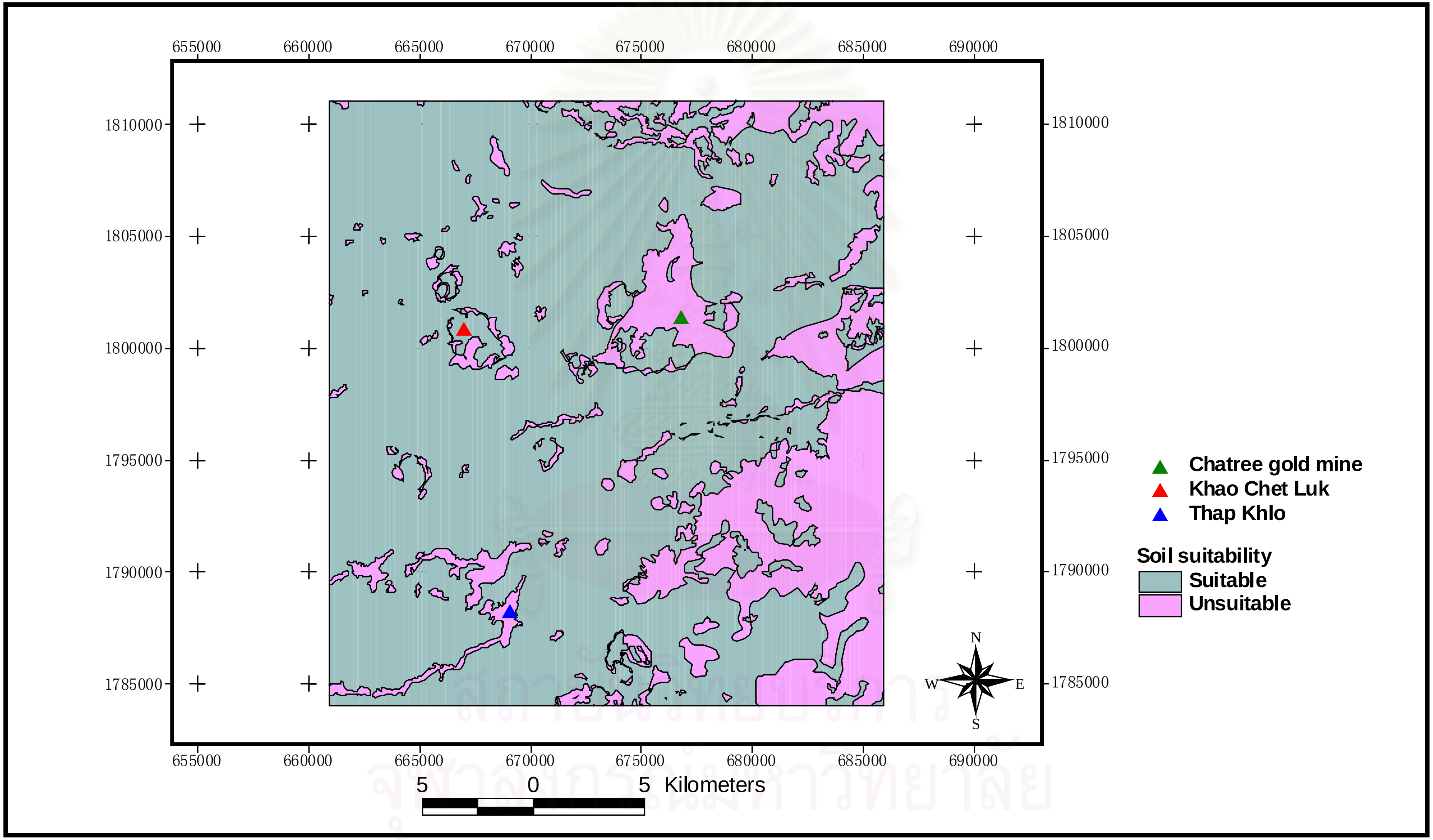


Figure 3.25. Suitability of the 2543 landuse.

CHAPTER IV

SOCIO-ECONOMIC CONDITION THROUGH TIME

The population data in this study are from the records the National Statistical Office which were given within the administrative district boundary. In this study area however many districts have been involved but mostly not of the entire district area. But as the pattern of population spreading is somewhat uniform in the entire area, the ratio of the population was thus decided according to the ratio of the district areas appeared in this study. This is not for the case of economic condition which cannot be rationalized by area. Such data were shown for the whole district areas.

4.1 Population and density

In this study, the population was obtained by averaging the total registered population according to the percentage of each areas of each administrative district appeared in this study. This method was thought to be the best fitted as it was noted that the pattern of settlement was evenly distributed throughout this region. Population growth rate can be calculated using Henry and Heinke's (1996) equation below.

$$P = P_0 e^{rt}$$

Where P = Future size of the population

P_0 = Current size of the population

t = Number of years for the extrapolation

r = Assumed constant growth rate for each of the years (as a function)

e = Base of natural logarithms.

The population density was simply obtained by dividing the amount of population by the area of study, that is 677.136 km^2.

The population between 2513 B.E. and 2545 B.E. is compared in Figure 4.1 and the population, density, growth rate, and net migration are as shown in Table 4.1. From the table, the growth rate in the period of 2513 B.E. to 2515 B.E. is the highest at 4.76% per year, while in the period of 2541 B.E. to 2542 B.E., the rate is the lowest, at –5.7% per year, that is a population decrease. The Density of population in 2541 B.E. is the highest at 117.19 persons per km^2.

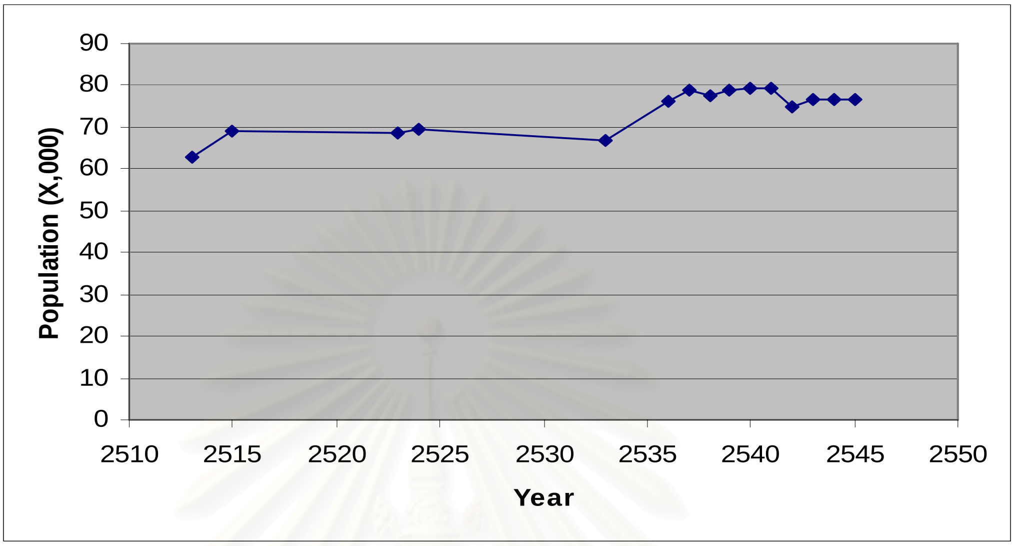


Figure 4.1. Population in study area from 2512 B.E. to 2545 B.E.

To analyze a natural resource exploitation, the data on population growth rate, birth rate, death rate, and net migration rate were used as to study the population dynamics in this study area. The birth rate, death rate, and net migration rate, which are shown in Table 3.11 are from the census. Growth rate are calculated from equation

$$r = (b-d) + (i-e) \qquad \text{(Henry and Heinke, 1996)}$$

where b, d, i, and e are birth rate, death rate, immigration rate, and emigration rate respectively. The net migration is especially an important factor to identify the natural resource exploitation. The net migration was calculated from the immigration subtracted by the emigration.

4.2 Educational and Religion

In 2545 B.E. at the time of field visit, there were totally 311 schools in the 7 districts in where the study area is located. Here, Buddhism was noted to be the major religion in the study area. Then, there were altogether 194 Buddhist temples and 173 Buddhist sanka abodes to house 2,266 monks and 405 novices. Furthermore there were

Table 4.1. Population data in the study area.

	Population (Total)	Birth rate (per 1000)	Death rate (per 1000)	Net Migration rate (per 1000)	Growth rate (per 1000)	Density (man/km^2)
2513	62709					92.6
2515	68979				4.76%	101.87
2523	68647	15.1	4.3		-0.06%	101.38
2524	69559				1.32%	102.72
2533	66644				-0.47%	98.42
2536	76218	6.26	1.59	1.56	3.35%	112.56
2537	78802	10.18	4.5	6.51	3.33%	116.38
2538	77564				-1.58%	114.55
2539	78739				-0.04%	116.28
2540	79179				0.56%	116.93
2541	79352				0.22%	117.19
2542	74948				-5.7%	110.86
2543	76716	7.61	4.74	5.18	2.33%	113.29
2544	76418	7	4.92	2.52	-0.38%	112.85
2545	76509	5.59	4.97	1.36	0.12%	112.99

Sources: Adapted from National Statistical Office’s data from 1970 to 2002.

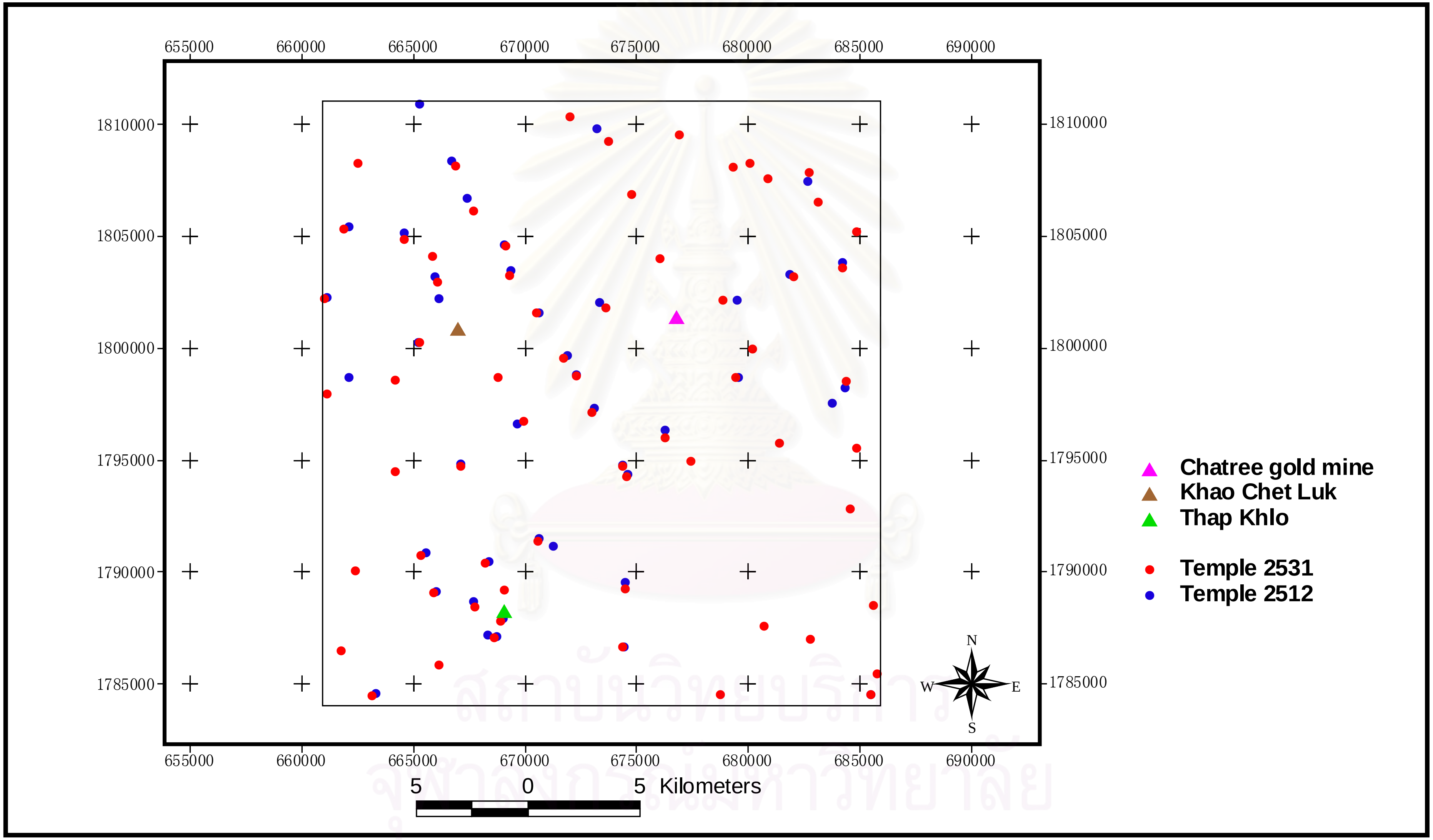


Figure 4.2. Sites of Buddhist temples in the study area.

5 Christian churches and 1 Islamic mosque. Figure 4.2 shows that there were only 43 Buddhist monasteries and sanka abodes in 2512 B.E. and 66 in 2531 B.E. respectively. The increase of the temples reflects the increase of population and their ablity to support the temples, to be inferred to their economic base. This is because the temples are such the social and cultural condition indicators. In Thailand, Buddhism is established as a national religion and the rural people are strictly believed in religion. The temples are not only the practice religion places to make people having peace of mind, but also are the center of the community, to where the most activities of any village's commune are performed.

From the interview of 25 temples in the study area, 17 monasteries had been developed from sanka abodes about 10 to 50 years ago, while 5 were monasteries since the beginning or being developed some 4 to 5 years ago. Three temples were still the sanka abodes.

People in the study area are agrarians who are living hand-to-mouth, with a low education and low income but they usually go to the temples on the religious days such as four Wan Phra (praying days) per month (Figure 4.3) and other important days such as Visakabhucha Day, Songkran Day, etc., to make merits and oftenly with donation. Each merit making will be composed of a minimum of 30 to 40 persons on regular Wan Phra to a maximum of 300 to 400 persons on Songkran Day. On these special days, almost all inhabitants in the neighborhood of the temples will get together at these central activity sites. Thus in 2531 B.E., the 66 temples reflects the inhabitants of 19,800 to 26,400, a number which is only about 30% to 40% of the population in the study area that shown in Figure 4.1.

Apart from a small budget of the governmental support, the temples have to rely mostly to the donation from the merit makers. The donation is used to build the much needed buildings such as Ubosot (main cathedral), Sala Karnprian (opened activity hall) and so on. Normally if the merit makers have surplus from more income than expense, they donate the surplus to the temples and the abbots will start the building program of the infrastructures. The size and elegance of the infrastructures

Figure 4.3. A merit making on a regular Wan Phra in the study area.

normally indicate the amount of donation. If that is from the local people alone, they indicate the economic status of the local inhabitants. However, in some special events, a much larger amount of donation will come from elsewhere, e.g. from the people from far-away, or from the local business sector. These special cases will normally be noted by the temple surrounding inhabitants, and for this study was not counted as the basic economic status of the local population. After the Chatree gold mining started, for example, Akara Mining Co.,Ltd. had donated money to about 8 temples in its neighborhood, 100,000 baht per temple per year in the form of the Kathin (rainy season-ending robe presentation), or Pha Pa (year-round robe presentation) donations, or simply built the structures for temples as shown in Figure 4.4. This makes some temples to be more developed than the others. Such temples do not really reflect the local inhabitants income. However, as some people had sold their land to the gold mining company and receive a huge sum of money, they donated more than before. So, the infrastructures of many temples are improving this way.

Furthermore, temples play an important role as center of community activities such as they are public place for meeting and gathering for all purposes. For instances, they are used for election polls, annual festivity, ceremony, celebration, or carnivals. In a specific of the relationship between the temple and gold mine, Wat Khao Mo had been used as the place for which people that throng and protest gold mine, came to negotiate with the gold mine on the description of project and environmental effect, after which the company offered to construction of the new roads to replaces the old roads where gold was explored.

4.3 Health services

Concerning the medical service in these 7 Amphoes, in 2545 B.E. there were 7 governmental hospitals, 4 private hospitals, 77 health centers, and 122 private medical clinics.

Figure 4.4. Buddhist monasteries in study area.

4.4 Transportation

The roads in the study area, from 2512 B.E. to 2543 B.E. are shown in Figure 4.5 (A), (B), and (C). In 2512, there was only 1 main road, Highway no. 113, which was asphalted with 2 traffic lanes. Other roads were dirt roads of 1 or 2 lanes though many were all-seasoned passable.

In 2531, there were 4 asphalted roads. The number of dirt roads were also increased and all were developed from one lane in 2512 to two or more lanes.

In 2543, there were 44 asphalted roads, some were developed from the previous dirt roads. Dirt roads were even increased.

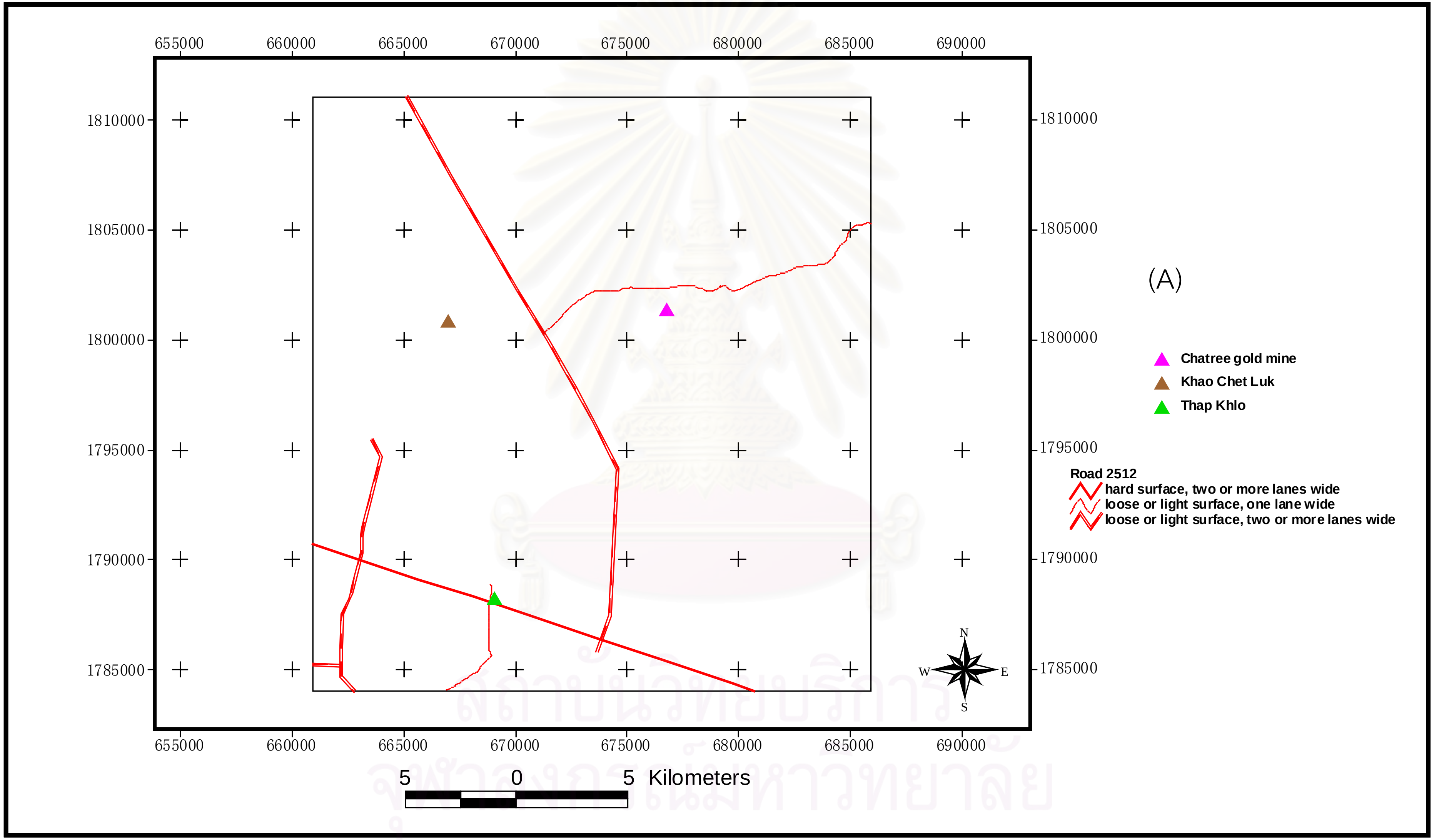


Figure 4.5. Road system in the study area. (A) in 2512 B.E. (from Royal Thai Survey Department, 1969).

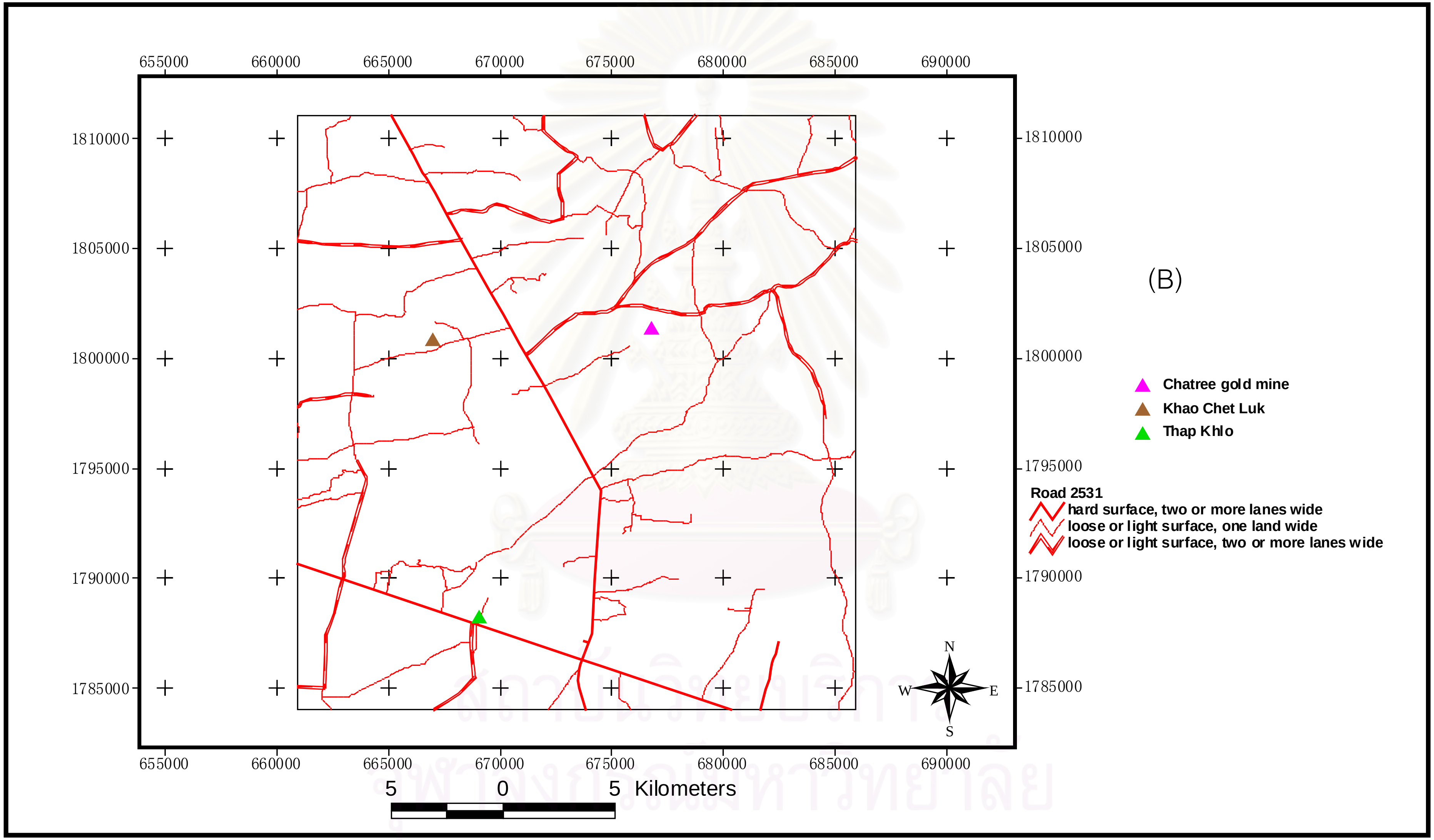


Figure 4.5. Continued. (B) in 2531 B.E. (from Royal Thai Survey Department, 1988).

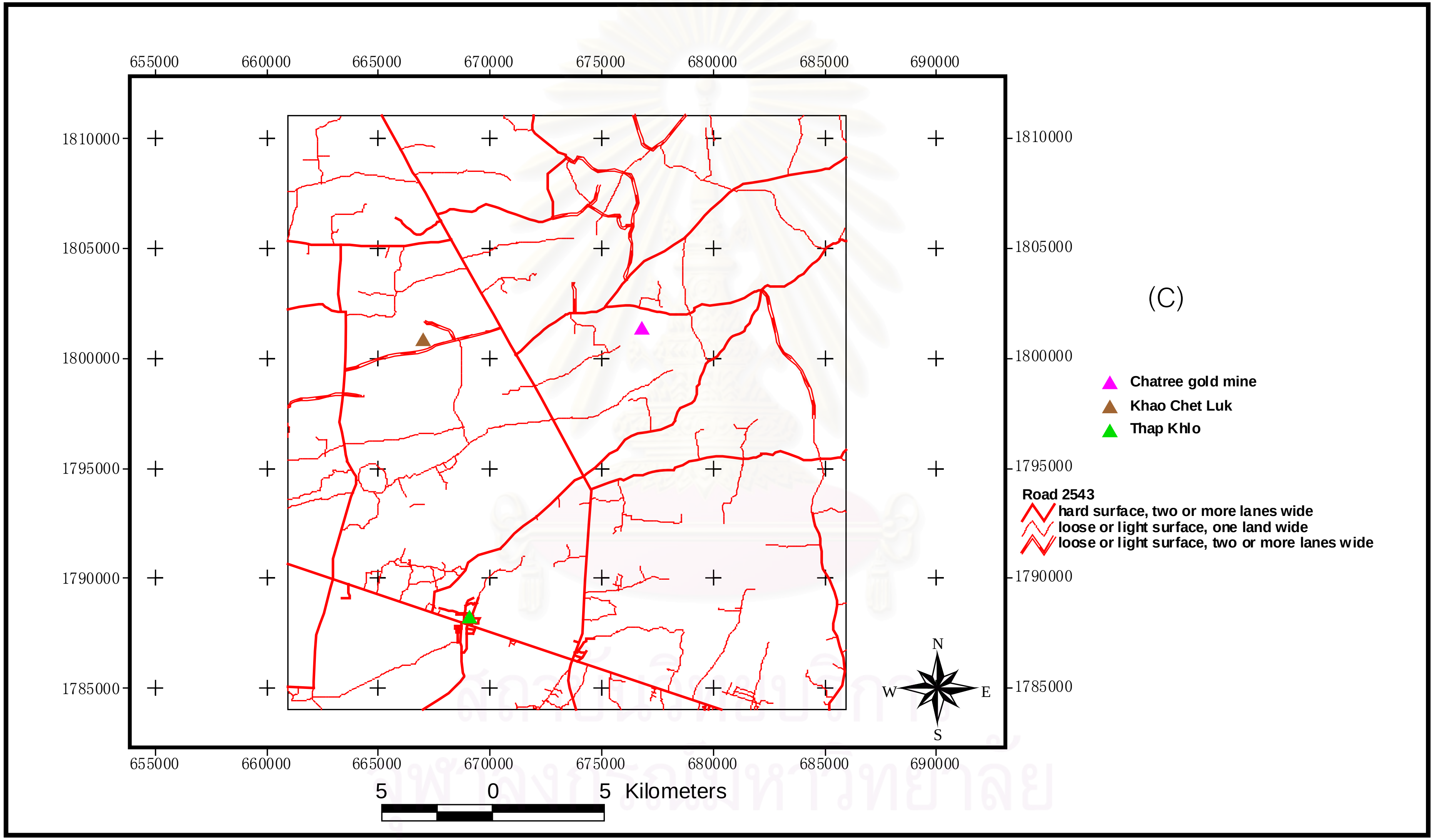


Figure 4.5. Continued. (C) in 2543 B.E. (from Department of Land Development, 2543a).

4.5 Electricity and water supplies

Regarding to electricity in the study area in 2543 B.E., the data were of combined Amphoe Chon Daen, Amphoe Wang Pong, Amphoe Muang Phetchabun and Amphoe Khao Kho of Changwat Phetchabun. The number of consumers were 135,886 persons. The total electricity sale was 251.298 million units, for residential usage 132.438 million units, business and industry 85.266 million units, government office and public utility 29.78 million units, and others 3.745 million units.

In 2545 B.E., the data of the same area were that the number of consumers were 144,407 persons. The total electricity sale was 348.726 million units, for residential 137.096 million units, business and industry 140.364 million units, government office and public utility 42.567 million units, and others 8.695 million units.

From the data above, it could be noted that the electricity sale increased. The highest increase was for business and industry and the lowest increase for residential usage. That means that the business and industry were more grown during this period while the residential grows at a low rate. However, the sense of the increased electricity supply may not be in the same proportion in the study area alone as the data above is for a much larger area, with different landuse pattern than this study area here.

The water supply for the entire area of 7 districts in 2545 B.E. was 19,707 houses. The amount of water production was 6,342,439 cubic meters, but only 3,632,824 cubic meters was for household consumption while that for public use and lose in the pipe system is 2,511,414 cubic meters totally.

4.6 Population income

4.6.1 Per capita income

The per capita income in the entire 3 provinces in the study area in 2521 B.E., 2537 B.E., 2538 B.E., 2539 B.E., and 2542 B.E. are compared in Table 4.2. The per capita income for the study area alone is not possible at the present.

Table 4.2. Per capita income (in Baht) in 3 provinces.

Year	Phichit	Phetchabun	Phitsanulok
2521	6,139	6,149	5,851
2537	22,675	22,839	29,046
2538	26,792	27,070	34,530
2539	30,260	28,982	39,410
2542	31,974	28,425	40,191

Sources: Adapted from National Statistical Office's data in 2521, 2537, 2538, 2539, and 2542 B.E.

4.6.2 Households in non-municipal area by annual income classes

The number of households in the non-municipal area as classified by the annual income in the study area in the 2524, 2539, and 2545 B.E. are shown in Table 4.3.

Table 4.3. Households in the non-municipal area by annual income classes of year 2524 B.E., 2539 B.E., and 2545 B.E. in the study area.

Year	Total number of households	Annual income class (Baht)			
		<10,000	10,000 to 19,999	>20,000	Unknown
2524	10,193	4,844	2,285	1,757	1,307
2539	11,357	4,041	2,349	4,179	788
2545	11,302	1,629	2,241	6,489	943

Sources: Adapted from National Statistical Office's data in 2524, 2539, and 2545 B.E.

4.7 Productive yield of rice

Rice is probably the only agricultural income for the inhabitants in the study area as the crops of the rainy season. Other field crops are sparsely grown in the dry season, only where water is available.

The major rice productive yield in crop-year 2537 B.E./2538 B.E. and 2543 B.E./2544 B.E. in the 7 districts is compared in Table 4.4. The productivity in 5 districts has been noted to decrease, while only in Amphoe Taphan Hin and Amphoe Chon Daen it increased. Compared between the crop-years 2537 B.E./2538 B.E. and 2543 B.E./2544 B.E., it was noted that the yield of Amphoe Muang Phichit decreased from 700 kgs./rai to 598 kgs./rai, Amphoe Taphan Hin increased from 650 kgs./rai to 710 kgs./rai, Amphoe Wang Sai Phun decreased from 628 kgs./rai to 522 kgs./rai, Amphoe Thap Khlo decreased from 539 kgs./rai to 481 kgs./rai, Amphoe Wang Pong decreased from 875 kgs./rai to 750 kgs./rai, Amphoe Chon daen increased from 534 kgs./rai to 685 kgs./rai, and Amphoe Noen Maprang decreased from 597 kgs./rai to 534 kgs./rai.

Table 4.4. Yield of rice in kilogram per rai in 7 districts around the study area (Crop year 2537 B.E./2538 B.E. and 2543 B.E./2544 B.E.).

Amphoe	2537 B.E./2538 B.E. (kgs./rai)	2543 B.E./2544 B.E. (kgs./rai)
Muang Phichit	700	598
Taphan Hin	650	710
Wang Sai Phun	628	522
Thap Khlo	539	481
Wang Pong	875	750
Chon Daen	534	685
Noen Maprang	597	534

Sources: Adapted from the National Statistical Office report, 2545 B.E.

4.8 Khao Phanompha gold-rush

The gold-rush event of Khao Phanompha was from the interview of the authorities of Phichit Administrative Organization (Provincial Administrative Organization personal communication, 2545).

The gold deposit at Khao Phanompha was first discovered by the geologists from the Department of Mineral Resources in 2534 B.E., but there had never been any systematic exploration until later. However the first wave of gold rushers into the area started in 2537 B.E. As reported by the Department of Mineral Resources (2544 B.E.), when the news about the gold deposits in Khao Phanompha had been known, a small group of gold rushers from Changwat Chanthaburi come to the area for gold panning in early 1999 (2542 B.E.). The news of their success in gold finding had further encouraged more people from the nearby area and elsewhere, including the surrounding provinces and further away, to rush into this area. At first the gold rushers trespassed the area which the concession was later granted to Phichit Provincial Administration Organization. Later they moved to the private lands nearby which was known to have less gold concentration. At the present time (2545 B.E.) the gold rushers are still working in the area, while panning for gold in the soils provided by the provincial administrative organization as well. This gold-rush is noted to affect the socio-economic condition in the surrounding area to some extent.

4.9 Akara gold mining

The possible gold deposits in the study area and its neighborhood received an interest from Akara Mining Co.,Ltd. to start applying for an exploration right in 2536 B.E. The exploration started in 2538 B.E. and led to a mining activity as the Chatree gold project in the area of Khao Mo-Khao Pong which is at the boundary between Changwat Phichit and Phetchabun. It covers an area about 2,209 rais. This gold mine is an open-pit mine which was planned to produce gold for 65,000 ounces and by-product silvers 160,000 ounces by using a Carbon-in-Leach process. This gold mining project time is 20 years from 2543 B.E. to 2562 B.E.

The activity of this company had impact on the socio-economic condition of the study area, both good and bad sides. The company hired the local native people to become workers. This activity certainly brought capital into the area while encouraged other related industries and services to start, thus improving the economic condition here. In the area surrounding the mine, the company built many new roads and donated money to schools and temples to satisfy the local people. However as the company had a plan to explore for more gold deposits nearby, it bought more land from the local people. Thus the sold plots of land around the present mining project stayed idle at the present time. Also, the gold mine brought other environmental problems and pollution to people such as dust and noise from transportation or mine activities including vibration from blasting and toxic leachates from the metal recovery processes.

CHAPTER V

LANDUSES THROUGH TIME

5.1 Landuse types

The term " Landuse " used throughout this paper includes the land being used for human purposes and the land being left in its original nature. The paper includes the land-cover natural forest because the original forest is now almost totally destroyed to be used on the other purposes. This is also for the case of marsh and swamp which is now totally disappeared. The landuse pattern was done using a GIS analysis and the field check to verify the correctness. In this study, GIS and its technique such as intersect and overlay were used for analyze landuse change.

In the study area there are 7 types of landuse. These are paddy field, mixed crop field (including orchard and plantation), conservation forest (with 25 to 75% canopy cover), village, shrub and grassland, marsh and swamp, and gold mine. Areas of landuse are shown in Table 5.1. The landuse data in 2512 B.E. were from the 1:50,000 topographic maps which indicated only 5 types of landuse, the paddy field, mixed crop field, conservation forest, marsh and swamp, and village. The landuse in 2531 B.E. was adapted from the landuse maps of the Land Development Department (2531 B.E.) and the 1:50,000 topographic maps (2531 B.E.). There were 5 types of landuse as paddy field, mixed crop field, shrub and grassland, conservation forest, and village. The landuse map in 2543 B.E. was adapted from the Land Development Department (2543 B.E. a) landuse map. There were 6 types of landuse, i.e. paddy field, mixed crop field, shrub and grassland, conservation forest, village, and gold mine. Landuse maps of each year are shown in Figures 5.1, 5.2, and 5.3.

A detail discussion of the landuse of each type in those years is as below.

5.1.1 Paddy field

5.1.1.1 In 2512 B.E.

Paddy field in 2512 B.E. appeared to be the largest landuse area of 427.213 square kilometers (km^2) or 63.1% of the whole study area. Most of the paddy field was in Changwat Phichit, less in Changwat Phitsanulok and Phetchabun. It was interpreted that the paddy field landuse was after then growing into Changwat Phetchabun to replace the conservation forest. This could be the beginning of a deforestation.

5.1.1.2 In 2531 B.E.

The paddy field was still the largest landuse in the area. It covered 499.184 km^2 or 73.72% of study area. The area was noted in every district in the study area. This type of landuse had increased 16.85% since 2512 B.E.

5.1.1.3 In 2543 B.E.

The paddy field was still the largest area of 500.164 km^2 or 73.86% of study area. The area also was in every district in the study area. This type of landuse had increased 0.2% since 2531 B.E.

5.1.2 Mixed crop field

The mixed crop field includes the field orchard, and plantation for fruits, cereal, and other agricultural plants.

5.1.2.1 In 2512 B.E.

The field covered 1.715 km^2 or 0.25% of all area. It was in the northeastern part of the study area in Amphoe Wang Pong which in 2512 B.E. this area was still a part of Amphoe Chon Daen.

5.1.2.2 In 2531 B.E.

The mixed crop field had become the second largest landuse area, 137.88 km^2 or 20.36% of the whole study area. The biggest area was in Amphoe Chon Daen of Changwat Phetchabun and along the boundary between Changwat of Phichit and Phetchabun in Khao Mo - Khao Pong, Thap Khlo – Wang Pong, Thap Khlo – Chon Daen, around Khao Chet Luk, Changwat Phichit, and northeast of study area in Amphoe Noen Maprang and Wang Pong. This type of landuse had increased 79.4% since 2512 B.E. by replacing the paddy field.

Table 5.1. Landuse types in the study area in year 2512 B.E., 2531 B.E., and 2543 B.E.

Landuse (km^2)	2512 B.E.	2531 B.E.	2543 B.E.
Paddy field	427.173 (63.09%)	499.184 (73.72%)	500.164 (73.86%)
Marsh and swamp	1.367 (0.2%)	0 (0%)	0 (0%)
Conservation forest	228.86 (33.8%)	9.974 (1.47%)	8.268 (1.22%)
Shrub and grassland	0 (0%)	9.342 (1.38%)	4.843 (0.72%)
Mixed crop field	1.715 (0.25%)	137.88 (20.36%)	136.892 (20.22%)
Village	18.021 (2.66%)	20.756 (3.07%)	23.113 (3.41%)
Gold mine	0 (0%)	0 (0%)	3.856 (0.57%)
Total	677.136 (100%)	677.136 (100%)	677.136 (100%)

5.1.2.3 In 2543 B.E.

The area then covered 136.892 km^2 or 20.22% of the study area. The biggest area was in Amphoe Chon Daen, Changwat Phetchabun, along the boundary of Amphoe Thap Khlo, Changwat Phichit and Amphoe Wang Pong, Changwat Phetchabun, and to the northeast of the study area in Amphoe Wang Pong, Amphoe Noen Maprang, and Amphoe Wang Sai Phun. The small area was around Khao Chet Luk. Corn was the cereal that was mostly planted. The others were mango, teak, and tamarind. This type of landuse had decreased 0.72% since 2531 B.E. by replacing the rice field and shrub and grassland.

5.1.3 Conservation forest

In the study area there is 4 national conserved forest, that is Khao Chet Luk-Khao Taphannak-Khao Cha-om conservation forest, Khao Sai-Khao Phra conservation forest which are situated in Amphoe Thap khlo, Changwat Phichit, Wang Pong-Chon Daen-Wang Kampang conservation forest in Amphoe Wang Pong, Changwat Phetchabun, and Left of Wang Thong Basin conservation forest in Amphoe Noen Maprang, Changwat Phitsanulok. They were conserved for economic utility and were announced to be conservation forest between year 2509 B.E. and 2526 B.E. The conservation forest map in 2543 B.E. from ESRI Thailand (2539) is shown in Figure 5.5. These conservation forests and the natural forests are included under this category.

5.1.3.1 In 2512 B.E.

In 2512 B.E., the conservation forest was the second largest area, at 228.86 km^2 or 33.8% of the whole study area. Most conservation forest was in Changwat Phetchabun in Tambon Dong Khui, Amphoe Chon Daen, and the east of Tambon Khao Sai and Amphoe Thap Khlo of Changwat Phichit. Conservation forest in other areas was along the stream banks.

5.1.3.2 In 2531 B.E.

The conservation forest in 2531 B.E. had reduced tremendously to only 9.974 km^2 or 1.47% of study area. It was found only on the hills and mountains. These are at Khao Chet Luk, Khao Taphan Nak, and Khao Cha-om conservation forest in Khao Chet Luk, Left of Wang Thong Basin conservation forest in Amphoe Noen Maprang. Other not reservation forests were Khao Ruak in the east of study area and Khao Nok Yung in the south of study area. This type of landuse had decreased 95.6% since 2512 B.E. that is the result of increasing of mixed crop field, paddy field, shrub and grassland, and village.

5.1.3.3 In 2543 B.E.

At this time the conservation forest was only the deciduos dipterocarp forest, disturbed deciduous forest, and mixed deciduous forest. In 2543 B.E. the conservation forest area covered 8.268 km^2 or 1.22% of study area. It mostly was in Changwat Phichit in Khao Chet Luk, Khao Phra, and Khao Ruak, Wang Thong conservation forest in Amphoe Noen Maprang. This type of landuse had decreased 17.1% since 2531 B.E. and changed to mixed crop field and paddy field.

5.1.4 Village

In this term, village was mean village, city, town, commercial, services, government places, and educational areas.

5.1.4.1 In 2512 B.E.

It was 18.021 km^2 or 2.66% of study area. It mostly was along the side of main roads in Changwat Phichit.

5.1.4.2 In 2531 B.E.

It was 20.756 km^2 or 3.07% of study area. It was in the same location as 2512 B.E. but was larger. This type of landuse had increased 15.18% since 2512 B.E. by replacing the decreasing conservation forest.

5.1.4.3 In 2543 B.E.

In 2543 B.E. this landuse covered an area 23.113 km^2 or 3.41% of study area. The largest area was in Thap Khlo municipal area, which was connected to Amphoe Taphan Hin along the main roads. This type of landuse had increased 11.36% since 2531 B.E.

5.1.5 Shrub and grassland

The shrub and grassland includes the shrub, grassland, and idle land.

5.1.5.1 In 2512 B.E.

Shrub and grassland did not appear in 2512 B.E.

5.1.5.2 In 2531 B.E.

It covered 9.342 km^2 or 1.38% of the study area in the middle of area along the boundary of Changwat Phichit and Phetchabun and in Amphoe Wang Pong and Chon Daen to the east of the study area. This shrub and grassland could be the abandoned or idle land after some previous uses.

5.1.5.3 In 2543 B.E.

Shrub and grassland of the study area covered 4.843 km^2 or 0.72%. There was a small area in Amphoe Wang Pong and at the boundary of Amphoe

Thap Khlo and Amphoe Wang Pong. This type of landuse had decreased 48.16% since 2531 B.E. to be replaced by the increasing village area and paddy field.

5.1.6 Marsh and swamp

The marsh and swamp only appeared in the 2512 B.E. topographic maps. It covered an area of 1.367 km^2 or 0.2% of study area. It was found among the conservation forest in Changwat Phetchabun. The marsh and swamp had disappeared completely and changed to agricultural land in the later landuse maps.

5.1.7 Gold mine

Gold mine is the smallest area that cannot be displayed in landuse map. It was the important type of landuse that made mobilization of population to exploited natural resources in study area.

The gold mine only appeared in the 2543 landuse map. It covered 3.856 km^2 or 0.57% of all area. In the study area had 2 gold mines that are Khao Phanompha gold deposit at Khao Chet Luk and Chatree gold mine at boundary between Changwat Phichit and Phetchabun.

The types of landuse through time from 2512 B.E. to 2543 B.E. in the study area are shown in Figures 5.1 to 5.3 and the graph lines are shown in Figure 5.4.

5.2 Landuse change

From 2512 B.E. to 2531 B.E., 272.699 km^2 or 40.27% of all area had changed. The most changing areas were at the boundary of Changwat Phichit and Phetchabun at Thap Khlo-Chon Daen, and Thap Khlo-Wang Pong-Noen Maprang. Figure 5.6 shows the unchanged area from 2512 B.E. to 2531 B.E., while Figure 5.7 (A) shows the changed area and what it had been changed to. Figure 5.7 (B) shows the changed landuse area from 2512 B.E. to 2531 B.E.

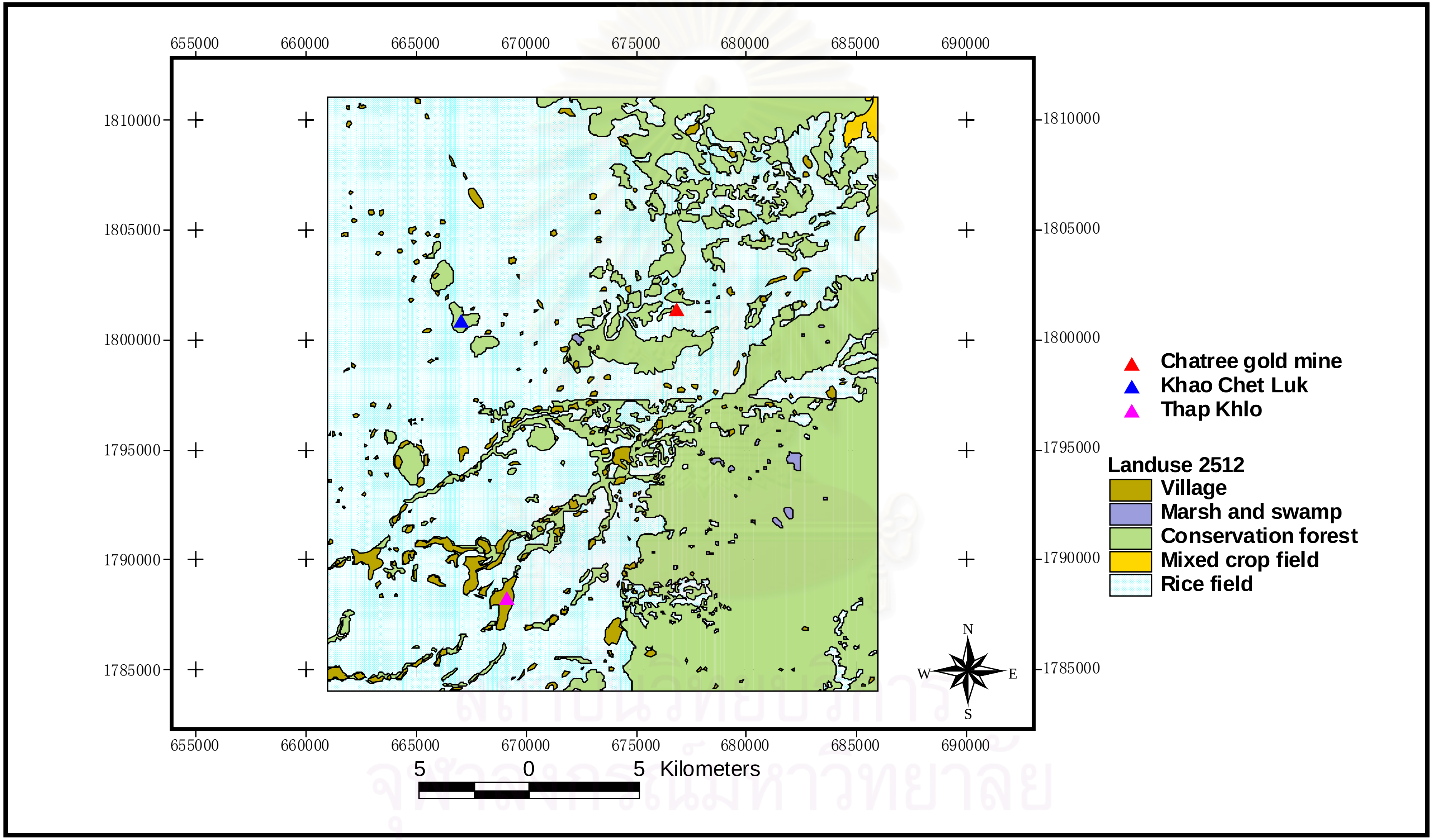


Figure 5.1. Landuse map of 2512 B.E.

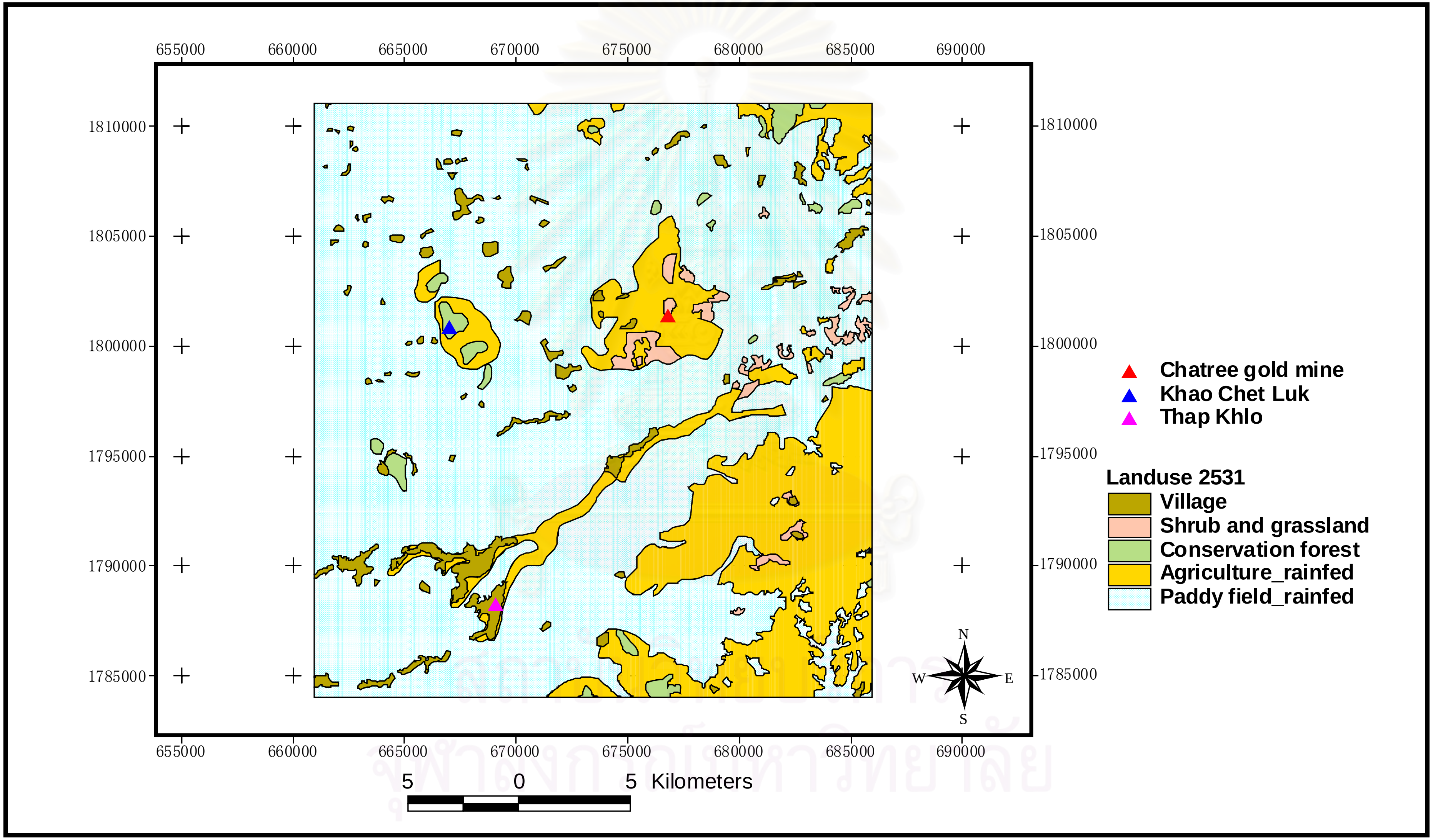


Figure 5.2. Landuse map of 2531 B.E.

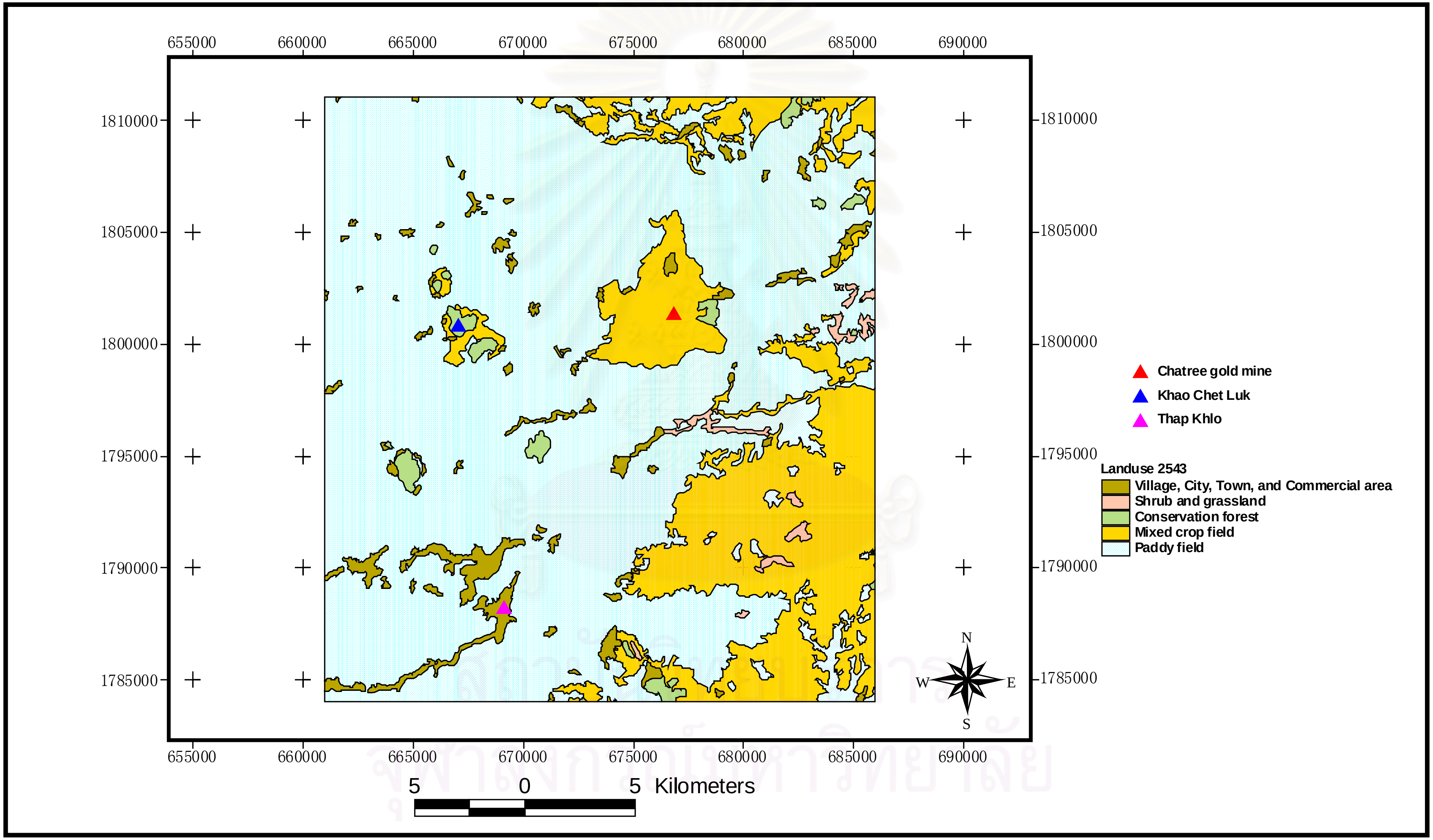


Figure 5.3. Landuse map of 2543 B.E.

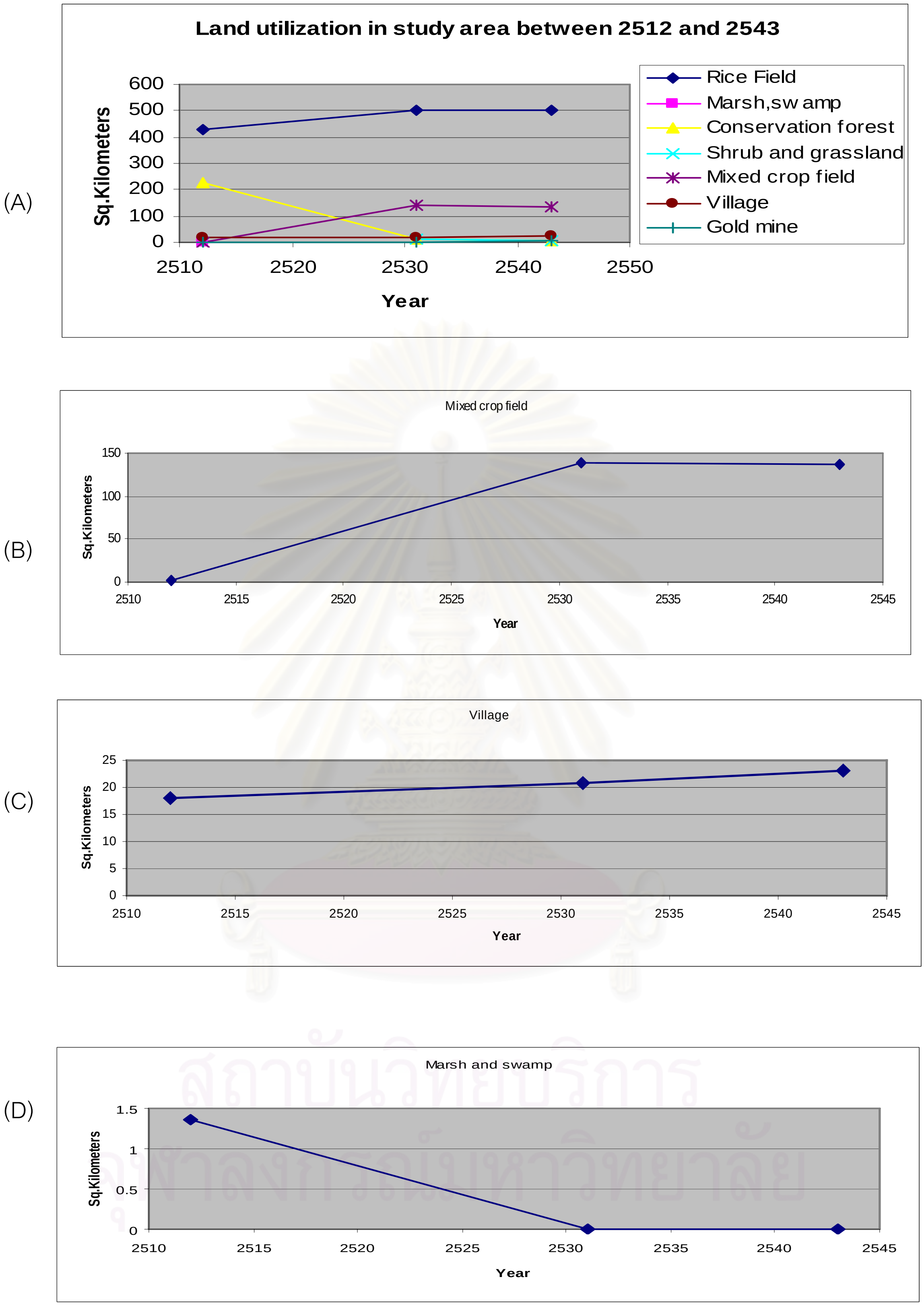


Figure 5.4. The areas of landuse types in the study area between 2512 B.E. and 2543 B.E. (A) Landuse of all types, (B) mixed crop field, (C) marsh and swamp, (D) village.

(E)

(F)

(G)

(H)

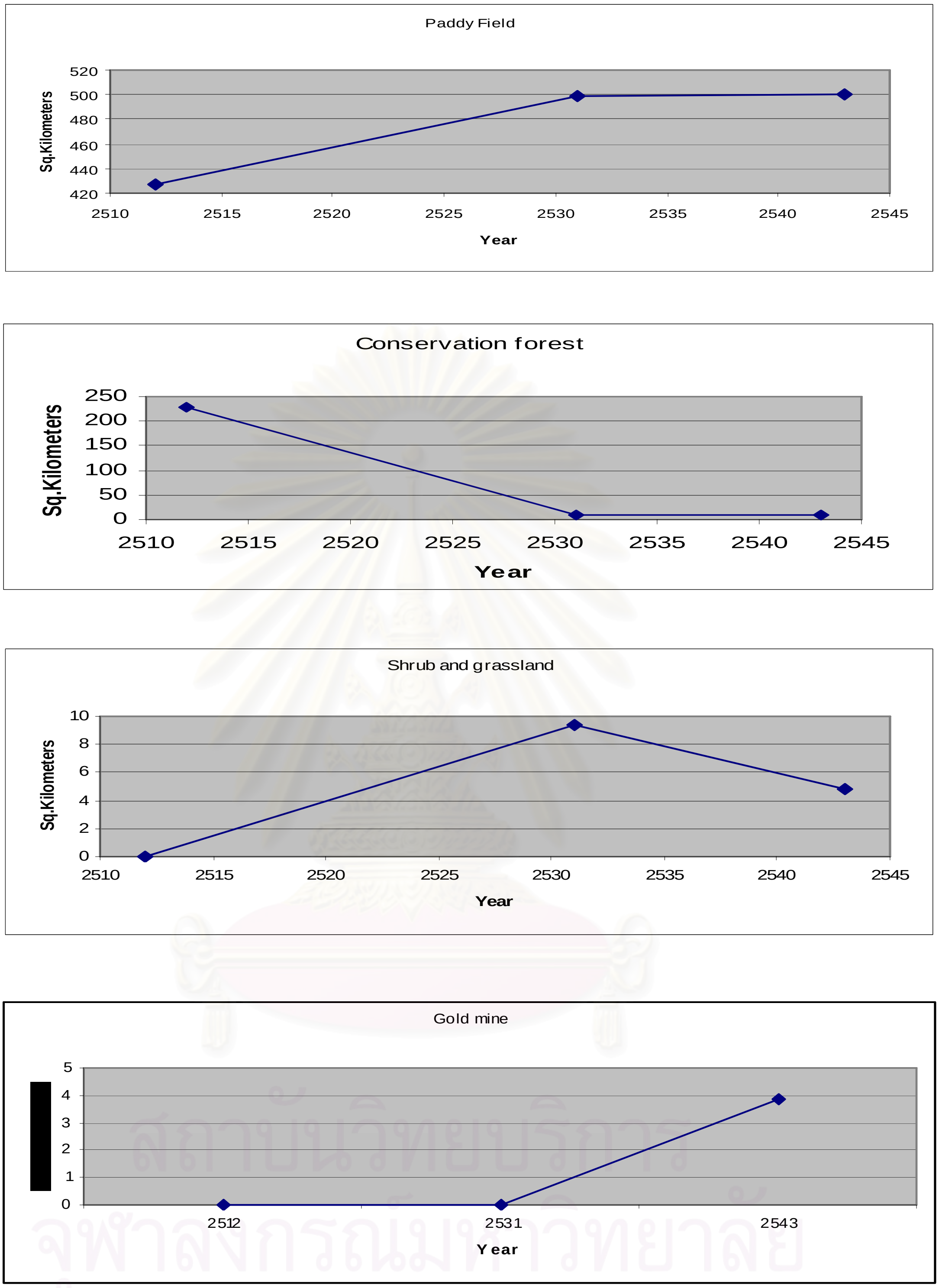


Figure 5.4. Continued. (E) paddy field, (F) conservation forest, (G) shrub and grassland, (H) gold mine.

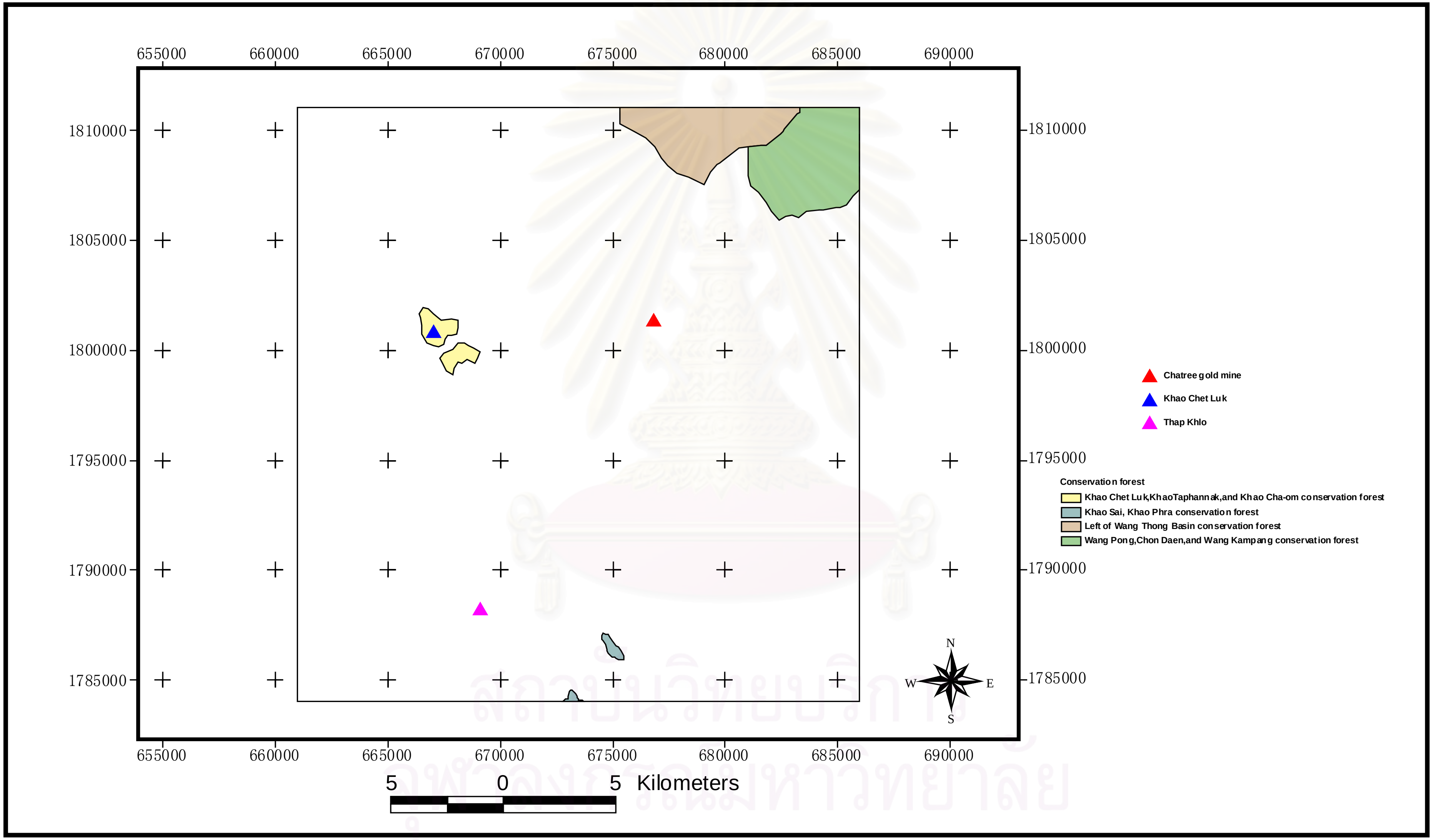


Figure 5.5. Conservation forest in study area (From ESRI Thailand, 2539).

During the period of 2531 B.E. and 2543 B.E. there was not much change. The changed area was only 79.526 km^2 or 11.74% of all area because the land had already been occupied and no conservation forest to be trespassed. However in year 2537 B.E. the gold resources were explored here and brought about population migrated into the study area. Figure 5.8 shows the unchanged area from 2531 B.E. to 2543 B.E. and Figure 5.9 (A) shows the changed area and what it was changed to. Figure 5.9 (B) shows the changed landuse area from 2531 B.E. to 2543 B.E.

It was noted that from 2512 B.E. to 2543 B.E. the landuse type in an area of 268.019 km^2 or 39.58% of study area had changed. The most change was in the middle to the west of study area in Amphoe Thap Khlo and Amphoe Wang Sai Phun, Changwat Phichit, Amphoe Chon Daen and Amphoe Wang Pong, Changwat Phetchabun, and Amphoe Noen Maprang, Changwat Phitsanulok. The change was noted to be that the conservation forest had been changed to an agricultural land mostly. Figure 5.10 shows the unchanged area from 2512 B.E. to 2543 B.E. and Figure 5.11 (A) shows the changed area and what it was changed to. Figure 5.11 (B) shows the changed landuse area from 2512 B.E. to 2543 B.E.

5.2.1 Paddy field

From 2512 B.E. to 2531 B.E. the paddy field area of 40.834 km^2 was changed to mixed crop field, and replace from other decreasing that made paddy field area had a net increase from 427.173 km^2 in 2512 B.E. to 499.184 km^2 in 2531 B.E. or increased at a rate of 3.79 km^2 per year.

From 2531 B.E. to 2543 B.E. the paddy field area was both decreased and increased. The area of 30.826 km^2 was changed to mixed crop field in north of study area in Amphoe Noen Maprang, changed to village in Tambon Tai Tung. The increased was noted to replace from decrease of mixed crop field in Amphoe Thap Khlo and Khao Chet Luk area. This made paddy field area to have a net increased from 499.184 km^2 in 2531 B.E. to 500.164km^2 in 2543 B.E. or increased at a rate of 0.081 km^2 per year.

Paddy field area of 32.607 km^2 was changed to mixed crop field and replace the decreased of conservation forest in Amphoe Thap Khlo, Wang Pong, and Chon Daen. This made the paddy field area to have a increased from 427.173 km^2 in 2512 B.E. to 500.164 km^2 in 2543 B.E. or increased at a rate of 2.35 km^2 per year.

5.2.2 Mixed crop field

From 2512 B.E. to 2531 B.E. the mixed crop field area 0.11 km^2 was changed to paddy field, and together with the decrease of conservation forest, the mixed crop field area thus had a net increase from 1.715 km^2 in 2512 B.E. to 137.88 km^2 in 2531 B.E. or at a rate 7.17 km^2 per year.

From 2531 B.E. to 2543 B.E. the previous mixed crop field area was both increased and decreased. The area 31.379 km^2 was changed to paddy field and village in Amphoe Thap Khlo which connected with Amphoe Chon Daen, to paddy field, grassland, and village in Tambon Khao Sai, in Khao Chet Luk the area changed to paddy field. The increase was noted to replace the decrease of paddy field. This made the mixed crop field area to have a net decrease from 137.88 km^2 in 2531 B.E. to 136.892 km^2 in 2543 B.E. or decrease at a rate of 0.082 km^2 per year.

Mixed crop field area of 3.861 km^2 was changed to paddy field and increased from the decreased conservation forest and paddy field. So, mixed crop field area was net increased from 1.715 km^2 in 2512 B.E. to 136.892 km^2 in 2543 B.E. or increased at a rate of 4.36 km^2 per year.

5.2.3 Conservation forest

From 2512 B.E. to 2531 B.E. the conservation forest area of 221.101 km^2 was changed to mixed crop field, paddy field, and grassland, mostly found in Changwat Phetchabun. It changed to mixed crop field and paddy field in Changwat Phichit, and to paddy field in Changwat Phitsanulok. So the conservation forest area had decreased from 228.86 km^2 in 2512 B.E. to 9.974 km^2 in 2531 B.E., or being decreased at a rate 11.5 km^2 per year here.

From 2531 B.E. to 2543 B.E. the conservation forest area of 5.012 km^2 was changed. Area of Left of Wang Thong Basin conserved forest in Phitsanulok attenuated and changed to paddy field and mixed crop field. In Khao Chet Luk, Changwat Phichit also attenuated and changed to paddy field and grassland. So, the conservation forest area decreased from 9.974 km^2 in 2531 B.E. to 8.268 km^2 in 2543 B.E. or decreased at a rate of 0.142 km^2 per year.

Conservation forest had changed 222.259 km^2 from 2512 B.E. into paddy field and mixed crop field apparently in Changwat Phetchabun and Phitsanulok. It changed to mixed crop field in Changwat Phichit around Khao Chet Luk and Khao Sai, and changed to paddy field was in Amphoe Thap Khlo. Thus the conservation forest had decreased from 228.86 km^2 in 2512 B.E. to 8.268 km^2 in 2543 B.E. or decreased at a rate of 7.12 km^2 per year.

5.2.4 Village

From 2512 B.E. to 2531 B.E. the village area of 9.287 km^2 was changed due to small villages added then, villages in same places were expanded. So, the village area had increased from 18.021 km^2 in 2512 B.E. to 20.756 km^2 in 2531 B.E., or being increased at a rate of 0.14 km^2 per year.

From 2531 B.E. to 2543 B.E. the village area of 5.866 km^2 was changed. The increased was noted to replace the decrease of mixed crop field in Khao Mo which was gold mining and Tambon Tai Tung. This made the village area had increased from 20.756 km^2 in 2531 B.E. to 23.113 km^2 in 2543 B.E. or increased at a rate of 0.2 km^2 per year.

Village area had change 7.925 km^2. It increased in Changwat Phetchabun and Phitsanulok and same places was expanded. It was net increased from 18.021 km^2 in 2512 B.E. to 23.113 km^2 in 2543 B.E. or increased at a rate of 0.16 km^2 per year.

5.2.5 Shrub and grassland

Shrub and grassland area was not occured in 2512 B.E. In 2531 B.E. it was first found to be 9.342 km^2. From 2531 B.E. to 2543 B.E., 6.443 km^2 was changed into mixed crop field around Khao Mo-Khao Pong area. The increase was noted to replace the decrease of conservation forest and mixed crop field in Khao Sai. This made the shrub and grassland area to have a net decrease from 9.342 km^2 in 2531 B.E. to 4.843 km^2 in 2543 B.E. or decreased at a rate of 0.37 km^2 per year.

5.2.6 Marsh and swamp

Marsh and swamp had change as all 1.367 km^2 had completely disappeared after 2512 B.E. to become the paddy field and mixed crop field.

5.2.7 Gold mine

Gold mine area of 3.856 km^2 appeared in 2543 B.E. which replace the decrease of conservation forest in Khao Chet Luk, Changwat Phichit and mixed crop field in Khao Pong, Changwat Phetchabun.

The landuse areas, their percentage proportion, and changing areas are shown in Table 5.2. The changed areas are noted from 2512 B.E. to 2543 B.E. to be 268.019 km^2 or 39.58%. It presents a tendency of landuse in the future that the area of rice field and mixed crop field might slightly increase, or having a tendency to be unchange in few places while the village areas are to be increases while other landuses decrease. Agricultural land areas composing of the paddy field and mixed crop field area had increased from 428.888 km^2 or 63.34% of total area to become 637.056 km^2 or 94.08% of total area.

5.3 Current landuse

As the field study on the landuse change was done in 2545 B.E. to 2546 B.E., it was unfortunate that there was no published map of the landuse at this field study time. The field check thus had to base on the interpreted map of 2543 B.E. It was noted that the landuse in 2545 B.E. to 2546 B.E. was slightly changed from that in 2543

Table 5.2. Area and percentage of landuse change.

	Landuse area 2512 B.E.	Landuse area 2531 B.E.	Landuse area 2543 B.E.	Changing area 2512 B.E.-2531 B.E. (km^2)			Changing area 2531 B.E.-2543 B.E. (km^2)			Changing area 2512 B.E.-2543 B.E. (km^2)		
				Change to other landuses	Other landuses change to	Net change	Change to other landuses	Other landuses change to	Net change	Change to other landuses	Other landuses change to	Net change
Paddy field	427.173 (63.09%)	499.184 (73.72%)	500.164 (73.86%)	-40.834 (6.03%)	+112.845	72.011	-30.826 (4.55%)	+31.806	+0.98	-32.607 (4.82%)	+105.598	+72.991
Marsh and swamp	1.367 (0.2%)	0 (0%)	0 (0%)	-1.367 (0.2%)	+0	-1.367	0 (0%)	0	0	-1.367 (0.2%)	0	-1.367
Conservation forest	228.86 (33.8%)	9.974 (1.47%)	8.268 (1.22%)	-221.101 (32.65%)	+2.215	-218.886	-5.012 (0.74%)	+3.306	-1.706	-222.259 (32.82%)	+1.667	-220.592
Shrub and grassland	0 (0%)	9.342 (1.38%)	4.843 (0.72%)	0 (0%)	+9.342	+9.342	-6.443 (0.95%)	+1.944	-4.499	0 (0%)	+4.843	+4.843
Mixed crop field	1.715 (0.25%)	137.88 (20.36%)	136.892 (20.22%)	-0.11 (0.02%)	+136.275	+136.165	-31.379 (4.63%)	+30.391	-0.988	-3.861 (0.57%)	+139.038	+135.117
Village	18.021 (2.66%)	20.756 (3.07%)	23.113 (3.41%)	-9.287 (1.37%)	+12.022	+2.735	-5.866 (0.87%)	+8.223	+2.357	-7.925 (1.17%)	+13.017	+5.092
Gold mine	0 (0%)	0 (0%)	3.856 (0.57%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	+3.856	+3.856	0 (0%)	+3.856	+3.856
Total	677.136 (100%)	677.136 (100%)	677.136 (100%)	-272.699 (40.27%)			-79.526 (11.74%)			-268.019 (39.58%)		
Unchanged landuse area				404.437 (59.73%)			597.61 (88.26%)			409.117 (60.42%)		

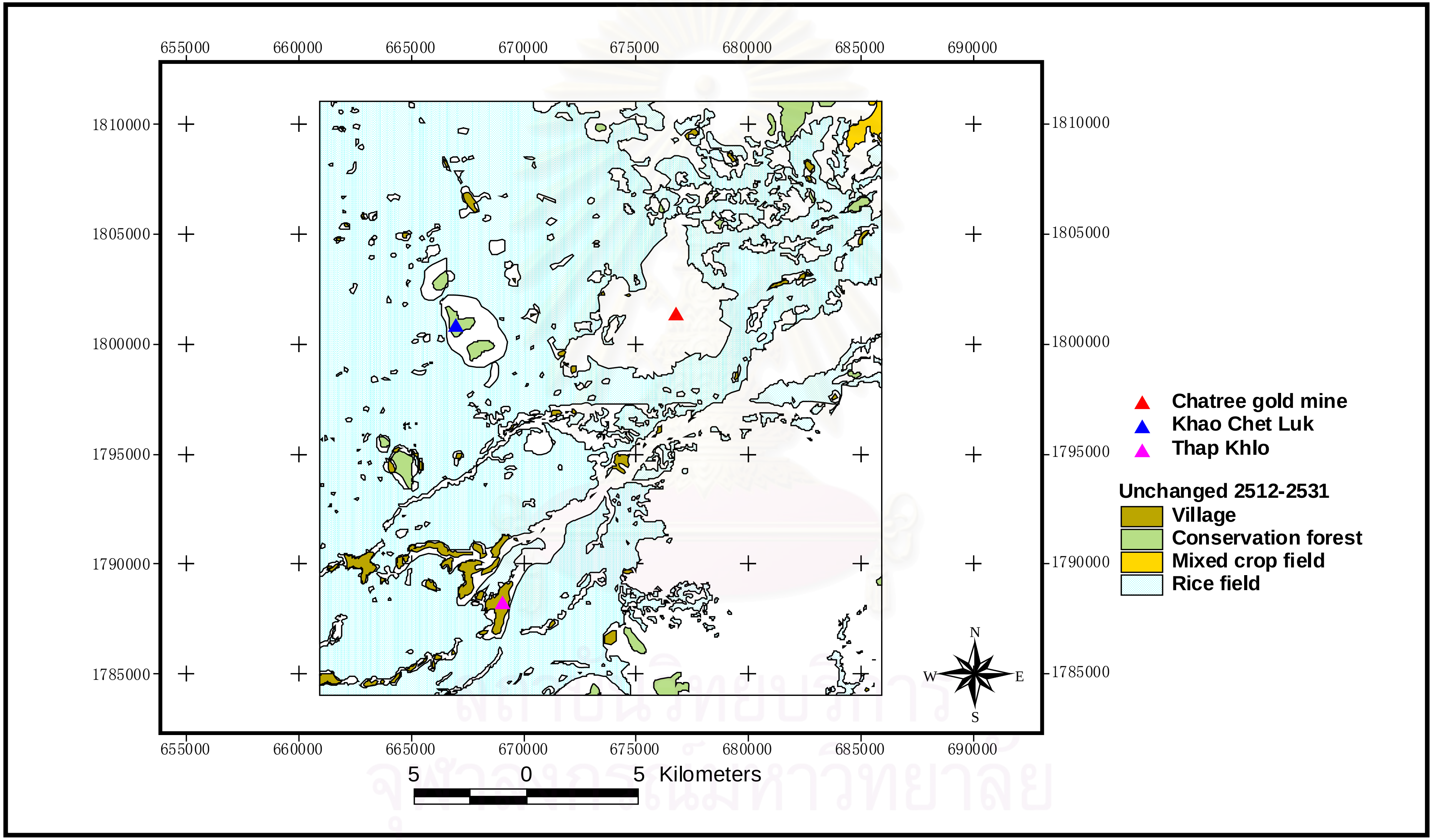


Figure 5.6. Unchanged landuse area (colored) from 2512 B.E. to 2531 B.E.

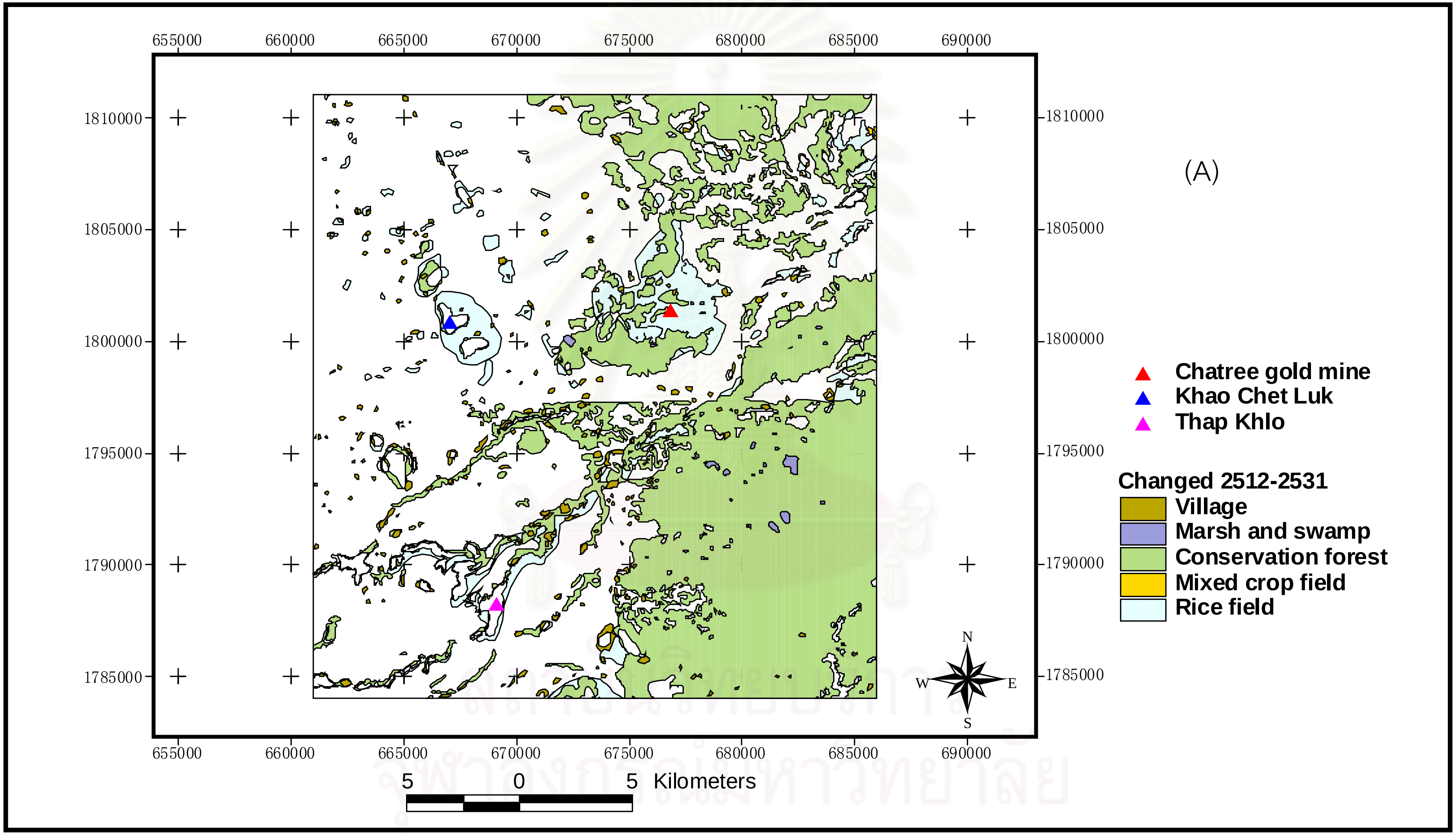


Figure 5.7. Changed landuse area (colored) from 2512 B.E. to 2531 B.E. (A) The colors indicate the landuse types in 2512 B.E.

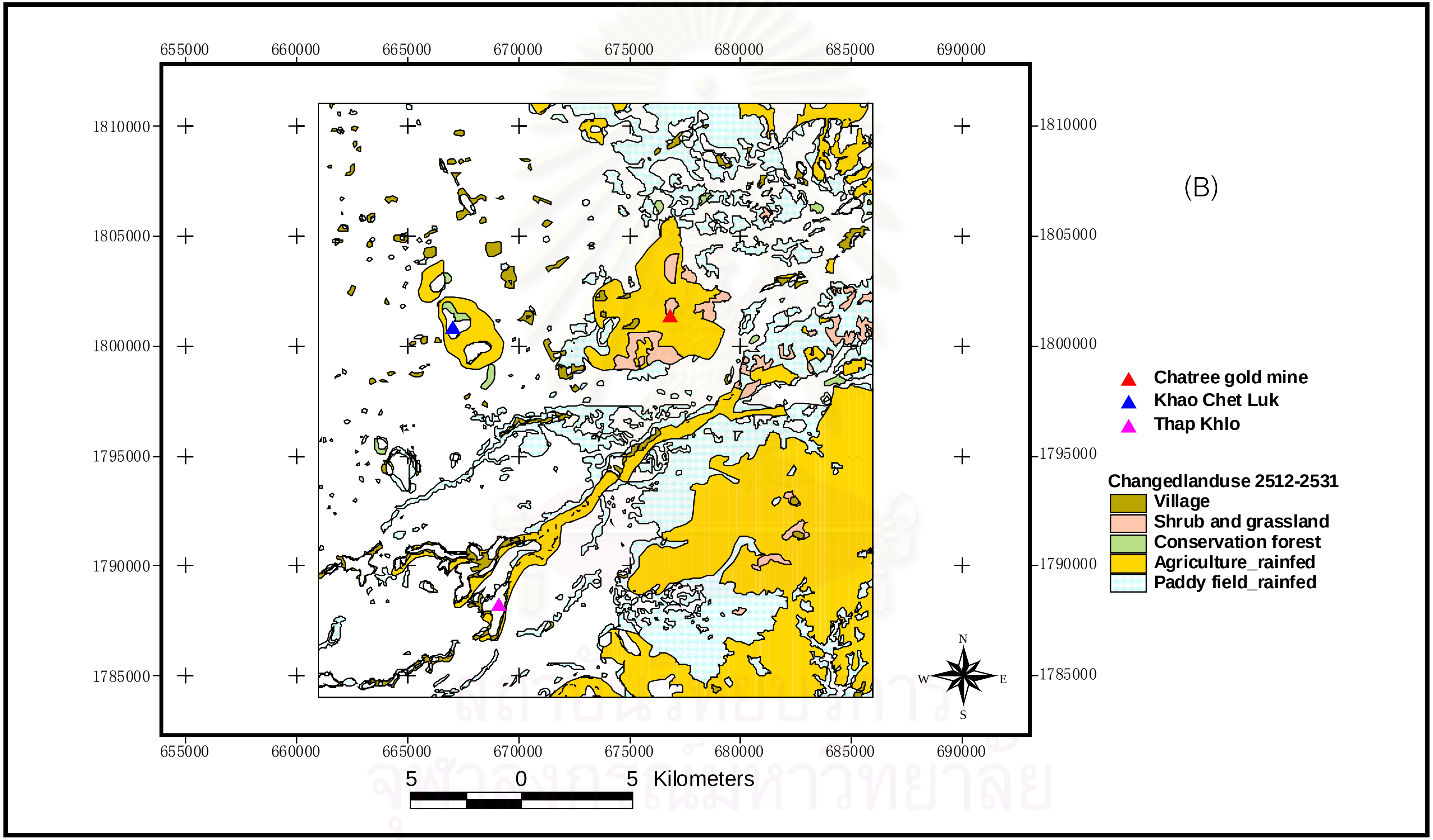


Figure 5.7. Continued. (B) The colors indicate the landuse type in 2531 B.E.

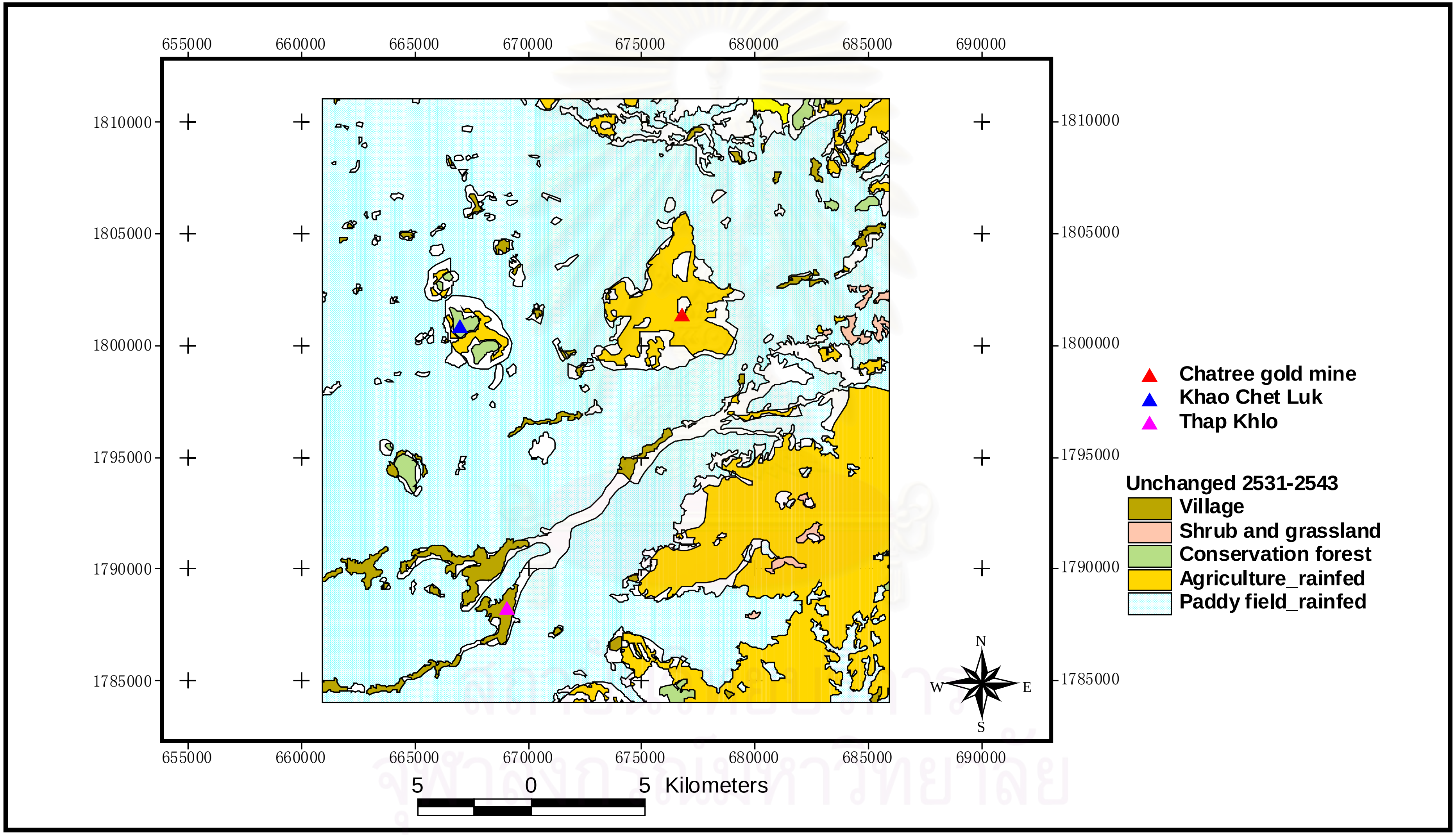


Figure 5.8. Unchanged landuse area (colored) from 2531 B.E. to 2543 B.E.

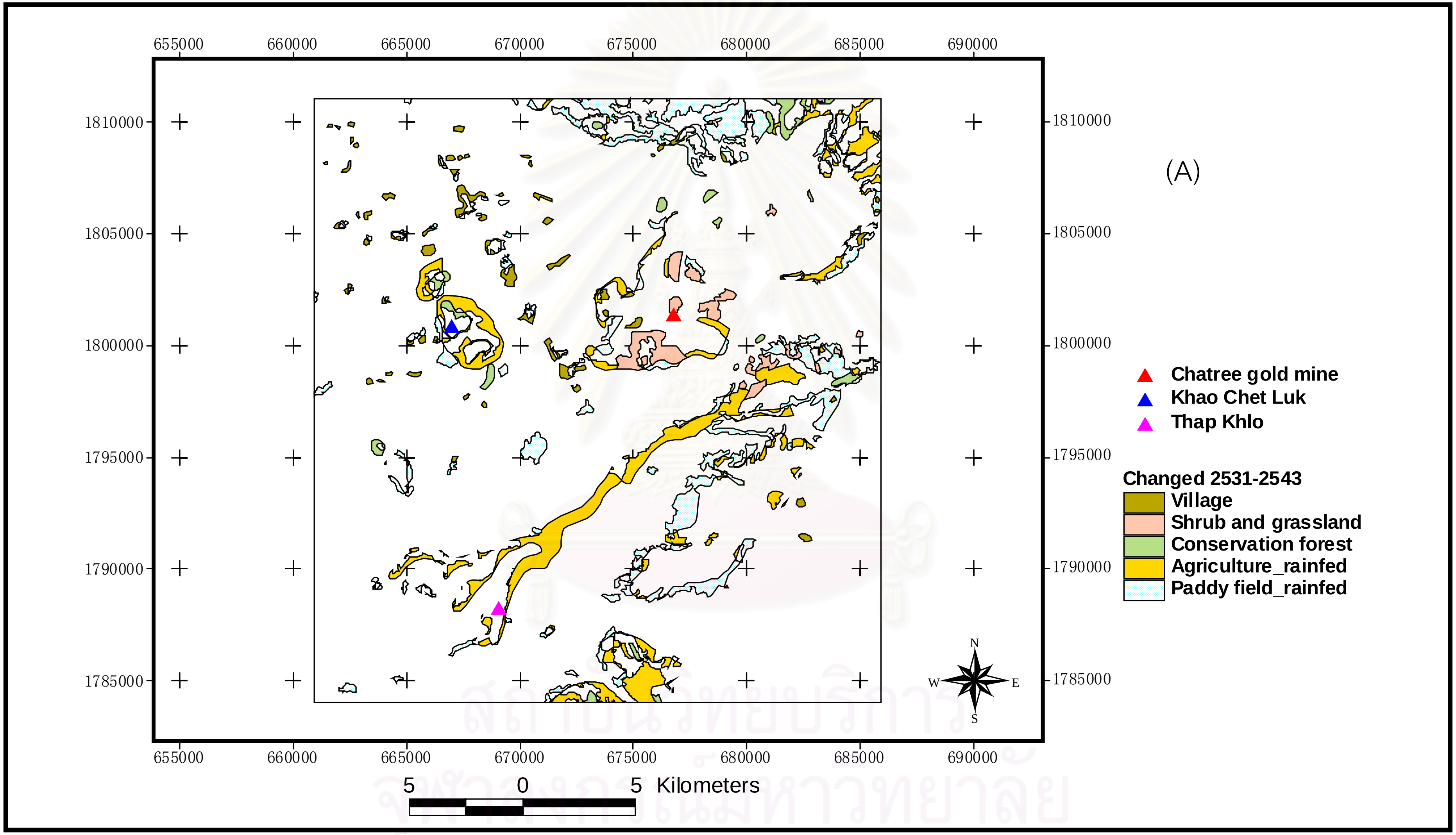


Figure 5.9. Changed landuse area (colored) from 2531 B.E. to 2543 B.E. (A) The colors indicate the landuse types in 2531 B.E.

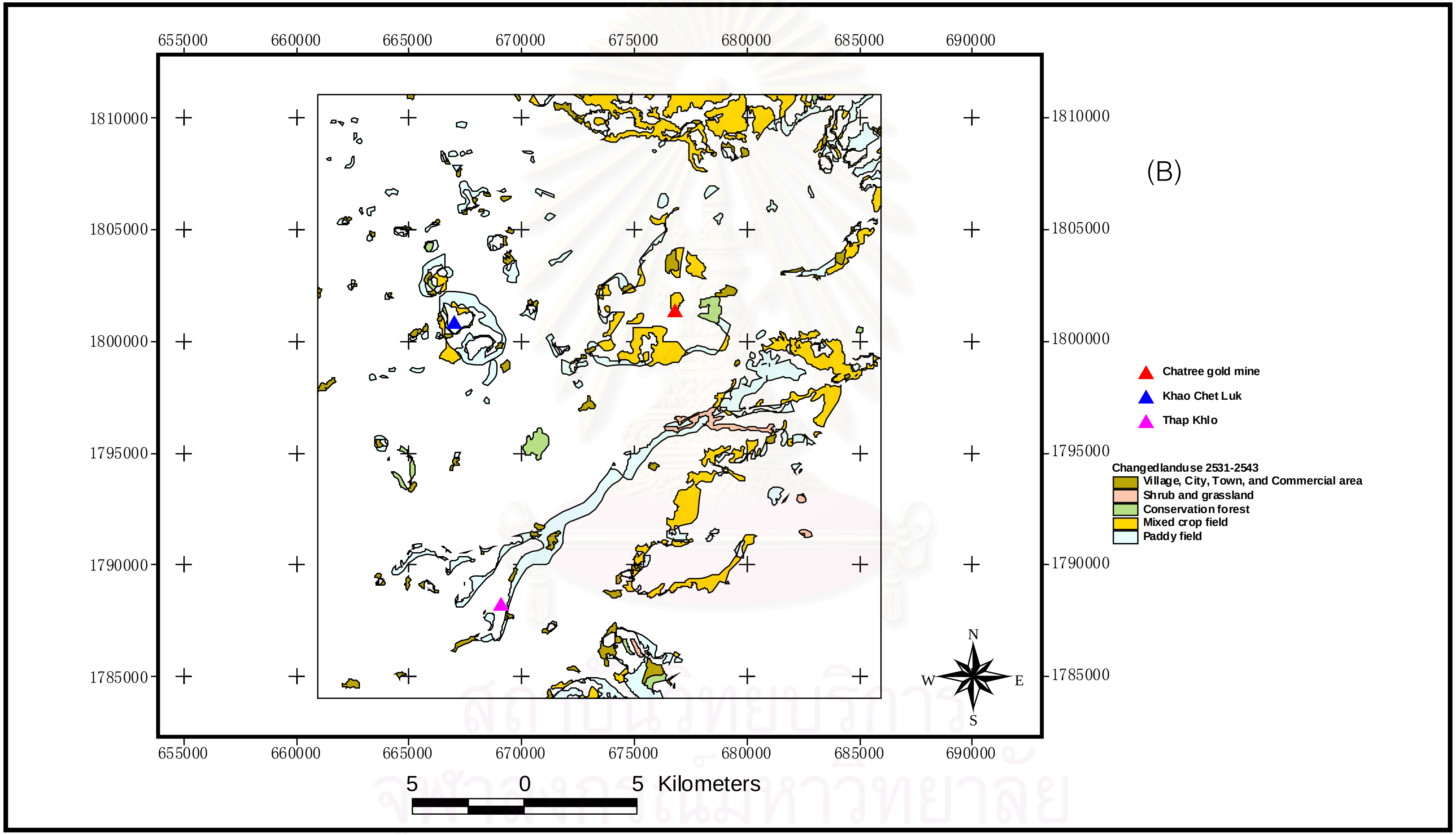


Figure 5.9. Continued. (B) The colors indicate the landuse type in 2543 B.E.

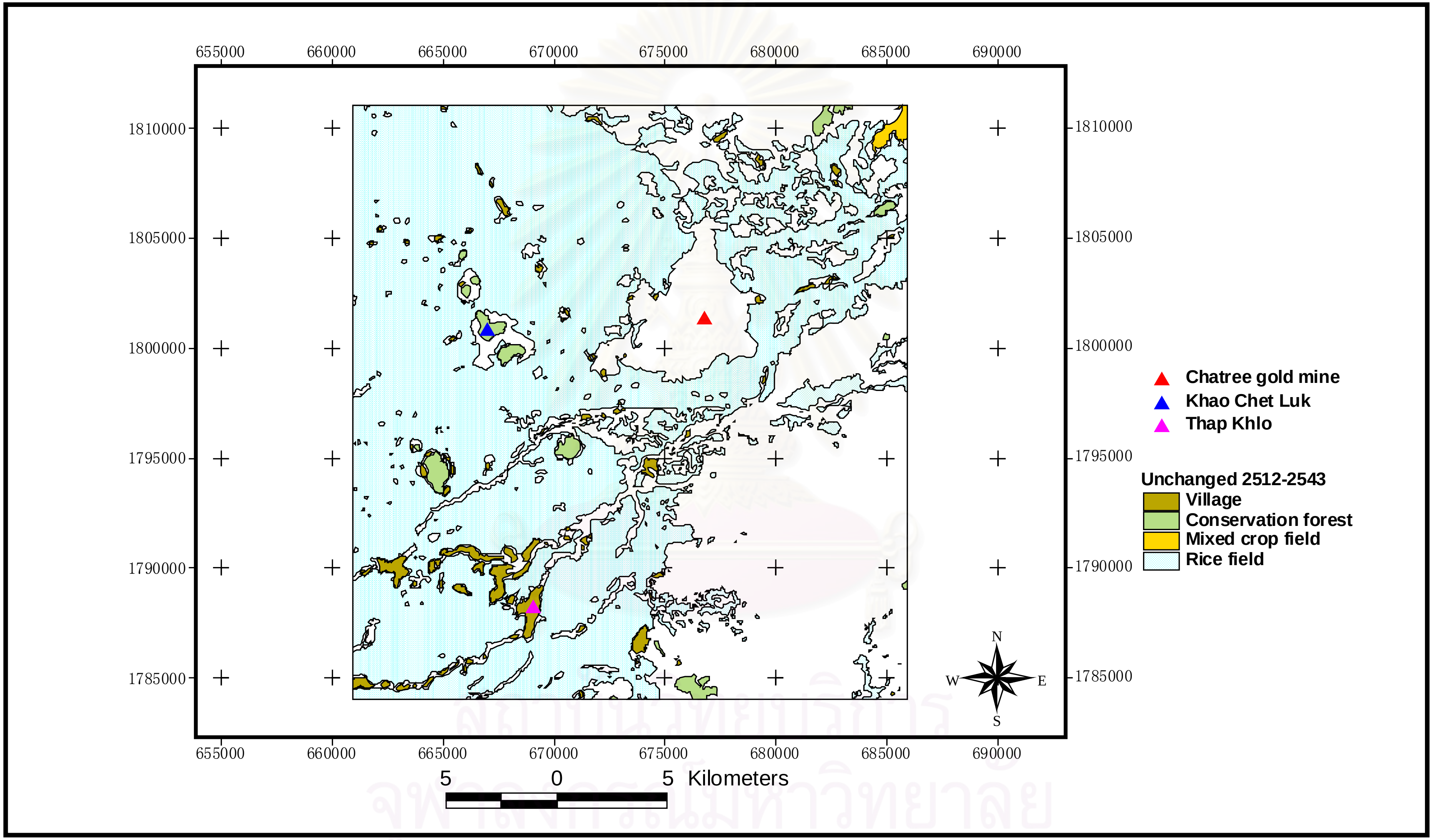


Figure 5.10. Unchanged landuse area (colored) from 2512 B.E. to 2543 B.E.

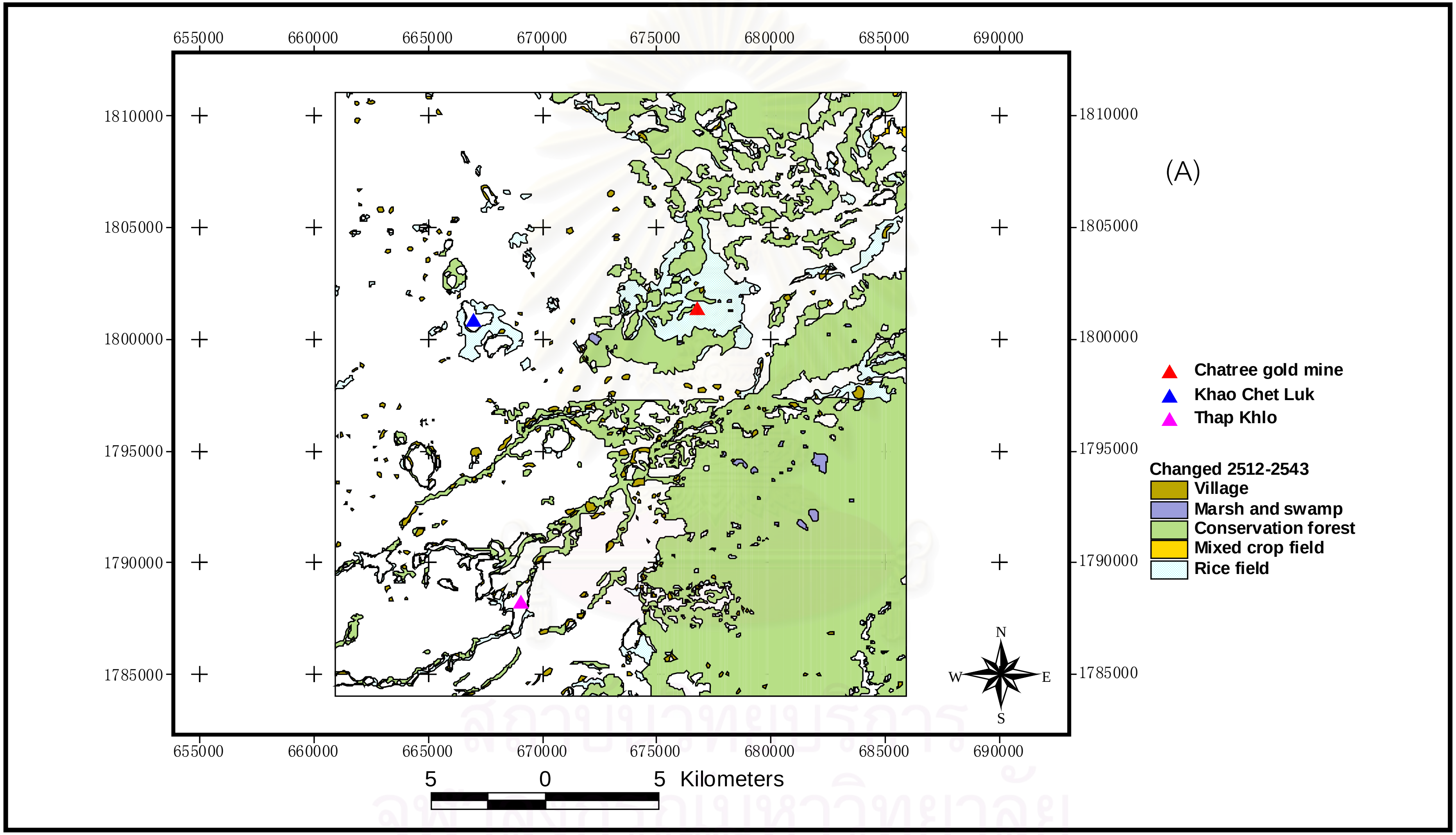


Figure 5.11. Changed landuse area (colored) from 2512 B.E. to 2543 B.E. (A) The colors indicate the landuse types in 2512 B.E.

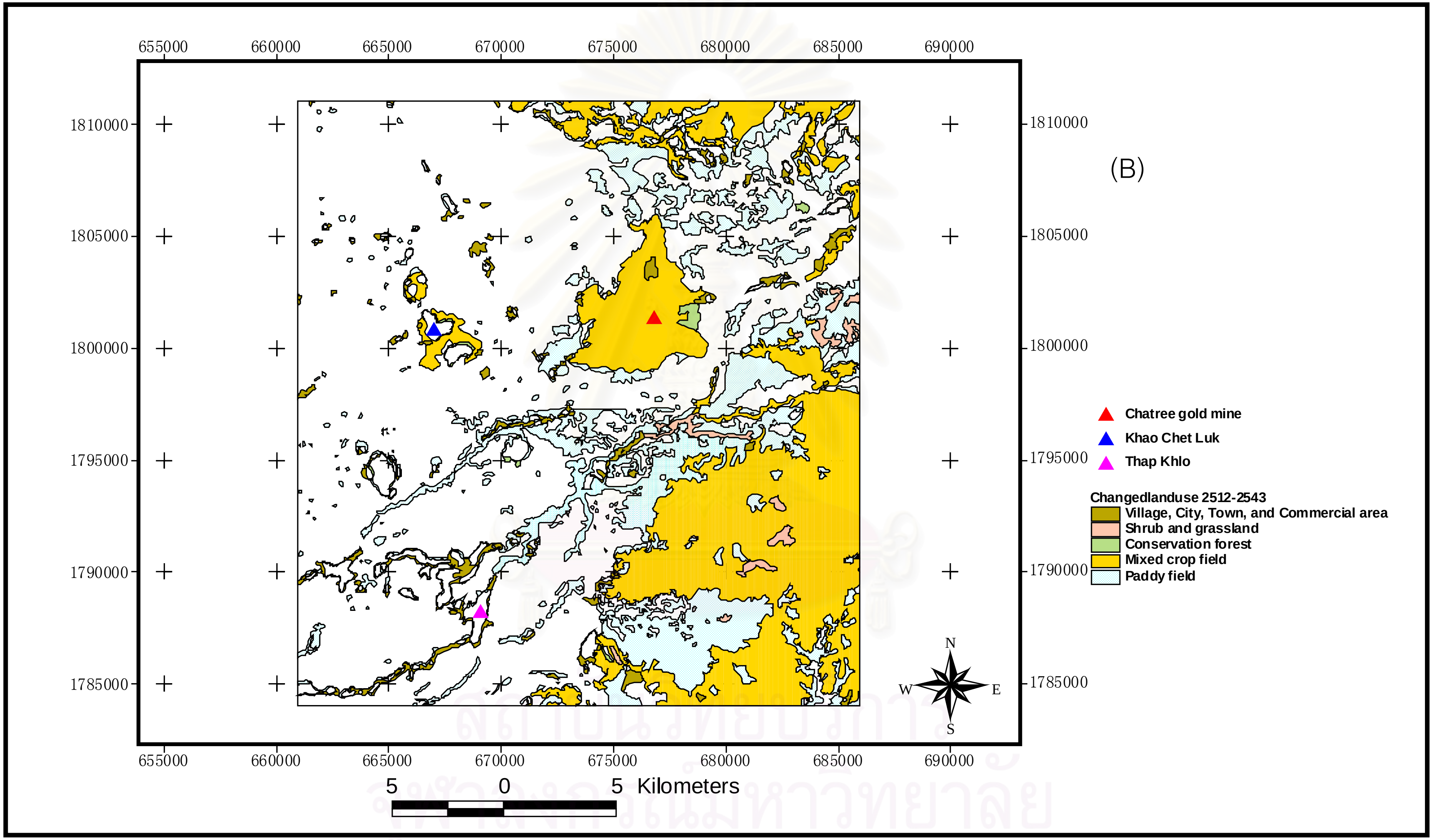


Figure 5.11. Continued. (B) The colors indicate the landuse type in 2543 B.E.

B.E. It was noted that the northwestern parts in Amphoe Wang Sai Phun and Amphoe Muang Phichit were mostly paddy field and a little area in Amphoe Wang Sai Phun was eucalyptus plantation and cornfield. In Amphoe Taphan Hin and Amphoe Thap Khlo, there was mostly paddy field with some forests in Khao Phra and Khao Chet Luk which was the gold panning area at Khao Phanompha. Around Khao Chet Luk, there were cassava fields and idle land which had a tendency to be expanded for gold panning. Amphoe Thap Khlo municipal area in the study area was a big town with governmental offices, commercial zone, schools, temples, 2 markets and housing. Near Thap Khlo-Wang Pong highway, there was a mango orchard. Near a road between Wang Daeng intersection and Khao Sai intersection there was a teak plantation. Near the road between Khao Sai intersection to Amphoe Chon Daen there were teak plantation, eucalyptus plantation, and fruit orchards. In Amphoe Chon Daen, away from the main roads the areas were mainly cornfield, teak plantation, and mango orchard, and small patches of bamboo and grassland or idle lands. In Amphoe Wang Pong which was adjacent to Amphoe Thap Khlo the areas were mainly cornfield and with small area for tamarind orchard and teak plantation. The Chatree gold mine also situated here. In the northeast of the study area, which was in Amphoe Wang Pong and Amphoe Noen Maprang, there was a small for forest. The landuses in 2545 B.E. - 2546 B.E. are shown in Figures 5.12 and 5.13.

5.4 Cause of landuse change

The landuse changes are caused by many factors such as economic growth, change in technology including farm-technology, constructing and improving of the infrastructures especially access and transportation system, availability of labor, need for income, and population change. Especially the population change is a major cause for changes because people use the land for their own needs, and change that all the time. In a case of population growth, i.e. the birth rate exceeds the death rate and the immigration exceeds the emigration together with the needs for higher income to cope up with the economic growth rate and inflation rate, the needs for more investment

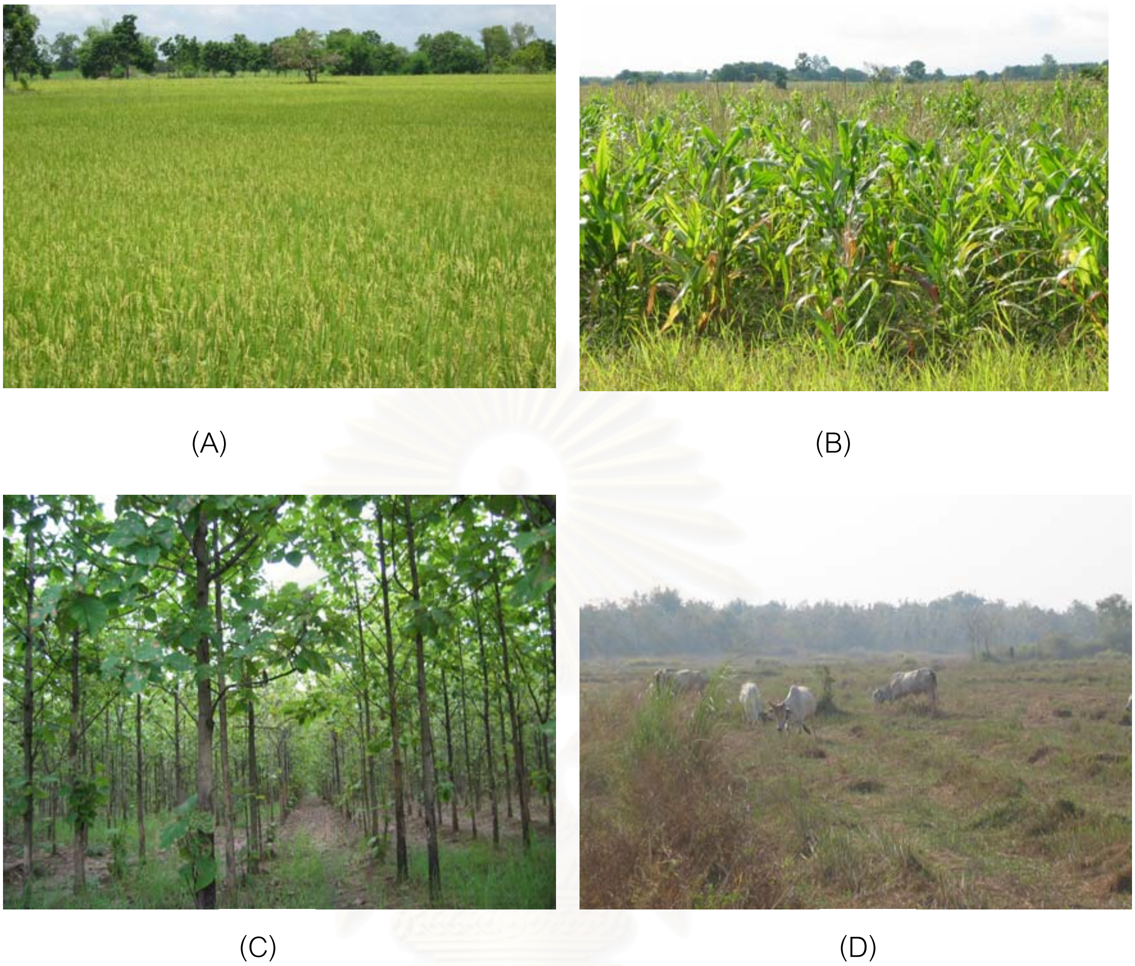


Figure 5.12. Landuse in the study area in 2545 to 2546 B.E. (A) Paddy field in Amphoe Thap Khlo, (B) Cornfield in Amphoe Wang Sai Phun, (C) Teak plantation in Amphoe Wang Pong, and (D) Grassland in Amphoe Thap Khlo.

on the natural resources will also increase. Also, the landuse changes, depend on other conditions such as social condition, government policy, and many other factors as well. In a case of the developing countries such as Thailand, the population growth is seemed to be a major driving force of landuse changes (Meyer and Turner, 1994) because the population have personal mobility that can increase a road building schemes, and the ongoing suburbanization of the countryside. Furthermore the population expands the cultivation and many times lead to the resource depletion and ultimately environmental degradation. The technological changes lead to the far-

(A)

(B)

Figure 5.13. Landuse in Khao Chet Luk in 2545 to 2546 B.E. (A) Panoramic view of Khao Chet Luk, (B) Area of gold panning at Khao Phanompha.

reaching transformations in agriculture through increase in land productivity and in labor productivity.

5.4.1 Cause of landuse change between 2512 B.E. and 2531 B.E.

Landuse changes in the study area between 2512 B.E. and 2531 B.E. was mainly from the population. From the first (2504 B.E. to 2509 B.E.) - which extended into the second (2510 B.E.to 2514 B.E.) National Economic and Social Developing Plans, the government had planned to built many infrastructures especially the transportation system. In the third National Economic and Social Developing Plan (2515 B.E. to 2519 B.E.) there had been a migration of people from the rural areas into the urbanized cities to earn a better income. However, in that development plan, it also concentrated on the family planning to decrease the birth rate and to urge a higher agricultural productivity by introducing in the varieties of the high yield, better priced plants such as corn, soybean, and coconut. From this condition, the people in the study area, which were mostly the agrarians, expanded their agricultural areas by invading the conservation forest especially in Changwat Phetchabun areas. As they needed more land for cultivation, the local people simply trespassed the conservation forest until the conservation forest was almost gone by being converted into lands for field crop and plantation. Meanwhile the areas in Changwat Phichit were still unchanged from the previous culture that was to grow rice as had long been done by their ancestors.

5.4.2 Cause of landuse change between 2531 B.E. and 2543 B.E.

In the period between 2531 B.E. and 2543 B.E., the natural resources were largely destroyed in study area. As in the later National Economic and Social Developing Plans which had planned to recover the natural resources such as to reforest in many areas. But in the study area the forest was planted only in the little areas while more forests still were diminishing and being converted to agricultural areas. The natural resources deterioration at that time had occurred from the population which continuously increased with the increasing of transportation systems and other infrastructures. Moreover, in 2537 B.E. many gold deposits were explored in this area. This was a main driving force for many people to move into this area to collect the precious metal. From the interview of the local people, first the migrants had intruded and settled semi-permanently in the idle lands around Khao Phanompha for a few years. Later they moved back to their home lands to grow rice in the growing seasons. After about 3 to 4 years, they then came back here again in the off-seasoned time to pan for gold.

5.4.3 Landuse change from gold production

During the last period of this study on the landuse change, it was noted that from 2543 B.E.on, the landuse pattern did not change very much. But along where the metal was mined in Khao Phanompha and in Chatree gold project area, the lands which were previously covered by the conservation forest, grassland, or field crops were converted into barren lands full of pits, piles of rocks and dirts, and the shacks, huts, houses and other mine buildings such as mine-plants and offices. Parts of the abandoned, pitted landscape without plant covers were noticed in Khao Phanompha area. These destroyed landscape, destroyed forest and agricultural areas are with toxicity in soil and water and will be expanded further. This certainly affects the quality of life and agriculture of the local people more.

5.5 Population change

Due to the fact that the study area is rural, non-irrigated and underdeveloped, it was noted that the agricultural lands were less productive that many people moved out to earn a better income elsewhere. The emigration continued until the year 2537 B.E. when gold was found in this area that drew many people from many other places to move in to mine for gold. This event brought about a net migration to be at the highest rate. In 2536 B.E. the net migration rate was 1.56 per 1,000 and in 2537 B.E. the net migration highly increased further to 6.51 per 1,000. In 2542 B.E. when Phichit Provincial Administration Organization had received Khao Phanompha gold concession, i.e. it had the right to control the gold panning, the number of population decreased from 79,352 in 2541 B.E. to 74,948 in 2542 B.E. and growth rate was down by 5.7%. After 2542 B.E. the population increased through time but though the net migration decreased, it showed that the social condition in the study area had gone back to its normality and perhaps would not change so much without any new stimulation or any driving force for migration back into the study area again.

About the population dynamics which is shown in Figure 5.14, in the year 2523 B.E., there was the highest birth rate at 15.1 per 1,000. In the, year 2545 B.E. there was the lowest birth rate at 5.59 per 1,000, and also the highest death rate at 4.97 per 1,000. The net migration rate in the year 2537 B.E. was the highest at 6.51 per 1,000 and the year 2545 B.E. the lowest at 1.36 per 1,000. It appears that the birth rate, death rate, net migration, and growth rate graph-lines declined in the period of 2523 B.E. to 2536 B.E. Then in 2537 B.E. all lines rose up sharply. After then, the birth rate, net migration, and growth rate started declining again while the death rate slightly increased until the present.

The picture of the population dynamics also shows that it has a strong change in 2542 B.E. when all the lines except that of the death rate declined even further until the study time in 2545 B.E. During the 33 year period, the population growth rate was on an average 0.64% per year, which was a very low growth rate. Judging from Figure 4.1 it shows a tendency of an insignificant change, either decreasing or increasing with a very low rate.

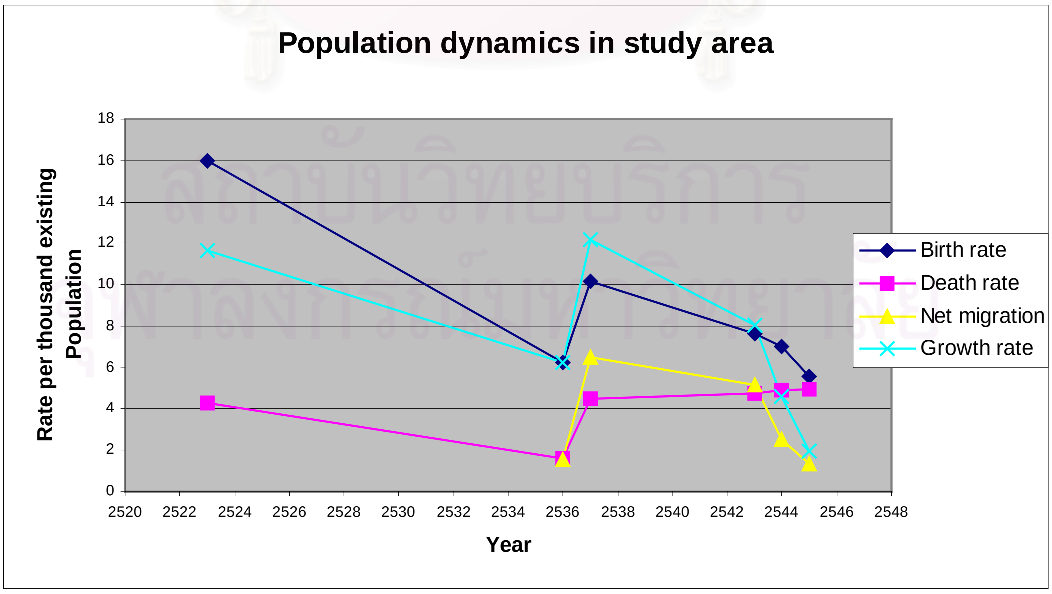


Figure 5.14. Population dynamics in study area.

The gold finding and further exploration in 2537 B.E. probably introduced the people to move into the study area with a hope to high income from gold recovery. That is why there are a lot of non-registered population to stay here. Thus the data on only-registered population the Statistical Department was not accurate enough for the analysis of population and natural resources in this study area. In this study the intensive interviewing of many local people to estimate the possible number of non-registered population was noted to be more appropriate with the consequence being that population increase was about 10,000 persons from 2537 B.E. to 2542 B.E., and then until the present, another increase of only about 5,000 persons. The main factor of lower rate of population increase was that Phichit Provincial Administration Organization had received the concession on the gold deposit and the gold rush simply decreased. Many people only moved in to pan for gold in the dry season and move back to their home lands in the rainy season for agricultural activities. The estimation of the non-registered population received from the interviewing is shown in Figure 5.15. It is unfortunately not very beneficial for predicting further because it came just from an estimation.

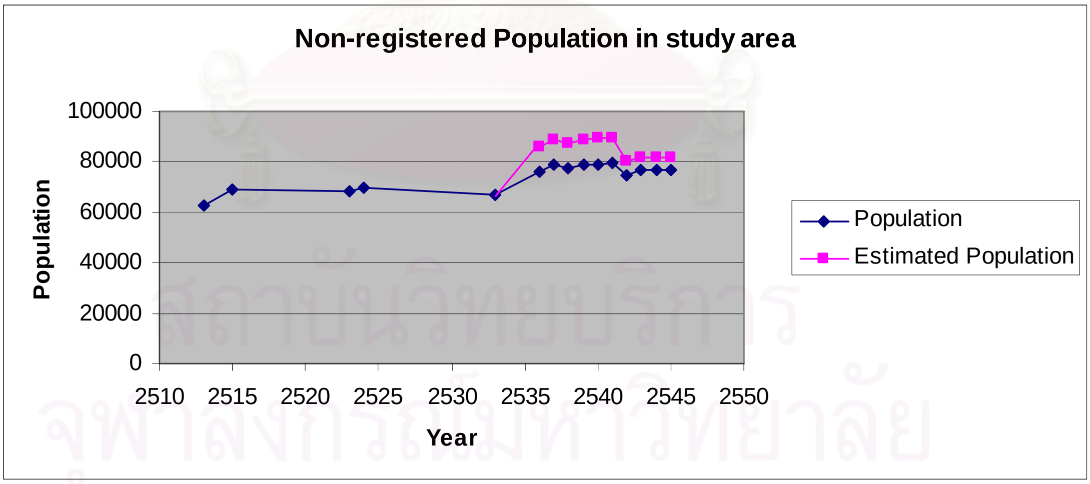


Figure 5.15. Estimated non-registered population in study area.

CHAPTER VI

FUTURE OF LANDUSE AND POPULATION

6.1 Tendency of landuse in 2560 B.E.

The history of the landuse and population changes in this part of area at the triple junction of Changwat Phichit, Phetchabun and Phitsanulok, could help to look for the future of the social activities in this poor, rural area, and perhaps could help for a better planning for the regional development for the benefit of the people.

From the landuse changes between 2512 B.E. and 2543 B.E. as the conservation forest was almost all disappeared, certainly there will be less chance for the deforestation for agricultural purposes in the future. Furthermore, the prediction for the future landuse is based on an assumption that the population growth rate will be in a normal rate and the economic and social conditions in the study area remain the same as in the present. Also the rate of change of landuse in Figure 5.4 indicates a tendency that the rice field, mixed crop field, and village will slightly increase. The prediction of the future landuse is attempted using Sayan Manmano's (2533) equation as below.

$$\text{Predicted area} = \text{Area of base year} + \frac{[\text{Area of base year} - \text{Area of previous data}]}{\text{Number of year}} \times \text{number of year to predict}$$

Using the year 2543 B.E. as the base year, and the year 2531 B.E. the year for the previous data, the prediction was attempted for the year 2560 B.E., or 17 years further from the base year. The result of the landuse prediction in 2560 B.E. is that the paddy field will be 501.551 km^2 or 74.07% of the study area, conservation forest 5.854 km^2 or 0.86%, shrub and grassland –1.53 km^2 or –0.22%, mixed crop field 135.492 km^2 or 20.01%, village 26.451 km^2 or 3.91%, and gold mine 9.318 km^2 or 1.37%, the prediction is shown in Table 6.1 and Figure 6.1.

Table 6.1. Changing areas per year and projected areas in 2560 B.E.

	Area in 2512 B.E. (km^2)	Area in 2531 B.E. (km^2)	Area in 2543 B.E. (km^2)	Net changing area from 2531 B.E. to 2543 B.E. (km^2)	Changing area per year (km^2)	Projection area in 2560 B.E. (km^2)
Paddy field	427.173 (63.09%)	499.184 (73.72%)	500.164 (73.86%)	+0.98	+0.0816	501.551 (74.07%)
Conservation forest	228.86 (33.8%)	9.974 (1.47%)	8.268 (1.22%)	-1.706	-0.142	5.854 (0.86%)
Marsh, Swamp	1.367 (0.2%)	0	0	0	0	0
Shrub and Grassland	0	9.342 (1.38%)	4.843 (0.72%)	-4.499	-0.3749	-1.53 (-0.22%)
Mixed crop field	1.715 (0.25%)	137.88 (20.26%)	136.892 (20.22%)	-0.988	-0.0823	135.492 (20.01%)
Village	18.021 (2.66%)	20.756 (3.07%)	23.113 (3.41%)	+2.357	+0.1964	26.451 (3.91%)
Gold mine	0	0	3.856 (0.57%)	+3.856	+0.3213	9.318 (1.37%)
Total	677.136 (100%)	677.136 (100%)	677.136 (100%)			677.136 (100%)

Shrub and grassland in 2560 will be used up and changed to other landuse entirely. It will be changed to rice field, village, or gold mine which have increasable trend.

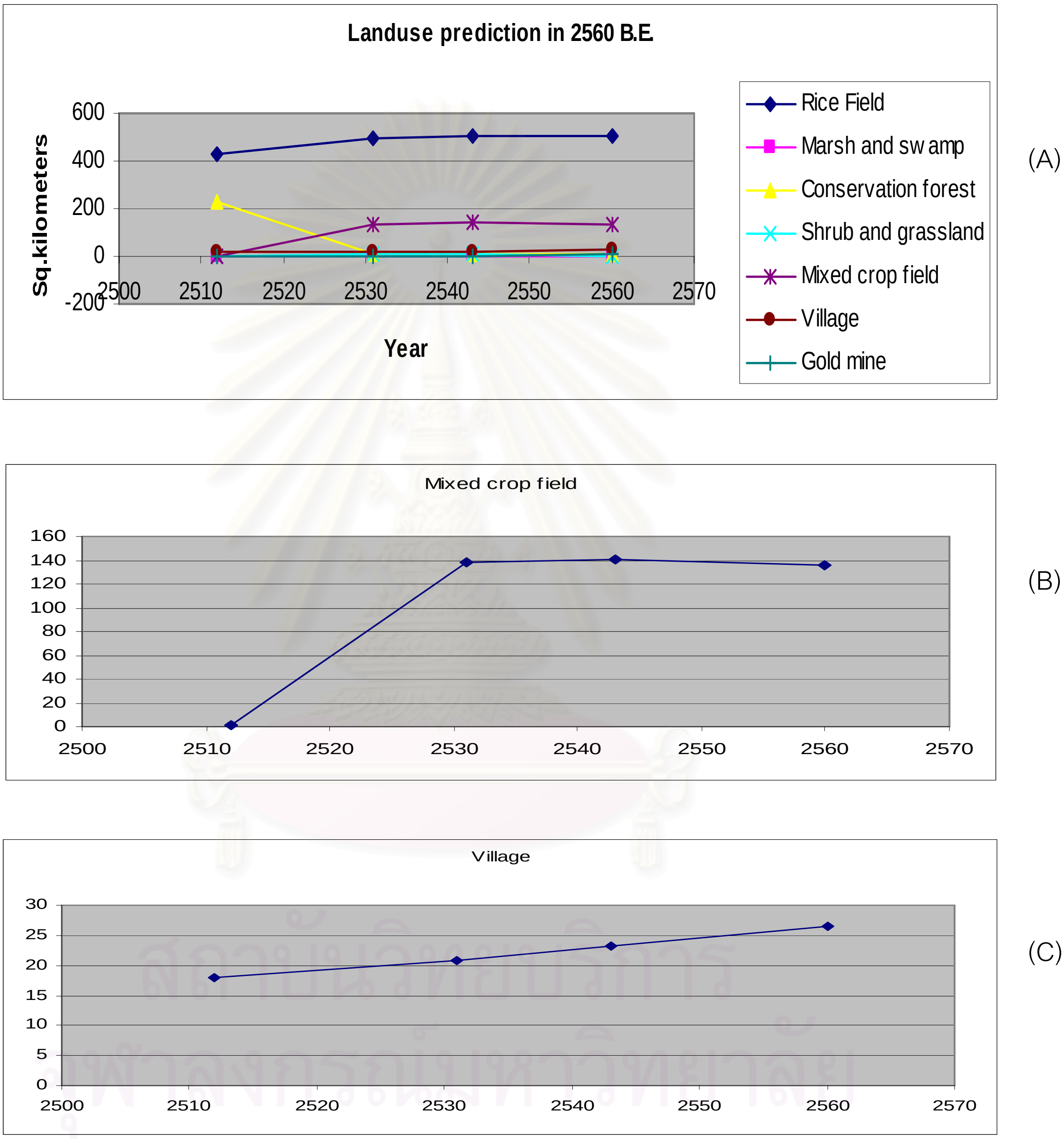
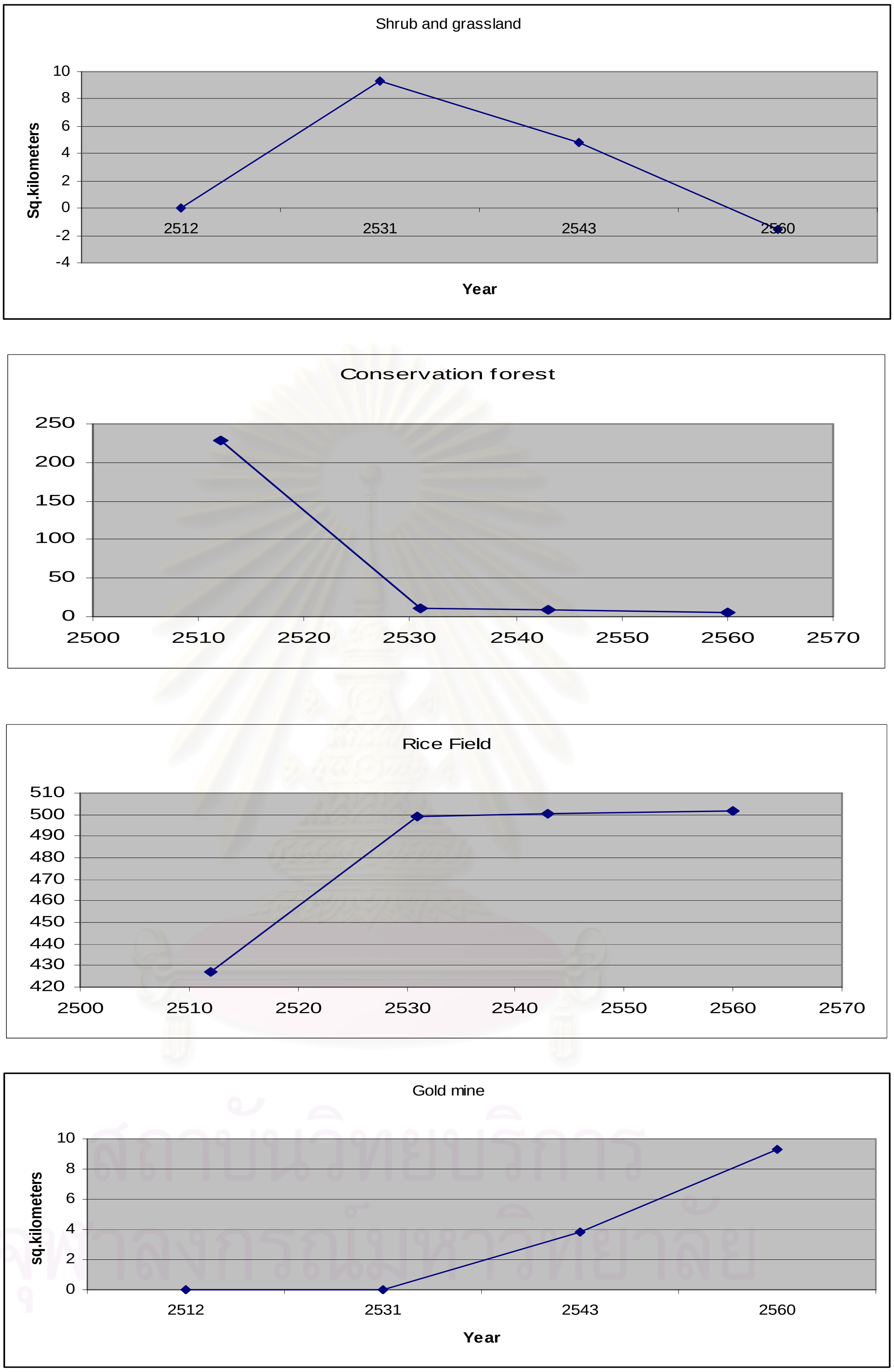


Figure 6.1. Landuse through time from 2512 B.E. till 2543 B.E. with a prediction for 2560 B.E. (A) Summation of all landuse types, (B) Mixed crop field, (C) Village.



(D)

(E)

(F)

(G)

Figure 6.1. Continued. (D) Shrub and grassland, (E) Conservation forest, (F) Paddy field, and (G) Gold mine.

6.2 Tendency of population in 2560 B.E

The prediction of the population in the study area was attempted for 2560 B.E. This prediction is also to obtain another basic factor for the future landuse, as the growing population density leads to a scarcity of land, thence widespreading changes in landuses. The human activities also result in a wide variety of environmental problems, including deforestation, overgrazing, and the depletion and contamination of land and water resources. And the most importance, the growth or reduction of working force will have an important financial impact on the revenue of the society as a whole for the capital expenditures and for the operating and maintenance of the expenditures. Therefore, the population change is very important for the future of the country as a whole.

The population tendency in the study area was projected under the varieties of possibility to happen here. This projection was made on the criteria that more gold deposits would be found and mined and the people would move in, or the gold mining would be done continuously without any change, or even that the gold deposits would be mined out and the immigrants moved out.

Henry and Heinke (1996) suggested the projection of the population as below.

6.2.1 High projection: Assuming the current population growth rate continues for 1/3 of the prediction period, followed by a growth rate of about 1/3 of the maximum growth rate ever occurred, until the prediction year is reached.

6.2.2 Medium projection: Assuming the current population growth rate continues without change until the year of prediction is reached.

6.2.3 Low projection: Assuming population drop 1/3 of the minimum population growth rate in the next 1/3 of prediction period, then followed by a slow growth rate of about 1/2 of the current population growth rate, until the prediction year is reached.

Using Henry and Heinke's (1996) method above, and based on the population of 2545 B.E., 76,509 persons, the prediction was made for 2560 B.E. The future population in the year 2560 B.E., a period of 15 prediction years is as following.

For the high projection, the current population increase per year is 91 persons while the highest increased rate per year which had occurred in 2513 B.E. to 2515 B.E. is 3,135 persons per year, this gives a calculation for the population in 2560 B.E. to be 87,414.

For the medium projection, the current population increase per year is 91 persons, so this gives a calculation for the population in 2560 B.E. to be 77,874.

For the low projection, the lowest increase-rate per year had been occurred in 2541 B.E. to 2542 B.E. to be –4,404 per year i.e. a record of population reducing, so this gives a calculation for the population in 2560 B.E. to be 69,624.

Furthermore, if there had never been any gold deposits found and mined in this area, it was predicted that the population would steadily decline due to the desertation of the local inhabitants to seek a better opportunity elsewhere. Starting in the year 2531 B.E. with the further population reduction, the prediction of population for the year 2560 B.E. would be 61,526. This number is much comparable to the low projection above. The projection of the population in the study area in the year 2560 B.E. is shown in Figure 6.2.

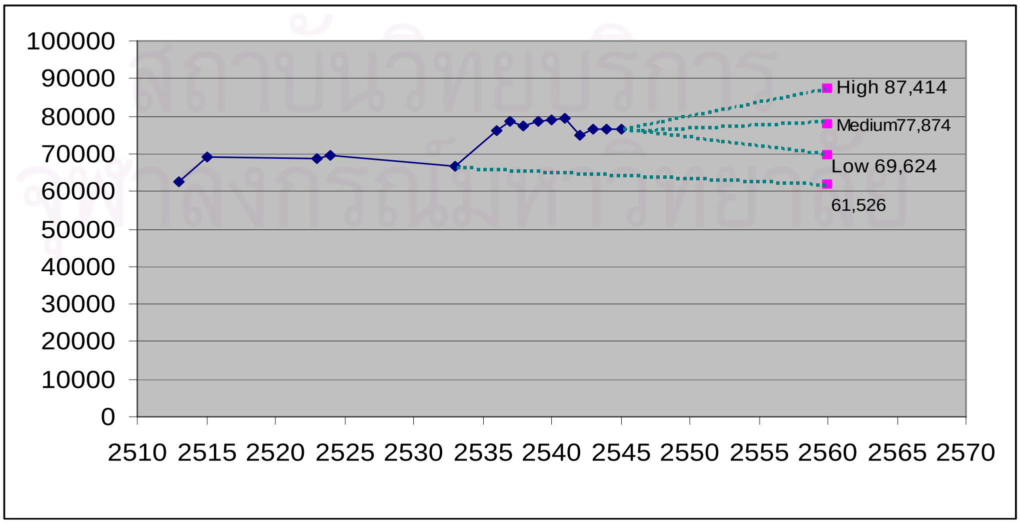


Figure 6.2. Population projection in 2560 B.E.

It was noted from the projection graphs above that in 2560 B.E. the population in the study area would be varied within a range from a minimum of 69,624 to the maximum of 87,414. The number should be more likely toward the minimum prediction than the others as the new large gold deposits are not very much likely to be found. Thus the people would simply move out of this poor land. Unless a better regional development plan is adopted, for examples, the introduction of the higher yielded, higher revenue created crops which require less water into the area, or a construction of irrigation system using the abandoned mine pits as the reservoirs, perhaps more people would move back.

CHAPTER VII
SUMMARY AND CONCLUSION

Due to the soils in the study area are mostly sandy and are moderate to low in their plant-growth quality, suitable soil areas for suitable crops in 2543 B.E. are about only 77% of all area. These soils could be most used for the agricultural purposes especially rice growing. The area is also with the intermittent streams which have the water flow only in the rainy season and without any irrigation system, so this rain-fed area is very dry and gives a low productivity that the local inhabitants have to move out continuously to find a better opportunity elsewhere. Those who stayed had caused the landuse changes as following.

The landuses in 2512 B.E. were the paddy field 427.173 km^2, conservation forest 228.86 km^2, marsh and swamp 1.367 km^2, mixed crop field 1.715 km^2, and village 18.021km^2. The landuses in 2531 B.E. were the paddy field 499.184 km^2, mixed crop field 137.88 km^2, village 20.756 km^2, conservation forest 9.974 km^2, and shrub and grassland 9.342 km^2. Of these areas, 272.699 km^2 had been changed and 404.437 km^2 remained unchanged. The landuses in 2543 B.E. were the paddy field 500.164 km^2, mixed crop field 136.892 km^2, village 23.113 km^2, conservation forest 8.268 km^2, shrub and grassland 4.843 km^2, and gold mine 3.856 km^2. It was noted that 79.526 km^2 had been further changed and 597.61 km^2 unchanged.

Of the entirely 677.136 km^2 of the study area, from 2512 B.E. to 2543 B.E. the area 268.019 km^2 had changed. This was mostly that the conservation forest had been changed and this forest was mostly changed to mixed crop field. The unchanged area was mostly the paddy field in Changwat Phichit. The agricultural land had increased from 428.888 km^2 to 637.056 km^2 during that period, however the productivity had decreased especially for the yield of rice because water was not enough while the quality of soils was niether very good.

The population in the study area from 2513 B.E. to 2545 B.E. was low in density and did not increase much along the time with the population growth of 0.64%. In fact it showed a tendency of decreasing instead, probably due to the drought in this area. But between 2537 B.E. and 2541 B.E., the population greatly increased due to the gold finding here. However the people moved out again later and thence the population in the area continuously declined. These people, the gold rushers who moved in during 2537 B.E. had gone back to their home lands to do the agricultural activities, and only came back in this area after the growing seasons to pan for gold. The moving in-and-out of the people, both local and out-of-area had help creating the change of landuse types together with the economic development plan of the country.

The prediction of the landuses in 2560 B.E. is that the most probable landuse in the near future will be that paddy field 501.551 km^2, conservation forest 5.854 km^2, shrub and grassland –1.53 km^2 that mean it will be used up, mixed crop field 135.492 km^2, village 26.451 km^2, and gold mine 9.318 km^2. Only the paddy field, village, and gold mine are on a significant increasing trend.

The population projection in 2560 B.E. was done with 4 possibilities: high projection (with continuous gold finding and mining) will be 87,414 persons, medium projection (continuous gold production as in the present) will be 77,874 persons, low projection (termination of gold mining) will be 69,624 persons, and projected from 2533 B.E. growth rate (without any gold finding) will be 61,526 persons. But if there are the other stimulations such as the new natural resources exploitations, or the better regional development plans, the population will change from the above prediction, and so will the landuses.

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APPENDIX

Soil analysis

Collection of samples

To collect the soil samles, the ground is dug in a V shape manner to a 15 cm. depth. At least 1 kg. of each sample is collected.

Soil collection.

Soil samples.

<u>Soil sample preparation</u>

The collected soil samples are dried in the oven (at 100°c). When dried, the samples are crushed and sieved. The sample particles needed for the further analysis are classed into the sizes of sand, silt, and clay.

Dried soil

Soil crushing

Laboratory soil test

1. Soil pH

1.1 Laboratorial test

Apparatus

- 500 ml. beaker
- pH meter

Chemical substance and solution

- 0.01M $CaCl_2$ 20 ml.

Procedure for measuring pH by using a pH meter (water method)

- Standardize pH meter by pH 7.0 and 4.0 buffer solutions before measuring pH level.
- Mix 10 g. soil sample with 20 ml. distilled water in 100 ml. beaker.
- Stir by glass rod to well mixed before measuring the pH level for 30 minutes, occasionally stir the soil mixture during the measurement.

Procedure for measuring pH by 0.01 M $Cacl_2$ method

- Mix 10 g. soil sample with 20 ml. 0.01 M $Cacl_2$ in 100 ml. beaker.
- Stir by glass rod to well mixed and leave for 30 minutes before measuring pH level. Occasionally stir the soil solution mixture during this 30 minutes period.
- Measure the pH level as in the water method.

pH test

1.2 Field test using pH soil tester

How to use a soil tester

A soil pH tester is an easy-to-use equipment in the field, though not as accurate as a laboratorial pH-meter. It normally is used by the farmers to test their own farm land for the soil pH. Below is an easy method to use the equipment.

1. Taking the tester out and see that the pointer needle points to pH 7.
2. The electrode is very sensitive, therefore before and after using wash off dirt and dust on the surface of the electrode and wipe with a dry cloth clean.
3. Insert the tester into soil vertically which is holding about 50-70% moisture and tread down the surrounding soil by foot tightly in order to let contact enough with soil and electrode. When soil is dry accurate pH index cannot be detected in which case it is advisable that water from river or well is properly sprinkled to the above moisture percentage and wait about 2 hours to measure.
4. The pointer needle settle soon (about 3 minutes) and stabilized position is pH index.
5. In case of measuring humidity, push the button and can get humidity index. After using keep to wash off dirt and dust on the surface of the electrode and wipe with a dry cloth clean.

Features

1. Being of electric generation system with the earth, no chemical, distilled water, and/or electric power source such as storage battery, etc. is needed.
2. Measuring is most simple, the desired pH index being shown by merely inserting the meter into soil.
3. The quantity of lime to be applied is readily ascertained.
4. Compact in size. Elegant in style and handy to carry.

Care to be Taken in Handling and measuring

1. When it is desired to put pointer needle to pH7 position, taken the lid and glass of and carefully turn the screw on the under part right and left and set correct position. Do not turn strongly.

2. Insert the tester vertically and let the soil contact compactly with the electrode by foot. If the soil does not come in contact completely with the metal parts on both of the tester, the pointer needle vacillate left and right and will not settle.
3. Keep the electrode clean and free from rust. When oxidation take place on surface, sensitivity becomes weakened and the needle will not point to higher pH and humidity than the true indexes, in relation to earth electric current, etc.
4. If high voltage electric pole, etc. be near the soil, avoid to measure in such position since it is probable that the pointer needle will point to the higher pH and humidity than the true indexes, in relation to earth electric current, etc.
5. Being designed to harness soil's electricity generating power for its functioning, index come more or less different depending on pressure by foot and moisture degree, and so it is ideal if average index figure is sought by doing measuring 5-6 times.
6. Handle carefully and never drop, oscillate strongly.

2. Soil Texture

The soil texture is done using a hydrometer method. The hydrometer method is based on the fact that the different sizes soil particles settle in a medium solution at the different rates. By using Stokes' equation:

$$r = \sqrt{\frac{9d\mu}{2(\rho_1 - \rho_2)gt}}$$

r = radius of a spherical particle (cm.),

μ = viscosity of suspending medium (poises),

d = setting distance (cm.),

ρ_1 and ρ_2= specific gravities of the particles and suspending medium, respectively,

g = gravitational constant, 981 cm/sec^2,

t = time from the start of test (sec.).

It is noted that it takes 40 seconds for the sand (60 μm – 2mm. diameter) particle to settle through a distance of 10 cm, in distilled water, whereas it takes a little over 8 hours for all of the silt (4 to 60 μm. diameter) particle to at settle the same distance while clay (<4 μm.) remains suspended longer. If soils and water are well mixed until the solid particles suspend thoroughly, the mixture will initially have an equal density throughout the container. But as the soil particle settles downward, the density of the suspension mixture at the top of the container will begin to decrease. If there is a lot of sand in the suspension, the density at the top will decrease rapidly. If the soil is very clayey, the suspension density will decrease much slower. By measuring the suspension density at a specific depth at the different times, the amount of sand, silt and clay in the sample can be determined.

The textural class of a soil is determined by its particle size distribution, namely sand, silt, and clay content. The texture represents a rather stable soil characteristics and exerts an influence on many physical and chemical activities of soil. This influence is directly related to the amount of surface activity presented by the mineral particles. Surface activity is a function of both particle size, which determines the total specific surface area; and clay type, which determines the relative surface reactivity. The particle size distribution analysis quantifies the particles size categories, but does not determine the clay type. The particle size distribution provides an information necessarily for determining the soil class on the textural triangle, an important standard for categorizing the soil physical and chemical behaviors on the basis of surface activity.

Part One: Sieve Analysis

A mechanical sieving can be used to separate the loose coarse grains from the soil components, to separate sand into classes, and to determine the sand fractions from silt and clay fractions. The silt and clay fractions cannot be distinguished from one another by using this sieve analysis. The method used in the second part of the laboratorial study can separate silt from clay particles.

Procedure:

1. Remove all pieces of visible organic matter from the soil sample and crush soil clumps, using a mortar and pestle.
2. Weigh approximately 50 g. of soil. Record the exact weight as Ws.

3. Stack the sieves, the sieve numbers are shown below, with the largest openings (the smallest mesh number) on the top and successively larger mesh numbers below. Place a pan under the stack of sieves. Pour sample into the top sieve, place the lid on top of the stack and secure the stack to the sieve shaker. Turn on the shaker and let it run for 10 minutes.

4. Carefully collect residue from each sieve for weighing. Weigh soil from each sieve, including that in the pan at the bottom of the stack. Record the weights as following:

W1 = weight of fragments retained by Sieve #10 (larger than sand; >2mm)

W2 = weight of Soil retained by Sieve #40 (coarse sand)

W3 = weight of Soil retained by Sieve #80 (medium sand)

W4 = weight of Soil retained by Sieve #230 (fine sand)

W5 = weight of Soil remaining in the bottom pan (silt and clay)

Calculate percentages of each of the above, as a percentage of the original soil weight (Ws), and keep as a record.

Part Two: Bouyoucos Hydrometer Method

A quantitative determination of the proportions of differently-sized solid particles is called a mechanical analysis. The present analysis had used the Bouyoucos hydrometer method for the mechanical analysis. The method is relied on the principles of dispersion and sedimentation.

Dispersion

The individual soil particles must be dispersed (separated from each other) in an aqueous solution and remain dispersed to enable a determination of particle size distribution. However, soils naturally exist as aggregates and not as a dispersed mixture of particles. Aggregates are secondary particles formed by cementing a mixture of primary particles, i.e. sand, silt, and clay. Cementing agents include the organic matter, mineral oxides, or polyvalent cations (ions possessing more than one + charge). Dispersive methods remove or inactivate these binding agents. Only after the binding forces have been negated can individual particles be separated and their settling rate be properly analyzed. Complete dispersion requires both mechanical and chemical assistance. Mechanical stirring overcomes weaker binding forces in the large aggregates, but chemical agents are also necessary, especially to deflocculate clays. Polyvalent cations (normally Ca^{+2} and Al^{+3}) flocculate clays by forming interparticle, electrostatic linkage. Chemical dispersing agents (such as sodium hexametaphosphate) are effective in dispersing these clay bundles because of the reasons below.

a. The sodium monovalent cation (Na+) replaces the polyvalent cations adsorbed on clays, thus breaking the interparticle linkage. The displaced polyvalent cations form the insoluble complexes with phosphorus which prevents re-establishment of floccules.

b. The adsorption of sodium, a highly hydrated cation, brings to an increasing hydration of clays. This condition diminishes the binding strength between clay and cation which raises a clay particle's electronegativity and, hence, their repulsion from other clays. The mixture of dispersed soil particles in water is called a suspension. Once a true suspension state has been achieved, differential settling rates can be used to distinguish particle size distribution.

<u>Sedimentation</u>

The sedimentation rate, a settling rate of a mineral particle in water, relies on the size of the particle. Large particles settle out of suspension more rapidly than the small particles. Analytical techniques based on this direct sedimentation relationship allow a quantification of particle size distribution.

The soil erosion into the surface water provides an environmental application of sedimentation principles and illustrates another criteria of Stoke's Law, namely, that the settling solution should be still. Moving water maintains the particles in a suspension that would otherwise settle in still water. Thus, the sediment loads in streams and rivers are determined by the water velocity and turbulence. Sediments segregate by a particle size during settling. Fast moving water can transport even very large particles, but as water flows slower, first sand particles and then silt are deposited. These deposits can cover an existing surface, alter the subsequent water flow patterns, and reduce a reservoir capacity. Clays, on the other hand, settle only when water movement has virtually ceased. Since clays constitute the most surface active fraction and bind chemicals that can constitute pollutants, clays deposits are frequently sites of environmental pollution.

In this analytical study, a hydrometer was used to quantify the solid material remaining in the suspension at each stage of the sedimentation process. The hydrometer was calibrated to measure the density of a suspension at the hydrometer's center of buoyancy in units of grams per liter. The previous researches had determined that within 40 seconds, sand particles (0.06 mm and larger) would have settled below the buoyancy center of the hydrometer. Within two hours, silt particles (0.004 to 0.06 mm) would have settled and no longer influenced the hydrometer. Thus, measuring the density of the soil suspension at 40 seconds after shaking and again at 2 hours provides the information necessarily to calculate the percentages of sand, silt, and clay in the soil.

Procedure:

1. Weigh 50 g oven-dried soil sample (not larger than sand-size) into a stirring cup. Fill the cup half full with deionized water and add 100ml of dispersing solution (5% calgon). Mix and let stand for 10 minutes to initiate a chemical dispersion.

2. Place the cup on a mixer and stir 3 minutes for coarse-textured soils and 4 to 5 minutes for highly clay soils. This step completes the mechanical and chemical dispersion.

3. Quantitatively transfer stirred mixture to a sedimentation cylinder with a stream of deionized water. Fill cylinder to the 1000 ml. mark with deionized water.

4. Agitate the mixture to be uniformly suspended with all materials throughout the liquid by inserting a stopper and inverting the cylinder several times (Do not shake in a manner that would produce circular currents in the liquid as this may alter the settling rate)

5. When the suspension is completely prepared, put the cylinder down on the table and mark the starting time. After about 30 seconds, slowly lower a hydrometer into the suspension and release it, then read the scale at the meniscus exactly 40 seconds after the agitation stops. Remove the hydrometer. Repeat Steps 4 and 5 until the hydrometer readings within 0.5 g. of each other are obtained and record the readings on the data sheet (assuming that it is a g/L which is sum of silt, clay, and dispersing agent quantity).

6. Immerse a thermometer into the suspension and let stay for about 3 minutes, record the temperature, and calculate the corrected hydrometer reading.

-For each degree above 18°C, add 0.25 g/L to the original hydrometer reading.

-For each degree below 18°C, subtract 0.25 g/L from the original hydrometer reading.

7. Mix the suspension again as described in Step 4 and place the cylinder where it will not be disturbed. After 2 hours, insert the hydrometer into the suspension and take another reading. Record the temperature and correct this hydrometer reading as described in Step 6 (assuming that it is b g/L which is sum of clay and dispersing agent quantity).

8. In another cylinder, add 100 ml. of dispersing solution (5% calgon) and fill the cylinder to the 1000 ml mark with deionized water, insert the hydrometer into the solution and take reading (assuming that it is c g/L at t°c)

9. Discard the liquid portion from the sedimentation cylinder into sink drain. Transfer settled materials to a designated waste receptacle.

<u>Calculation</u>

$Rs = Rt + 0.36\,(t - L)$............for soil suspension at 40s and 2 hours

and $Cs = Cr + 0.5\,(t_c - L)$.............for dispersing agent solution

whereas

Rs = Appropriate value of soil suspension at L°c or when hydrometer read the justified value, g/L

Rt = Readed value of soil suspension at t°40 or t°2 (40 the temperature at the seconds and 2 hours readings), that are a or b value, g/L

Cs = Appropriate value of dispersing agent at L° c or when hydrometer read the justified value, g/L

Cr = Readed value of dispersing agent at t°c, that is c value, g/L

t = Temperature of soil suspension at 40 seconds (t°40) or 2 hours (t°2) reading time

L = Temperature that identified on hydrometer, °c

t_c = Temperature of dispersing agent

Replace the reading value in the equations

Rs (40 sec.) = Rt + 0.36 (t - L)

= a + 0.36 (t_{40} – L), g/L

Rs (2 hr.) = Rt + 0.36 (t – L)

= b + 0.36 (t_2 – L), g/L

Cs = Cr + 0.5 (r – L)

= c + 0.5 (t_c – L), g/L

<u>Silt and clay quantity</u>

Subtract Calgon quantity (40 second value)

= Rs 40 sec. – Cs g/L

= A g/L

<u>Clay quantity</u>

= Rs 2 hr – Cs g/L

= B g/L

Assuming that soil the sample weight is X g.

<u>Sand quantity</u> = X – A g/L

<u>Silt quantity</u> = A – B g/L

Calculate for percentage of sand, silt and clay by using following equations.

$$\text{Sand, \%} = \frac{100}{X}(X - A)$$

$$\text{Silt, \%} = \frac{100}{X}(A - B)$$

$$\text{Sand, \%} = \frac{100B}{X}$$

Organic matter removing

Wet sieving

Soil sieving with Sieve # 10 (2 mm. size or larger)

Hydrometer inserted in soil suspension and in dispersing agent

3. Organic Matter

The analysis for the organic matter was done using Walkley-Black method.

Apparatus

- Analytical balance
- 5 ml. Volumetric flask
- 250 ml. Erlenmeyer flask
- 50 ml. Burette
- 10 ml. measuring cylinder
- 20 ml. measuring cylinder
- Titration base, with bright light source

Chemical substances and solution

- 1 litre of 1N $K_2Cr_2O_7$: Dissolve 49.04 g $K_2Cr_2O_7$ (desiccated at 105°C) in distilled water and adjust the total volume to a litre.
- Concentrated sulfuric acid

- 1 litre of 0.5 $FeSO_4$: Dissolve 196.1 g $Fe(NH_4)_2 6H_2O$ in distilled water, add 15 ml. concentrated H_2SO_4, cool it down and adjust to 1 litre.

- 100 ml. 0.025M O-phenonthraline ferrous sulfate indicator: Dissolve 1.48 g O-phenonthraline and 0.7 g ferrous sulfate in distilled water.

Procedure

- Use an analytical balance to weight 0.5 to 2 g fine soil samples (been grinded and sifted by 0.5 sieve plate already) and put in a 250 ml. Erlenmeyer flask.
- Add 5 ml. 1N dichromate by using pipet.
- Pour 10 ml. concentrated H_2SO_4 instantly into the mixture.
- Swirl the flask softly about 1 to 2 minutes for mixing well.
- Set aside the flask for 30 minutes for reactions
- Add 15 ml. distilled water and 3 drops of indicators.
- Titrate soil suspension by ferrous sulfate until the suspension color change from green to reddish brown. In case of too much ferrous sulfate, add 0.5-1 ml. dichromate and titrate by ferrous sulfate again. The end point is when indicator change from green to reddish brown.
- Record the amount of dichromate and ferrous sulfate used.
- This method have to do with a blank and record the amount of dichromate and ferrous sulfate for calculating the exact normality of ferrous sulfate before calculating the amount of dichromate being reduced by the soil sample.
- Reduce the amount of soil samples and repeat the test again in case of the results show the amount of dichromate reduced by soil sample is more than 4 ml.

Calculation formula:

- % organic carbon = $$\frac{(\text{me } K_2Cr_2O_7 - \text{me } FeSO_4) \times 0.003 \times 100 \times 1.33}{\text{weight of sample (grams)}}$$

- % organic matter = % organic carbon x1.72

Mixing Sulfuric acid with soil and dichromate

4. Conductivity

This process was done using a conductivity meter.

Apparatus

- 600 ml. Beaker
- Buchner funnel
- Suction flask
- Vacuum pump
- Conductivity meter

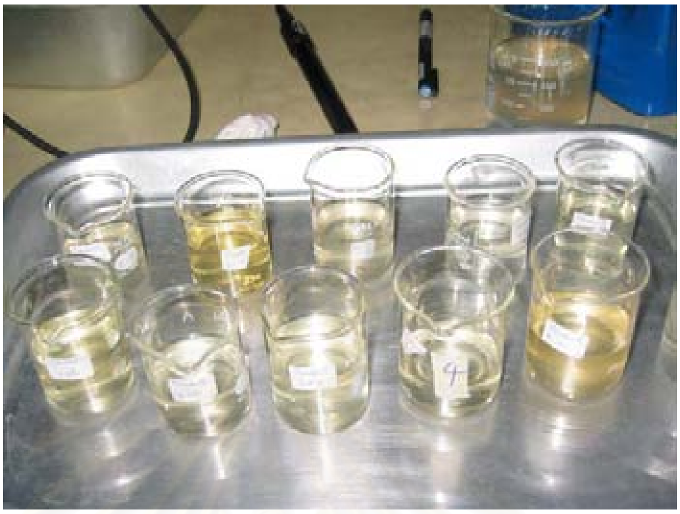
Procedure

- Put 200 g soil sample (not larger than 2 mm. in diameter) in a 600 ml. beaker. Slowly pour in deionized water and stir by spatula constantly until saturated, as noticed that the soil is shimmered in light and moves down slowly when tilt the beaker.

- Leave the beaker for an hour, then either add soil or water if it is not completely saturated.

- Move the prepared sample to a suction flask with Buchner funnel set up.

- Use vacuum pump to suck out the soil extraction for measuring a conductivity value.



Extracted solution

Conductivity measuring

5. Salinity

Salinity value is calculated from the conductivity value using the below formula.

- Quantity of salt in soil (me/l) = (Conductivity x13.1)+10
- Quantity of salt in soil (ppm) = 642 x Conductivity + 44

- Percentage of salt in soil = 0.0642 x Conductivity + 0.0044

6. Total exchangeable bases

Apparatus

- Buchner funnel, fitted with 4.2 Whattman filter paper
- Analytical balance
- Atomic absorption spectrophotometer (AAs)

Chemical substances and solution

- Ammonium acetate: Dilute 68 ml. of NH_4OH with 500 ml. distilled water. Add 56.5 ml. of acetic acid, and add distilled water until its volume become 1 litre. Stir to be mixed well. Adjust the solution pH to 7 by diluted ammonium hydroxide or acetic acid.
- Standard solution for each cation.

Extraction solution

- Weight 10 g soil (not larger than 0.2 mm. in size).
- Add 250 ml. 1N NH_4OAc. Shake well and left overnight.
- Filter by suction: Use the Buchner funnel for gradually washing out the soil by neutral 1N NH_4OAc.
- Prevent the soil drainage by adding NH_4OAc in the funnel when the solution level lower to be near to the soil surface.
- Keep leachate for measuring exchangeable bases later.

Procedure

- Bring leachate from NH_4OAC washing above to an AAs (Atomic absorption spectrophotometer) analysis.
- Calculation by plus each cations concentration for total exchangeable bases

Buchner funnel for extracting leachate (solution).

Standard solutions and extracted solutions.

Atomic absorption spectrophotometer for reading of the various chemical constituents.

(In this study PerkinElmer AAnalyst 300 AAs was used.)

7. Micronutrients

Apparatus

- 125 ml. Erlenmeyer flask
- Shaker
- Filtering apparatus
- Atomic absorption spectrophotometer (AAs)

Chemical substances and solution

- DTPA 0.005M: consisting of 0.005M DPTA, 0.005M $CaCl_2$, and 0.1M TEA (Triethanolamine), buffered to pH 7.3
- Standard solution for each chemical elements.

Extraction solution

- Put 25 g soil sample in 125 ml. Erlenmeyer flask. Add 50 ml. of 0.005 M DTPA, and shake for 2 hours.
- Filter out the leachate to be used for measuring each micronutrient later.

Procedure

- Analyze the chemical constituents as the micronutrients using AAS.

Samples on the shaker.

8. Nitrate

Apparatus

- 100 ml. Erlenmeyer flask
- Filter paper
- Shaker
- Potable Spectrophotometer (HACH DR/2010)

Chemical substances and solution

- $Ca(OH_2)$ 0.2 g
- Nitra Ver 5 Nitrate Reagent Powder pillow

Extraction solution

- Put 10 g soil in Erlenmeyer flask, add 50 ml. distilled water.
- Place the flask on a shaker and shake for 10 minutes.
- Add 0.2 g $Ca(OH_2)$ into the flask, shake for 5 minutes more.
- Filter and keep the filtrated solution for measuring for the nitrate concentration by using a Spectrophotometer.

Procedure

- Enter the stored program number in the Spectrophotometer for the high range nitrate nitrogen (NO_3^-N) and press [USER PRGM 3] [TIMER 5] [TIMER 5] [ENTER]
- Turn the wavelength dial until the screen reads **500 nm.** When the correct wavelength is reached the screen will quickly show **Zero Sample**, then: **mg/L NO_3^--N HR.**
- Fill a sample cell with 25 ml. of sample. A reagent blank must be determined by using deionized water as the sample.
- Add the content of one Nitra Ver 5 Nitrate Reagent Powder Pillow to the cell filled with the prepared sample. Part on stopper.
- Press [SHIFT] [TIMER 5] . Shake the cell vigorously until the timer beeps in one minute.
- When the timer beeps, press [SHIFT] [TIMER 5] . A five-minute reaction period will begin. (An amber color will be seen if nitrate nitrogen is presented).

- Fill another sample cell with 25 ml. (the blank), using deionized water as the sample.

- When the timer beeps, the display will show **mg/L $NO_3^{-}N$ HR**. Place the blank cell into the cell holder. Close the light shield.

- Press ZERO. The screen display will read **Zeroing**, then **0.0 mg/L $NO_3^{-}N$ HR**.

- Remove the stopper. Place the prepared sample into the cell holder. Close the light shield (A cadmium deposit will remain after the Nitra Ver 5 Nitrate Reagent Powder dissolves and will not affect the results).

- Press READ. The display will show **Reading…** then the result in mg/L nitrate nitrogen ($NO_3^{-}N$) will be displayed Rinse the sample cell immediately after use to remove all cadmium particles.

Portable Spectrophotometer. (HACH DR/2010)

Twenty-five ml. sample cell for portable spectrophotometer.

9. Ammonia

Apparatus

- 250 ml. Erlenmeyer flask
- Filter paper
- Shaker
- Portable spectrophotometer (HACH DR/2010)

Chemical substances and solution

- 2N KCl 100 ml.
- 3 drops of Mineral Stabilizer
- 3 drops of Polyvinyl Alcohol Dispersing Agent
- 1.0 ml. Nessler Reagent

Extraction solution

- Put 10 g soil in 250 ml. Erlenmeyer flask.
- Add 100 ml. 2N KCl
- Place the flask on the shaker and shake for 1 hour.
- Filter and keep the filtrated liquid for measuring of ammonia concentration by using the spectrophotometer.

Procedure

- Enter the stored program number for ammonia nitrogen (NH_3-N). Press [USER PRGM 3] [ABS 8] [. 0] [ENTER]. The display will show **Dial nm to 425**.

- Turn the wavelength dial until the screen reads **425 nm**. When the correct wavelength is reached the screen will quickly show **Zero sample**, then **mg/L (NH_3-N) Ness**.

- Fill a 25 ml mixing graduated cylinder (the prepared sample) to the 25 ml. mark with sample.

- Fill another 25 ml. mixing graduated cylinder (the blank) with deionized water.

- Add 3 drops of Mineral Stabilizer to each cylinder. Invert several times to mix. Add 3 drops of Polyvinyl Alcohol Dispersing Agent to each cylinder. Invert several times to mix.

- Pipet 1.0 ml. of Nessler reagent into each cylinder. Part on topper. Invert several times to mix.

- Press [SHIFT] [TIMER 5] . A one-minute reaction period will begin.

- Pour each solution into a sample cell.

- When the timer beeps, the display will show **mg/L NH_3-N Ness**. Place the blank cell into the cell holder. Close the light shield.

- Press [ZERO] .The screen display will read **Zeroing,** then **0.00 mg/L NH_3-N Ness**.

- Place the prepared sample into the cell holder. Close the light shield (do not wait more than five minutes after reagent addition before performing).

- Press [READ] . The display will show **Reading…** then the result in mg/L ammonia expressed as nitrogen (NH_3-N) will be displayed.

Mineral stabilizer, Polyvinyl Alcohol Dispersing Agent, and Nessler reagent.

Measuring of ammonia concentration by spectrophotometer.

10. Sulfate

Apparatus

- 125 ml. Erlenmeyer flask
- Shaker
- Portable spectrophotometer (HACH DR/2010)

Chemical substances and solution

- Extraction solution (Acetate-acetic solution): dissolve 39 g NH_4OAc by 1 litre of 0.25N Acetic acid (diluted 14.4 ml. of conc. CH_3COOH and adjust its volume to 1 litre)

Extraction Solution

- Put 10 g soil in 125 Erlenmeyer flask .
- Add 25 ml. acetate-acetic solution.
- Place the flask in shaker machine and shake for 30 minutes.
- Filter and keep filtrate to measure sulfate concentration by Spectrophotometer.

Procedure

- Enter the appropriate stored program number for sulfate (SO_4^{2-}) powder pillows. Press [BATT 6] [ABS 8] [. 0] or [CONC 9] ? ? [ENTER]. The display will show **Dial nm to 450**.

- Turn the wavelength dial until the screen will quickly show **Zero Sample**, then **mg/L SO_4^{2-}**.

- Fill a clean sample cell with 25 ml. of sample.

- Add the contents of one Sulfa Ver 4 Sulfate Reagent Powder Pillow to the sample cell (the prepared sample). Swirl to dissolve. A white turbidity will develop if sulfate is present. Accuracy is not affected by undissolved powder.

- Press [SHIFT] [TIMER 5]. A five-minute reaction period will begin. Allow the cell to stand undisturbed.

- Place the blank cell into the cell holder. Close the light shield.

- Press [ZERO]. The screen display will read **Zeroing**, then **0.0 mg/L SO_4^{2-}**.

- Within five minutes after the timer beeps, place the prepared sample into cell holder. Close the light shield.

- Press [READ]. The display will show **Reading…** then the results in mg/L SO_4^{2-} will be displayed. Clean sample cells with soap and a brush.

Measuring for sulfate concentration.

BIOGRAPHY

Ms. Patcharapa Limpongstorn was born in Bangkok, Thailand on February 23, 1980. In 2000 she received a B.Sc. degree in Material Science from the Department of General Science, Faculty of Science, Srinakarinwirot University. After then she entered the Earth Science Program in the Department of Geology, Faculty of Science, Chulalongkorn University for a M.Sc. degree study.