การประยุกต์ใช้เทคนิคภูมิสารสนเทศเพื่อประเมินความเหมาะสมของที่ดินทางการเกษตรในพื้นที่ลุ่มน้ำขนาดเล็ก กรณีศึกษา ลุ่มน้ำแม่กวง จังหวัดเชียงใหม่ ประเทศไทย

นายรัตนะ บุลประเสริฐ

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต
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ปีการศึกษา 2552

APPLICATION OF GEOINFORMATICS TECHNIQUE IN EVALUATION SUITABILITY OF AGRICULTURAL LAND IN SMALL WATERSHED AREA: CASE STUDY MAE KUANG WATERSHED, CHIANG MAI, THAILAND

Rattana Boonparsert

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Geoinformatics

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APPLICATION OF GEOINFORMATICS TECHNIQUE IN EVALUATION SUITABILITY OF AGRICULTURAL LAND IN SMALL WATERSHED AREA: CASE STUDY MAE KUANG WATERSHED, CHIANGMAI, THAILAND

Suranaree University of Technology has approved this thesis submitted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy.

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รัตนะ บุลประเสริฐ : การประยุกต์ใช้เทคนิคภูมิสารสนเทศเพื่อประเมินความเหมาะสมของที่ดินทางการเกษตรในพื้นที่ลุ่มน้ำขนาดเล็ก กรณีศึกษา ลุ่มน้ำแม่กวง จังหวัดเชียงใหม่ ประเทศไทย (APPLICATION OF GEOINFORMATICS TECHNIQUE IN EVALUATION SUITABILITY OF AGRICULTURAL LAND IN SMALL WATERSHED AREA: CASE STUDY MAE KUANG WATERSHED, CHIANG MAI, THAILAND) อาจารย์ที่ปรึกษา : ผู้ช่วยศาสตราจารย์ ดร.หัสไชย บุญจุง, 167 หน้า.

การวิจัยครั้งนี้วัตถุประสงค์คือ การสร้างแบบจำลองความเหมาะสมของที่ดินเพื่อการเกษตรของพืชเศรษฐกิจหลักที่เป็นข้าว และ ลำไย โดยใช้วิธีการตัดสินใจแบบหลายเกณฑ์ และการวิเคราะห์แบบคูณไขว้ เพื่อประเมินความเหมาะสมของที่ดินเพื่อการเกษตร โดยทำการศึกษาในช่วงปี พ.ศ. 2545 ถึง ปี พ.ศ. 2550 ในบริเวณพื้นที่ลุ่มน้ำแม่กวง จังหวัดเชียงใหม่ ประเทศไทย เป็นการประเมินความเหมะสมของที่ดินเพื่อการเกษตร ความเสถียรภาพของความเป็นประโยชน์ของที่ดินเพื่อการเกษตร และ ความสอดคล้องระหว่างดัชนีความเหมาะสมของที่ดินเพื่อการเกษตรกับการใช้ประโยชน์ที่ดินในปัจจุบัน ในลำดับของการสร้างทั้งหมดประกอบด้วย 3 แบบจำลอง คือ แบบจำลองความเหมาะสมของที่ดินเพื่อการเกษตร แบบจำลองความเสถียรภาพของความเป็นประโยชน์ของที่ดินเพื่อการเกษตร และ แบบจำลองความสอดคล้องของความเหมาะสมของที่ดินเพื่อการเกษตรกับการใช้ประโยชน์ที่ดินในปัจจุบัน โดยที่ผลลัพธ์ของแบบจำลองทั้งหมดนำเสนอได้เป็น 3 ส่วน คือ แบบจำลองความเหมาะสมของที่ดินเพื่อการเกษตรเป็นการสร้างโดยใช้วิธีการตัดสินใจแบบหลายเกณฑ์ และ สถิติเชิงพื้นที่ เพื่อประเมินความเหมาะสมของที่ดินเพื่อการเกษตร ผลของแบบจำลองความเหมาะสมที่ดินทางการเกษตรของศักยภาพทางด้านกายภาพ และ แบบจำลองผลกระทบของศักยภาพทางด้านเศรษฐสังคมของข้าว และลำไยให้ผลในลักษณะเดียวกัน อยู่ระดับชั้นที่ไม่มีความเหมาะสมมากกว่าร้อยละ 50 ซึ่งสามารถอธิบายในเชิงคุณสมบัติของความไม่เหมาะสมระหว่างข้าวและลำไย ขยายตัวไปเนินเขาและภูเขา ในทางตรงกันข้ามผลลัพธ์ของแบบจำลองผลกระทบทางด้านเศรษฐสังคมได้แสดงให้เห็นถึงระดับชั้นที่มีส่งผลเชิงบวกต่อลำไยมีค่าเป็นร้อยละ 62.24 แต่ระดับชั้นที่มีส่งผลเชิงลบต่อข้าวมีค่าเป็นร้อยละ 72.65 โดยที่ผลลัพธ์ บ่งชี้ว่าการตัวเกษตรเอง เป็นส่วนที่จะส่งเสริมเพิ่มขึ้นของพื้นที่ปลูกลำไย ในทางตรงกันข้ามพื้นที่ปลูกข้าวส่วนใหญ่อยู่ในบริเวณที่เช่าพื้นที่ทำนา และแทบที่จะไม่มีการขยายตัวของพื้นที่ปลูกข้าว แต่อย่างไรก็ตามภาพรวมของผลลัพธ์ทั้งหมดของแบบจำลองความเหมาะสมที่ดินทางการเกษตรทั้งข้าวและลำไย จะอยู่ในระดับชั้นที่มีไม่มีความเหมาะสมที่ ร้อยละ 65.07 และ 68.49 ตามลำดับ ในขณะที่ภาพรวมของปัจจัยทางด้านกายภาพ และ ด้านเศรษฐสังคมของข้าว และลำไย

คือระดับที่ไม่มีความเหมาะสม แบบจำลองความเสถียรภาพของความเป็นประโยชน์ของที่ดินเพื่อการเกษตรคือการเปรียบเทียบระหว่างการใช้ประโยชน์ที่ดินในปีพ.ศ. 2550 กับการเปลี่ยนแปลงการใช้ประโยชน์ที่ดินในช่วงระยะเวลา ปี พ.ศ. 2545 ถึง 2550 แบบจำลองประกอบด้วย 3 แบบจำลองย่อย ได้แก่ 1) แบบจำลองดัชนีความเข้มข้นของความเป็นประโยชน์ต่อการเกษตร 2) แบบจำลองดัชนีการเปลี่ยนแปลงความเป็นประโยชน์ต่อการเกษตร และ 3) แบบจำลองความเสถียรภาพของความเป็นประโยชน์ของที่ดินเพื่อการเกษตร :ซึ่งภาพรวมของผลลัพธ์ของดัชนีความเสถียรภาพของความเป็นประโยชน์ของที่ดินเพื่อการเกษตร ถ้าเรานำเอาระดับชั้นดัชนีความเสถียรภาพระดับที่ 1 ระดับชั้นดัชนีความเสถียรภาพระดับที่ 2 และ ระดับชั้นดัชนีความเสถียรภาพระดับที่ 3 รวมเข้าด้วยกัน สามารถใช้ในการอธิบาย และ แสดงให้เห็นถึงความเสถียรภาพ ของข้าวและลำไย ได้ชัดเจนยิ่งขึ้น โดยพื้นที่ปลูกข้าวมีระดับความมีเสถียรภาพอยู่ที่ร้อยละ 78.29 และ พื้นที่ปลูกลำไยมีระดับความมีเสถียรภาพอยู่ที่ร้อยละ 95.97 เนื่องจากพื้นที่ปลูกลำไยมีแนวโน้มของการเปลี่ยนแปลงไปสู่พื้นที่ที่ไม่ใช่การเกษตร เช่น ตัวเมือง อาคารบ้านเรือน โรงงาน สนามกอล์ฟ และอื่นๆ ซึ่งส่วนใหญ่จะอยู่ในบริเวณที่ไม่มีน้ำท่วม แต่ในส่วนของพื้นที่ปลูกข้าวส่วนใหญ่จะอยู่ในบริเวณมีน้ำท่วม จึงมักจะไม่มีการเปลี่ยนแปลง แบบจำลองความสอดคล้องของความเหมาะสมของที่ดินเพื่อการเกษตรกับการใช้ประโยชน์ที่ดินในปัจจุบันเป็นการสรุป สำหรับข้าวและลำไยสามารถสรุปโดยจำแนกโดยใช้ แบบจำลองย่อย 3 แบบจำลอง ได้ดังนี้ 1) แบบจำลองความสอดคล้องของความเหมาะสมของที่ดินเพื่อการเกษตร 2) แบบจำลองความสอดคล้องของความเหมาะสมของที่ดินเพื่อการเกษตรกับแนวโน้มการใช้ประโยชน์ที่ดิน และ 3) แบบจำลองความสอดคล้องของข้าวและลำไยกับการการใช้ประโยชน์ที่ดินปัจจุบัน ภาพรวมของผลลัพธ์ของแนวโน้มความสอดคล้องของพื้นที่ปลูกข้าวสูงกว่าลำไย โดยค้นพบว่าผลลัพธ์ซึ่งได้รับการยืนยันจากผลการวิเคราะห์ความมีเสถียรภาพของพื้นที่ปลูกข้าวมีการเปลี่ยนแปลงน้อยกว่าพื้นที่ลำไย

สาขาวิชาการรับรู้จากระยะไกล ลายมือชื่อนักศึกษา_______________

ปีการศึกษา 2552 ลายมือชื่ออาจารย์ที่ปรึกษา_______________

ลายมือชื่ออาจารย์ที่ปรึกษาร่วม_______________

RATTANA BOONPARSERT : APPLICATION OF GEOINFORMATICS TECHNIQUE IN EVALUATION SUITABILITY OF AGRICULTURAL LAND IN SMALL WATERSHED AREA: CASE STUDY MAE KUANG WATERSHED, CHIANG MAI, THAILAND. THESIS ADVISOR : ASST. PROF. HATSACHAI BOONJUNG, Ph.D. 167 PP.

AGRICULTURAL LAND SUITABILITY MODEL/STABILITY OF LAND UTILIZATION CHANGE MODEL

The main objective of this study was to build GIS models using Muti Criteria Decision Making methods (MCDM) and cross matrix analysis to evaluated agricultural land suitability. This study conducted during 1997 to 2007 at Mae Kuang watershed, Chiang Mai, Thailand. The evaliations were land suitability, stability of land utilization change and agreement between agricultural land suitability indexes with existing land use. In order to accomplishment those tasks, three models were: 1) The Agricultural Land Suitability model (ALS model) was built using MCDM, GIS techniques and geostistical methods to evaluated agricultural land suitability. The results concluded that Physical Potential of Agricultural land Suitability module and Socio-economic Potential of Agricultural Suitability module gave similar results for lowland rice and longan which were likely more than 50% of unsuitable classes. This could be explained in term of physical properties that both lowland rice and longan grown in unsuitable areas such as hill and mountains. Whereas the outputs of Effects of Socio-economic Factor module produced positive classes for longan (62.24%) but negative classes for lowland rice (72.65%). This results indicated that the longan growing areas were growing in farmers own land and having expertise on growing them whereas most lowland rice growing areas were in the rent farms and having less expertise of growing rice. However the overall results of Agricultural Land Suitability module for both lowland rice and longan were fallen in the unsuitable classes as 65.07% and 68.49%, respectively. 2) The Stability of Land Utilization Change model (SLUC model) was built to compare the existing land use in 2007 with agricultural land use change occuring in the short period (2002-2007) and in the long period (1997-2007). This model also comprised of three modules as: (1) Agricultural Land Utilization Intensity Indexing module, (2) Agricultural Land Utilization Change Indexing module and 3) Stability of Land Utilization Indexing module. The overall results were presented in SLUC-Indexes which could be explained the land stability for both lowland rice and longan. If we combined classes of SLUC-1, SLUC-2 and SLUC-3 together, this clearly demonstrated that lowland rice areas (SLUC- Indexes 78.29%) were having more stability than longan (SLUC-Indexes 95.97%). 3) The Agreement of Agricultural Land Utilization model (AA2LU model).was conducted for lowland rice and longan separately. This model comprised of three modules as: 1) Agreement of Potential Agricultural Land Utilization Type module, 2) Agreement of Potential Agricultural Land Suitability with Tendency Agricultural Land Utilization module, and 3) Agreement of Agricultural Land Suitability with Existing Land Use/Land cover module. Overall results pointed out that tendency agreement of lowland rice was higher than longan. This finding confirmed the results of stability analysis that lowland rice areas had less tendency to changes than longan areas.

School of Remote Sensing | Student's Signature______________________

Academic Year 2009 | Advisor's Signature______________________

Co-advisor's Signature___________________

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Rattana Boonparsert

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LIST OF ABBREVIATIONS

AALS2ELU/LC	=	Agreement of Agricultural Land Suitability with Existing LU/LC
AHP	=	Analytical Hierarchical Process
ALS	=	Agricultural Land Suitability
ALUC	=	Agricultural Land Utilization Change
ALUI	=	Agricultural Land Use Intensity
ALUT	=	Agricultural Land Utilization Type
APA2LU	=	Agreement of Potential Agricultural Land Utilization model
APALS2PLUT	=	Agreement of Potential Agricultural Land Suitability with Present Land Utilization Type
APALS2TLUT	=	Agreement of Potential Agricultural Land Suitability with Tendency Agricultural Land Utilization Type
BMN	=	Basic Minimum Need
ESFI	=	Effect of Socio-economic Factor Index
GIS	=	Geographic Information System
GWR	=	Geographical Weighted Regression
LC	=	Land Characteristic
LMU	=	Land Mapping Units

LIST OF ABBREVIATIONS (Continued)

LQ	=	Land Quality
LU	=	Land Unit
LU/LC	=	Land Use/Land Cover
LUR	=	Land Use Requirement
LURs	=	Land Utilization Requirement of socio-economic
LUT	=	Land Utilization Types
MCDM	=	Multi Criteria Decision Making methods
MSL	=	Mean of Sea Level
PAR	=	Participatory Action Research
PLUT	=	Present Land Utilization Type
PPALS	=	Potential Physical Agricultural Land Suitability
PRA	=	Participatory Action Research
RS	=	Remote Sensing
SPALS	=	Socio-economic Potential Agricultural Land Suitability
SAW	=	Simple Additive Weighting
SLUC	=	Stability of Land Utilization Change
SS	=	Socio-economic Status
TLUT	=	Tendency Land Utilization Type

CHAPTER I

INTRODUCTION

1.1 Background problem and significance of the study

In general the evaluation of agricultural land suitability involves considerable use of Geographic Information System (GIS) and Remote Sensing (RS) to build up a quantitative model. But there are some limitations in establishing suitable criteria at watershed scale because land use and land cover in this area is always changed. The driving force for land use and land cover change is human activity which is represented as socio-economic factor. Thus socio-economic factor should be included in evaluation of agricultural land suitability.

The evaluation of land suitability of agriculture must also take consider an important factor of the recent past-to-present land use. Significant land management involves assessment of the impacts of land and water at field levels on the small watershed and even landscape. Because agro-ecological landscapes are diverse, farmers and land users have developed a broad set of cropping and natural resource management strategies to cope with the diversity of production and ecological conditions. Rossiter (1995) claimed that this required Land Mapping Units (LMU) to enable the identification of specific parameters employed in decision making processes.

Land suitability and assessment require an effective approach to achieve the desired goals and objectives, evaluate alternative as well as control development programs that are in line with the current and future prospects. Yaakup, Bakar and Bajuri (2005) suggested that the advent of information technology encouraged the integration of the spatial GIS model for land suitability and assessment.

Therefore, multi-attribute techniques under GIS environment which are also referred to the discrete methods will be used for evaluation of land suitability for agriculture in this study.

1.2 Research objectives

This research focused on the following three main objectives:

1.2.1 To build agricultural land suitability model by using the Multi Criteria Decision Making methods (MCDM).

1.2.2 To compare derived agricultural land suitability data with existing land use data.

1.2.3 To investigate the agreement between potential agricultural land suitability and tendency of use at present.

1.3 Scope of the study

1.3.1 Agricultural land suitability model based on balancing the change of physical and socio-economic factors was built using the MCDM methods.

1.3.2 Lowland rice and longan that are respectively represented for a short-term (2002-2007) and long-term (1997-2007) of cropping system were selected for agricultural land suitability model.

1.3.3 The relationship between agricultural land suitability data and theirs existing land use was evaluated by using geostatistics techniques.

1.4 Study area

1.4.1 Location

Mae Kuang watershed which is the branch of Mae Ping river, covers 2,699.54 km^2. It covers Doi Saket, Sansai, Saraphi, Mae Rim, San Khamphang, Muang, Mae On districts of Chiang Mai province and Mae Tha, Ban Hong, Ban Thi, Li and Pa Sang districts of Lum Phun province as shown in Figure 1.1.

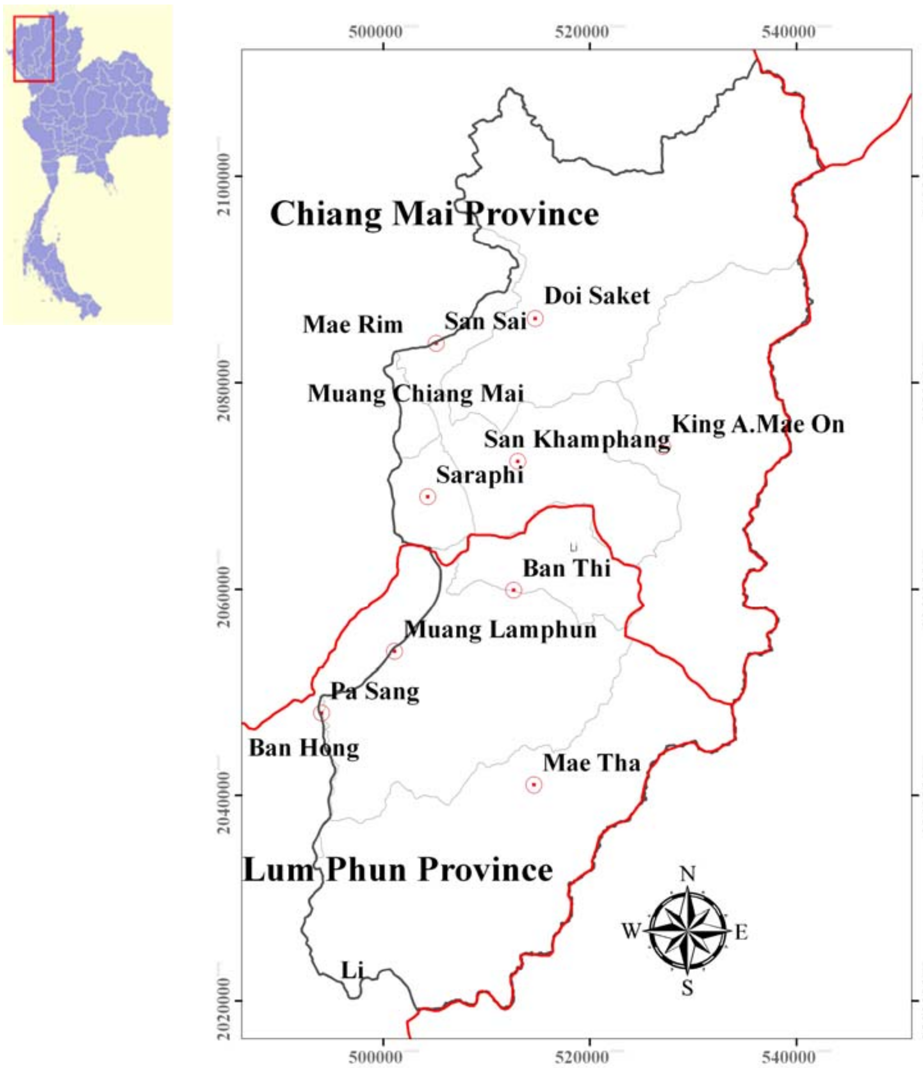


Figure 1.1 Location of the study area.

1.4.2 Climate characteristics

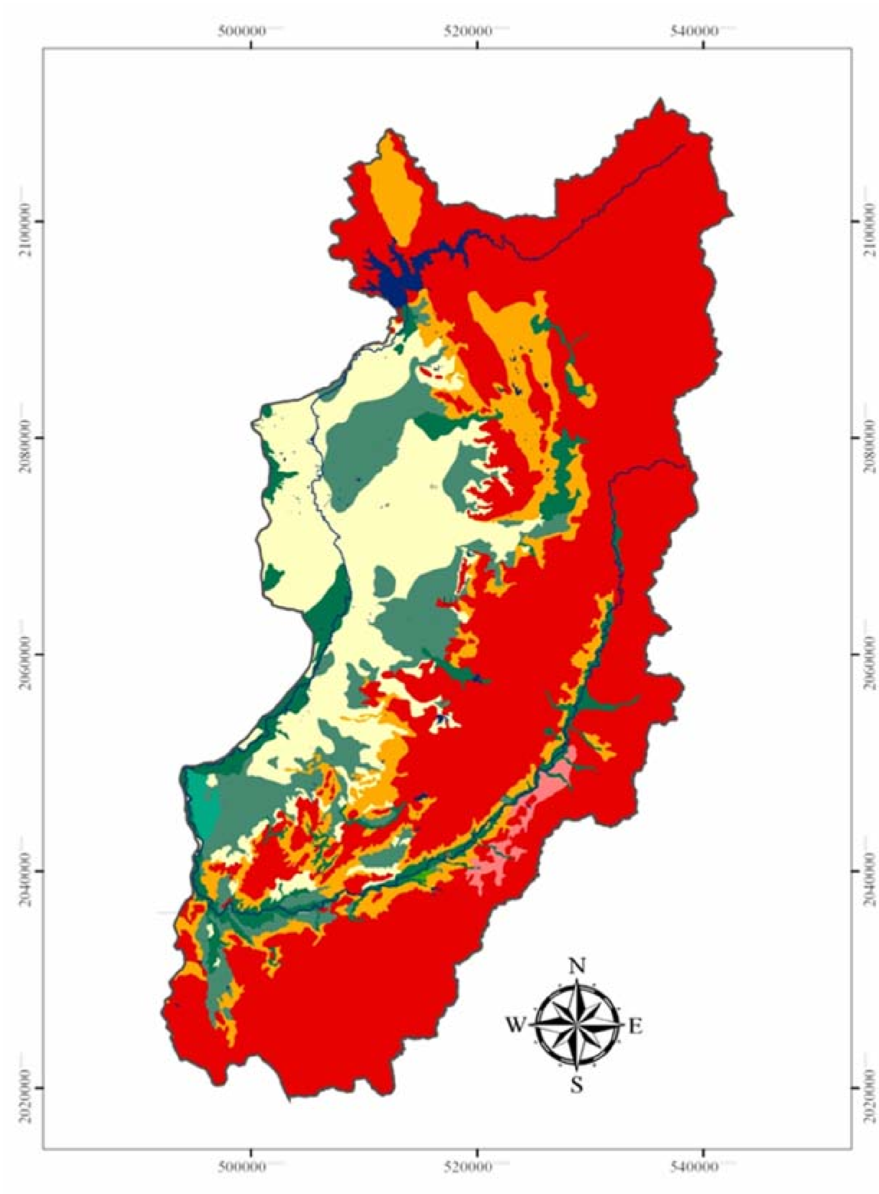
The tropical monsoons influence the climate in study area, mainly from major winds system, the northeast (November to early February) and southwest (June to September). In mountainous area is cool during the northeast monsoon. The rainy season starts from May up to October during southwest monsoon which brings warm moisture-laden air from Indian Ocean. Rainfall is generated by convection or as frontal- system storms. Occasional tropical depressions, the remains of China Sea typhoons, move westward across the north bringing high-intensity and short-duration rainfall. Much of rainfall occurs as heavy shower or thundershowers. Cloudiness varies appreciably from season, with the greatest cloudiness experienced from June through September. The average annual rainfall of 988.76 mm over 40 years (using data from 37 weather stations of Meteorological Department in year 1966 to 2006), ranges from 739 to 1,576 mm/year, a downward trend. The largest number of rainy days was 137 (annual rainfall 898.54 mm.) and the smallest 96 days (annual rainfall 90.21 mm.). The maximum temperature reaches their peak in March and April and the afternoon temperature ranges from 37.5˚C to 41.4˚C. The minimum temperature occurs in December through February. In the coldest seasons, minimum temperature ranges from 3.7˚C to 12.3˚C .The mean relative humidity ranges from 96% in rainy season to 46% in dry season.

1.4.3 Topography characteristics

The study area constitutes a region of parallel north, south and oriented hill ridges and high plateaus alternating with elongated level flood basin. In western and northern part of the watershed area, most land (85% of the total area) is mountainous with deep narrow alluvial valleys. The ridges are part of the folded mountain ranges; these ridges are formed partly of granite and limestone. Limestone mountains have pointed peak, uneven ridges and generally are of lower elevation than granite mountains. To the east are watersheds, which have several distinct river terraces and seasonally floodable plains. The flood plains consist of alluvial wider plains at the average of about 300 meters above mean sea level (MSL). The alluvial soils of flood plains and semi-recent floodplains are fertile. The elevation of landscape varies from 300 to 1,020 meters above the MSL. Forty five percent of the study area varies between 300 to 600 meters above MSL and the rest of the study area varies between 600 to 1,020 meters above MSL.

1.4.4 Soil characteristics

The study area has many different soil types. Two soil groups can be identified based on major landform namely old alluvial soil group and forest soil group. For the first group, old alluvial soils and recent alluvial soils find on the edges of the valley and in lowest part of the flat area along the Mae Kuang River and its tributary creeks, respectively. This includes the semi-recent alluvial soils which lie in between and are the most extensive. Many characteristics of soils in the valley are very similar from loam to silt loam, and silty clay loam to clay, with a few sandy loam and sandy clay loam soils. The clay mineral is predominantly kaolinite. Surface drainage is slow, with poor to moderate permeability of internal drainage. The second group, forest soil, represents characteristics of recent alluvial soils, which are flooded annually, and thus have fresh deposits, and the soils are weathered more than in the semi-recent alluvial soils, and are lowest in the old alluvial soils. The detail of soil series map is shown in Figure 1.2 and Table 1.1.



Legend

	1. Alluvial fans		6. Sami - recent terrace
	2. Flood plain		7. Dissected erosion surfaces and hills
	3. Old riverine alluvium		8. Hills and mountains
	4. Old alluvial terraces and fans		9. Reservoir and river
	5. Low terraces		

Figure 1.2 Land from map of Mae Kuang watershed.

Sorce: Land Development Department (1975) relate to soil series (Table 1.1).

Table 1.1 Soil series base on land form in Mae Kuang watershed.

Landform	Soil series type	Area sq. km
1. Alluvial Fans	1.1 Alluvial Soil poorly drained	11.5
	Total	11.5
2. Flood Plain	2.1Alluvial Complex	107.78
	2.2 Alluvial Fan Complex	1.08
	2.3 Phimai series	16.81
	2.4 Ratchaburi / Sanphaya association	0.91
	2.5 Ratchaburi series	19.51
	2.6 Tha Muang / Sanphaya association	9.11
	2.7 Tha Muang series	8.1
	Total	163.3
3. Low Terraces (Piedmont surface)	3.1 Phu Sana hydromorphic Variant	3.41
	3.2 Phu Sana series	17.42
	Total	20.83
4. Old Alluvial Terraces and Fans	4.1 Hang Chat, hydromorphic Variant	1.83
	4.2 Hang Chat,undulating Phase	5.42
	4.3 Hang Chat/Mae Rim Association, Undulating Phase	9.14
	4.4 Korat series	7.79
	4.5 Lampang / San Sai association	56.96
	4.6 Lampang series	18.3
	4.7 Mae Rim series, undulating phase	3.89
	4.8 Mae Rim,rolling Phase	1.77
	4.9 Mae Rim,undulating Phase	5.06
	4.10 Mae Taeng,undulating Phase	0.47
	4.11 San Pa Tong series	0.53
	4.12 San Sai series	76.09
	4.13 San Sai/Phan Association	15.34
	4.14 Sanphaya series	5.92
	4.15 Satuk series	6.94
	4.16 Ubon series	43.73
	Total	259.18

Table 1.1 Soil series base on land form in Mae Kuang watershed. (Continued)

Landform	Soil series type	Area sq. km
5. Old Riverine Alluvium	5.1 Phon Phisai series	0.98
	Total	0.98
6. Semi - recent Terrace	6.1 Chaing Rai	60.01
	6.2 Chan Tuk	0.13
	6.3 Chiang Rai/Phan Association	8.48
	6.4 Hang Dong series	283.12
	6.5 Mae Sai	1.7
	6.6 Nam Pong series	57.51
	6.7 Phan series	12.03
	Total	421.7
7. Dissected Erosion Surfaces and Hills	7.1 Lat Ya series	3.02
	7.2 Li series	5.12
	7.3 Pak Chong series, rolling phase	54.65
	7.4 Pak Chong series, undulating phase	11.01
	7.5 Pak Chong,undulating Phase	0.98
	7.6 Sop Prap series	20.53
	7.7 Takhli series	0.33
	7.8 Tha Ta Ko series	3.29
	7.9 Tha Yang / Lat Ya association	15.59
	7.10 Tha Yang series	104.34
	7.11Tha Yang/Lat Ya Association	60.85
	Total	279.71
8. Hills and Mountains	8.1 Fluorite Mine Land	1.89
	8.2 Granite Rock Land	54.38
	8.3 Limestone Rock Land	0.44
	8.4 Sandstone Rock Land	0.93
	8.5 Slope Complex	1,473.21
	Total	1,530.85
Total		**2,689.28**

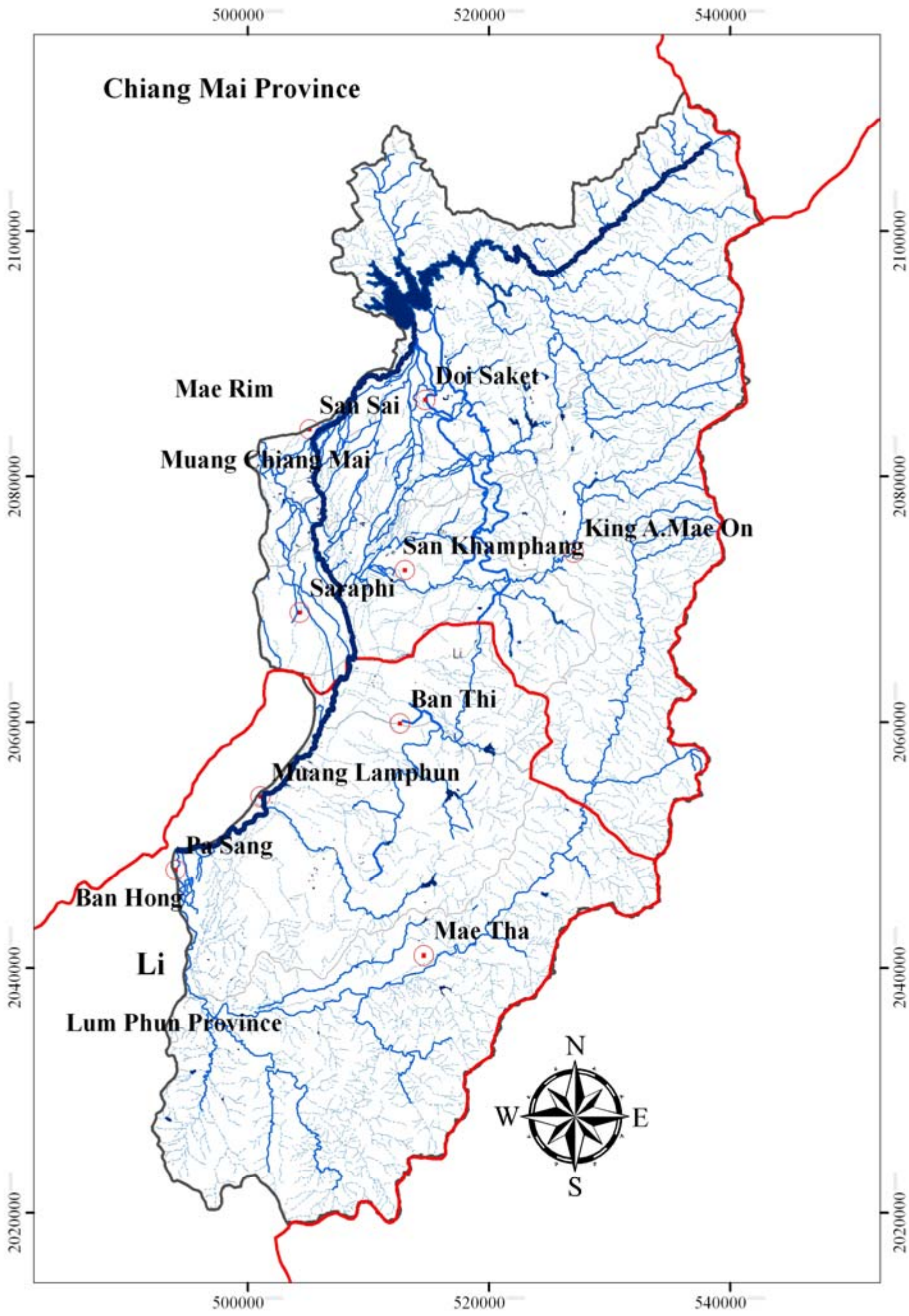
Source: Land Development Department (1975).

1.4.5 Hydrology characteristics

Mae Kuang River flows southward through the study area. It forms a small watershed, approximately 37 km wide and about 94 km long. Mae Kuang watershed situates in the eastern part of Chiang Mai province and in southeastern part of Lam Phun province, which drains to Mae Ping River in the south. A series of rivers, streams and channels flow down into the watershed from the eastern and western hill and mountain ranges. The Mae Kuang River, its branches and its tributaries, flows throughout the year with the water levels fall considerably in the dry season, and in some rainy seasons raise very high flooding the adjacent alluvial plains area. Minor creeks and drainage channels, especially those in the terrace and hill area, dry up in the dry season, unless fed by perennial springs showing in Figure 1.3.

1.4.6 Irrigation characteristics

Almost all of the paddy land in the study area is irrigated. Mae Kuang Audomtara Dam situates in northern part of the watershed area and supply water for agricultural areas of 2,000 rais. This irrigation system supports lowland rice cultivation in some areas of San Sai, Doisaket, Saraphi districts, Chiang Mai province and Mae Tha and Ban Hong districts of Lum Phun province.



Legend

Major River
Irrigation canal
Perennial lake
Intermittent stream
Watershed boundary
Manmade reservoir
Major River
Perennial stream
Province boundary

Figure 1.3 Hydrology characteristics in Mae Kuang watershed.

1.4.7 Cropping system

Base on annual report of Office Agriculture Economics for Chiang Mai and Lum Phun provinces (2007) a typical cropping system in Mae Kuang watershed can be categorized as in the following:

(1) Single rainfed lowland rice cropping system outside irrigated area: This is found in the water deficient terrace and fan-terrace complex in the eastern part of the watershed.

(2) Single rainfed lowland rice cropping system in irrigated area: This is found mainly in the relatively poorly irrigation fan-terrace complex.

(3) Multiple lowland rice cropping system in irrigated area: This is found in some areas of San Sai, Doisaket, Saraphi districts of Chiang Mai province and Mae Tha and Ban Hong districts of Lum Phun province.

(4) Single lowland rice cropping system followed by annual crop: Major annual crops include potato, mungbean, soybean, groundnut, and various vegetables. Examples of practical cropping system are rice-soybean, rice-garlic, rice-groundnut, rice- shallot and rice-rice. This cropping system is only found in the irrigated area.

(5) Triple cropping system: Three crops are orderly practiced in one year for examples of typical cropping system are: (a) rice-vegetables-vegetables, (b) rice-soybean-vegetable, (c) rice-garlic/shallot-vegetable, (d) rice-garlic/shallot-rice, (e) rice-garlic/shallot-soybean, and (f) soybeans-garlic/shallot-soybeans or vegetables. This system found along Mae Kuang River channel.

(6) Mixed orchard system: This system is found on the plain in the central part of watershed. longan is the main orchard.

1.5 Expected results

There models can be applied to evaluate the land suitability of agricultural area in other watershed area (level of the small watershed scale) for agricultural land suitability using GIS based and remote sensed data.

1.5.1 Agricultural Land Suitability model (ALS model) was used to evaluate the suitability of agricultural land use for lowland rice and longan.

1.5.2 Stability of Land Utilization Change model (SLUC model) was used to evaluate intensity of agricultural land utilization and recent past-to-present land use change.

1.5.3 Agreement of Potential Agricultural Land Utilization model (APA2LU model) was used to evaluate the agreement between agricultural land suitability classes.

CHAPTER II

LITERATURE REVIEW

2.1 Physical evaluation agricultural land potential

In general, physical evaluation of agricultural land potential is formulated by classifying lands with different capabilities. The suitability for various potential land uses is identified in relation to individual crop requirements.

Yamada, Suzuki, Amorndham, and Sukjarn (1995) reported a comprehensive study on sustainable agricultural systems with Thai agricultural organizations in the northeast Thailand. Agriculture of the region was faced with diverse problems associated with environmental degradation such rapid reforestation. They developed a geographical database for northeast Thailand using PAMAP to evaluate the land suitability of paddy rice production of the Khon Kaen Province. Related factors of suitability for paddy rice were identified including consolidated layer, soil texture, permeability, nutrient status, salinity, slope topography, and rockiness. Based on the limitation of cultivation for paddy rice, these factors were classified into five ranks of potential and overlaid to generate polygons with suitability.

Mongkolsawat, Thirangoon, and Kuptawutinan (1997) studied a physical evaluation of land suitability for rice in Lower Nam Pong watershed. The objective was to establish spatial model in land evaluation for rice using GIS. The evaluation of land in terms of the suitability classes was based on the method as described in FAO guideline for land evaluation for rainfed agriculture. A land unit resulting from the overlay process of the selected theme layers has unique information of land qualities form which the suitability is based on. Those selected layers of rice include water availability, nutrient availability, landform, soil texture, and soil salinization. The theme layers were collected from existing information and satellite data. Analysis of rainfall data and irrigation area show water availability. Spatial information of nutrient availability was formulated using soil map of Land Development Department (LDD). Landform of the area was prepared from Landsat-TM. Soil texture and soil are based on the soil map. Each of the above mentioned layers with associated attribute data was digitally encoded in a GIS database to create thematic layers. Overlay operation on the layers produce a resultant polygonal layer, each of which is a land unit with characteristics of the land. Land suitability rating model applied to the resultant polygonal layer provided the suitability classes for rice. The resultant suitability classes were checked against the rice yield collected by the Department of Agriculture Extension. It was found to be satisfactory.

Mongkolsawat, Thirangoon, and Kuptawutinan (1999) evaluated and formulated land for agricultural land use by classifying lands with different capabilities in Song Kram Watershed, Sakon Nakhon basin. The major economic crops in the study area are rice, cassava, sugarcane and pasture crops. The suitability assessment for each crop was conducted using the method as described in FAO guidelines for land evaluation for rainfed agriculture. For each crop, land unit was created from overlay process of the defined theme layers or land qualities on which the suitability is based. As a result, suitability map layers with their associated class attributes for rice cassava, sugarcane and pasture crops were obtained. Furthermore, the overlay process was then performed on these suitability map layers with selection criteria of only highly and moderately suitable classes. The resultant map obtained is a result of combination of the defined suitability class of combining crops (rice, cassava, sugarcane, and pasture) within the area. Economically, the planning alternative that best matches land use to land suitability should therefore be the most valuable and efficient.

Yamamoto and Sukchan (2003) evaluated land suitability for rice, sugarcane and cassava based on soil properties and water resource availability. It was then compared with the current land use map produced by multi-temporal satellite imagery to consider the conformity to it.

Apai and Navanugraha (2004) investigated and evaluated the suitability of agricultural land use taking into account the physical, socio-economic and environmental conditions in order to make a soil conservation oriented land use planning for Uthai Thani Province, Thailand using GIS technology together with the Two-stage Land Evaluation Approach, Universal Soil Loss Equation (USLE), macro nutrient loss assessment and linear programming techniques. Physical land suitability evaluations for major present and alternative land utilization types were performed. Predicted potential soil Erosion (PE) and Actual soil Erosion (AE) volume in agricultural land under present land cover management and alternative crop types were measured. Then, the predicted actual soil loss together with nutrient availability data of each soil type were used to calculate the macro plant nutrient loss in the form of urea, super phosphate, and potassium chloride in each soil series under alternative crop types. The overall land suitability assessment using linear programming was conducted using two postulates-minimizing macro nutrient losses while maintaining current levels of average net farm income and maximizing net farm income while not exceeding current levels of macro nutrient loss. Results indicate that even though most of the soil types in the study area are not fertile, changing farming patterns from intensive mono-crops to fruit trees may provide more profitable and sustainable returns.

2.2 Socio-economic evaluation agricultural land potential

Evaluation of agricultural socio-economic land potential usually requires quantitative and qualitative evaluations that allow the intuitive integration of many factors including (1) agricultural nutrient balance and present farming practices (2) crop yields, (3) fertilizers management, (4) farm pest management, (5) farm management and marketing, (6) agricultural soil conservation management, (7) irrigation management, and (8) household farm management.

Vieth and Suppapanya (1996) examines the predictability of a profit maximization model, an expected value-variance utility maximization (E-V) model, and two versions of the target-MOTAD model for modeling risky agricultural production decisions of Maejai and Dokkhamtai Districts in Payao Province. Model solutions were translated into expected value and variance of farm income for analysis. Direct comparison and chi-square analysis of actual and predicted expected income distributions were used in the analyses. They concluded that the utility maximization and cash-cost target-MOTAD models predicted distributions of farm income better than the variable-cost target-MOTAD and profit maximization models.

Letcher, Croke, Jakeman, and Merritt (2006) described an integrated modelling toolbox that has been developed for highland catchments-specifically the Mae Chaem catchment in Northern Thailand. This toolbox contains models of crop growth, erosion and rainfall-runoff, as well as household decision and socio-economic impact models. The approach described advances and complements previous approaches by: considering more complex interactions between land-use decisions and the hydrological cycle; modelling household decisions based on uncertain expectations; and assessing impacts of changes not only on flows and household income, but also on subsistence production and erosion. An example of the types of trade-offs and scenarios that can be assessed using the integrated modelling toolbox was also presented. This demonstrates that for the scenarios presented, the magnitude and direction of impacts simulated by the model is not dependent on climate.

Son and Shrestha (2008) examined the sustainability of the agricultural production system in Tri Ton district of Mekong delta in Southern Vietnam. The major objective of the study was to examine the misuse of land and suggest appropriate land-use alternatives. The data used were both spatial and socio-economic collected through household survey. Land suitability classification for biophysical suitability and infrastructural suitability was carried out following FAO framework of land evaluation using GIS. Mapping of land misuses indicated that fair amount of current land-use practices does not match the given land quality probably due to the prevalent socio-economic constraints that influence land use decision-making eventually resulting into lower farm household income. A land-use allocation plan is suggested base on biophysical suitability and socio-economic preferences with an aim to restore the declining land quality and support livelihoods of the land users with reasonable income from agriculture.

Thapa and Murayama (2008) presented an integrated technique of Analytical Hierarchical Process (AHP) and GIS to evaluate the land for peri-urban agriculture.

Hanoi province in Vietnam was selected for the case study. Transformation of conventional agriculture to modern cash crops is the current trend in peri-urban Hanoi. A field survey with focused group discussions was conducted. Based on field survey data analysis, soil, land use, water resources, road network, and market were chosen as major factors affecting the peri-urban agriculture. A map of each factor with different logical criteria was prepared. The AHP method was applied to identify the priority weight of each factor. Five spatial layers with their corresponding weights were linearly combined to prepare the suitability map. The map was further scaled as high suitable, medium suitable, low suitable and unsuitable land for the peri-urban agriculture. This empirical scenario provides a cost effective, rapid land evaluation framework which may help policy makers, urban and regional planners, and researchers working in developing countries.

2.3 Evaluation of agricultural land suitability

A quantitative classification is one in which the distinctions between classes are defined in common numerical terms, which permits objective comparison between classes relating to different kinds of existing land use. A classifications normally involve considerable use of physical productive potential factor criteria, i.e. crop production, topography, climate, soil, physiographic patterns, water resources, Land Use/Land Cover (LU/LC) Land Characteristic (LC) or Land Utilization Types (LUT), and infrastructure.

Land suitability is the fitness of a given type of land for a defined use. The land may be considered in its present condition or after improvements. The process of land suitability classification is the appraisal and grouping of specific areas of land in terms of their suitability for defined uses. Thus land evaluation is carried out using multi criteria evaluation methods and the FAO framework.

Nisar Ahamed, Gopal Rao, and Murthy (2000) studied crop-land suitability, with the analysis as a prerequisite to achieve optimum utilization of the available land resources for sustainable agricultural production. The evaluation of the spatial variability of relevant terrain parameters was carried out in a geographic information system environment while assigning the land suitability for crops in the study area of Kalyanakere sub-watershed in Karnataka. Nine parameters (i.e. texture, soil drainage, Cation Exchange Capacity (CEC), base saturation, slope, gravelliness, and pH values) were considered and suitability analysis was carried out by fuzzy membership classification with due weighted factors included to accommodate the relative importance of the soil parameters governing the crop productivity.

Wirén-Lehr (2001) studied sustainability in agriculture and evaluation of principal goal oriented concepts to close the gap between theory and practice. The objective of concepts to assess and implement sustainability in agriculture is to consolidate the complex and diverse principles of the theoretical paradigm and to transform them into recommendations for agricultural practice. Since only goal-oriented concepts show a high adaptation to different conditions and target groups, their fundamental strategy was highlighted and their suitability for successful operational station was worked out. Seven goal-oriented concepts, representing the main current methods of sustainability assessment, were evaluated regarding potential and drawbacks for a successful transfer of the theoretical paradigm into practice. A principal strategy of goal-oriented concepts has been identified in all concepts: goal definition, indicator selection, evaluation based on indicator sets and final formulation of management advice. In most of the seven reviewed concepts, the protection of the agricultural production system itself is postulated as a major aim. Consequently, indicator sets mainly consist of production-oriented indicators and eco-balancing predominantly represents the methodological framework. Six of the seven selected concepts base sustainability assessment on an evaluation strategy with estimated threshold values or margins of tolerance. Three main drawbacks of goal-oriented concepts have been identified that restrict to transfer the theoretical sustainability paradigm into agricultural practice: (1) the lack of systemic and transferable indicators which characterize agricultural and other eco-systems regarding all dimensions of sustainability, (2) the deficit of an adequate evaluation of agro-ecosystems, and (3) the lack of principal guidelines for the formulation of management advice for practical application. Goal-oriented concepts based on models for agronomy and management show a high potential to overcome these drawbacks and therefore represent a promising tool to bridge the gap between theory and practice of sustainability in agriculture.

Charuppat (2003) studied the land evaluation for economic crops of Lam Phra Phloeng watershed in the Northeastern Thailand using GIS modeling. The suitability of planting eight economic crops (rice, sugar cane, maize, cassava, rubber, mango, tamarind and pasture) was evaluated in a land area covering 81,977.44 ha in Lam Phra Phloeng watershed in Northeastern Thailand. Land quality crop requirements used for evaluation were: (1) temperature condition, (2) water availability, (3) nutrient retention, (4) nutrient availability index, (5) water retention, (6) rooting condition, (7) oxygen availability, and (8) topography. The land evaluation involved: (1) generating each land quality as a thematic layer in a GIS model, (2) assigning factor-rating values to the diagnostic factors of each thematic layer, (3) calculating the land suitability rating for each crop as the product of the factor-rating values, and (4) classifying each crop into land suitability classes (highly suitable, moderately suitable, marginally suitable and not suitable). The results from this study showed that maizes, mangos, tamarinds, and pasture crops are the four most suitable for planting in Lam Phra Phloeng watershed. Sugar cane, cassava and rubber are only moderately and marginally suitable. Rice is only marginally suitable. The study results also revealed that more than one-half the area of Lam Phra Phloeng watershed is marginally suitable.

Boonyanuphap, Wattanachaiyingcharoen, and Sakurai (2004) used GIS-based for assessment land suitability of bananas and plantains in Phitsanulok Province. GIS was used to build the geographic database for banana plantations as well as the land suitability assessment for banana plantations using multifactor spatial analysis. The selected nineteen variables have been grouped into five environmental factors on the basis of their specific relationship with the assessment of land suitability for banana plantation namely (1) soil property, (2) topographic, (3) climatic, (4) supplementary water, and (5) marketing factor. These five environmental factors were basically different in their dependence on land suitability. This procedure created new datasets of the overall current environmental suitability for banana plantation based on all environmental factors. This new dataset was finally reclassified into 4 classes of current environmental suitability in the study site. One site was chosen for site assessment. This site fell into a range of categories from highly suitable (S1) to not suitable (N1). To supply future demand for dried banana, products information has to be integrated from land use types, current environmental conditions, soil characteristics, and the possibility for adjusting environmental conditions to make them more suitable for future growth. All of these factors were used to determine possible areas for new banana plantations under land management practices in Thailand.

Carr and Zwick (2005) used GIS suitability analysis to identify potential future land use conflicts in north central Florida. This article presented the Land Use Conflict Identification Strategy (LUCIS) that employed role playing and suitability modeling to predict areas where future land use conflict is likely to occur. A simple land use classification system of conservation, urban, and agricultural land was derived from E. Odum's Compartment Model to organize land use suitabilities and compare land use preferences. The strategy's six step process includes (1) developing a hierarchical set of goals and objectives that become suitability criteria, (2) inventory of available data, (3) determining suitabilities, (4) combining suitabilities to represent preference, 5) reclassifying preference into three categories of high, medium and low, and (6) comparing areas of preference to determine the quantity and spatial distribution of potential land use conflict. A case study in north central Florida, USA, is used to demonstrate the strategy and to provide results for consideration and discussion. The study area occurs in a region with a trend of steady population increase that has resulted in conversion of lands with conservation and agricultural importance to urban use. Altogether the results suggest considerable conflict among the three basic land use classifications, but particularly between urban and agricultural land uses. LUCIS results have the potential to be used in at least three ways including decision support for local or regional planning activities, environmental regulation, or population modeling including representations of alternative futures.

Radiarta, Saitoh, and Miyazono (2006) identified the most suitable sites for hanging culture of Japanese scallop using GIS-based multi-criteria evaluation models. Remote sensing data (Sea-viewing Wide Field-of-view Sensor (SeaWiFS), Moderate Resolution Imaging Spectroradiometer (MODIS) and Advanced Land Observing Satellite (ALOS)) were used to extract most of the parameters. Seven thematic layers were grouped into two basic requisite for scallop aquaculture, namely biophysical (sea temperature, chlorophyll, suspended sediment and bathymetry) and social–infrastructural (distance to town, pier and land-based facilities). A constraint layer was used to exclude the areas from suitability maps that cannot be allowed to develop scallop aquaculture, including harbor, area near town/industrial and river mouth. A series of GIS models was developed to identify the most suitable areas for scallop culture using multi-criteria evaluation known as weighted linear combination. Suitability scores were ranked on a scale from 1 (least suitable) to 8 (most suitable) and about 56% of the total potential area with bottom depths less than 60 m had the higher scores (scores 7 and 8). These areas were shown to have the optimum condition for scallop culture in this region. The final suitability model outputs were compared with field verification data and found to be consistent.

Lubowski, Bucholtz, Claassen, Roberts, Cooper, et al. (2006) examined evidence on the relationship between agricultural LU changes, soil productivity and indicators of environmental sensitivity. If cropland that shifts in and out of production is less productive and more environmentally sensitive than other cropland, policy-induced changes in land use could have production effects that are smaller and environmental impacts that are greater than anticipated. To illustrate this possibility, this report examines environmental outcomes stemming from LU conversion caused by two agricultural programs that others have identified as potentially having important influences on land use and environmental quality: Federal crop insurance subsidies and the Conservation Reserve Program, the Nation’s largest cropland retirement program.

CHAPTER III

METHODOLOGY

3.1 Introduction

The main objective of this chapter is to describe the study area and conceptual framework for agricultural land suitability evaluation in the small watershed. These procedures include GIS based analysis of physical and socio-economic data in terms of crop requirements for lowland rice and longan by using land evaluation guideline for rainfed agriculture of FAO (1980) and land evaluation guideline for economic crops of Land Development Department (1996). Addition of ground survey was also conducted to collect basic information for crop production and to verify land use and land cover maps. Socio-economic indicator was evaluated based on standard sustainable land management guideline of the World Bank (2006) and Basic Minimum Need (BMN) data base from Rural Development Information Center of Community Development Department (2007).

3.2 Data and equipment

3.2.1 Data

Basic data used in this study are summarized in the Table 3.1.

Table 3.1 Basic data.

Data	Date	Utilization	Sources
(1) Primary data			
Landsat-TM	3/2/1997, 25/2/2002 and 25/11/2007	Land use and land cover classification	GISTDA and office of the narcotics control board
IKONOS	2002	Land use and land cover classification	Office of the Narcotics Control Board
Color orthophotos	2003	Verify model	Ministry of Agricultural and Cooperatives
Topography map base on L7018 Series 1:50,000	2004	Slope class	Thai Ministry of Defense
Basic information of socio-economic	2006-2007	Existing socio-economic factors classification	Field survey
(2) Secondary data			
Soil series data (1:50,000)	1996	Modelling	Land Development Department
Information of basic minimum need data base	1997-2007	Socio-economic data analysis	Community Development Department
Statistics of crop production data	1997-2007	Socio-economic data analysis	Office Agriculture Economics and Local Administration (sub district level)
Baic information (GIS data base of basic information of environment quality)	2004	Modelling	Department of Environmental Quality Promotion

3.2.2 Equipment

Basic equipments used in this study are summarized in the Table 3.2.

Table 3.2 Basic equipments.

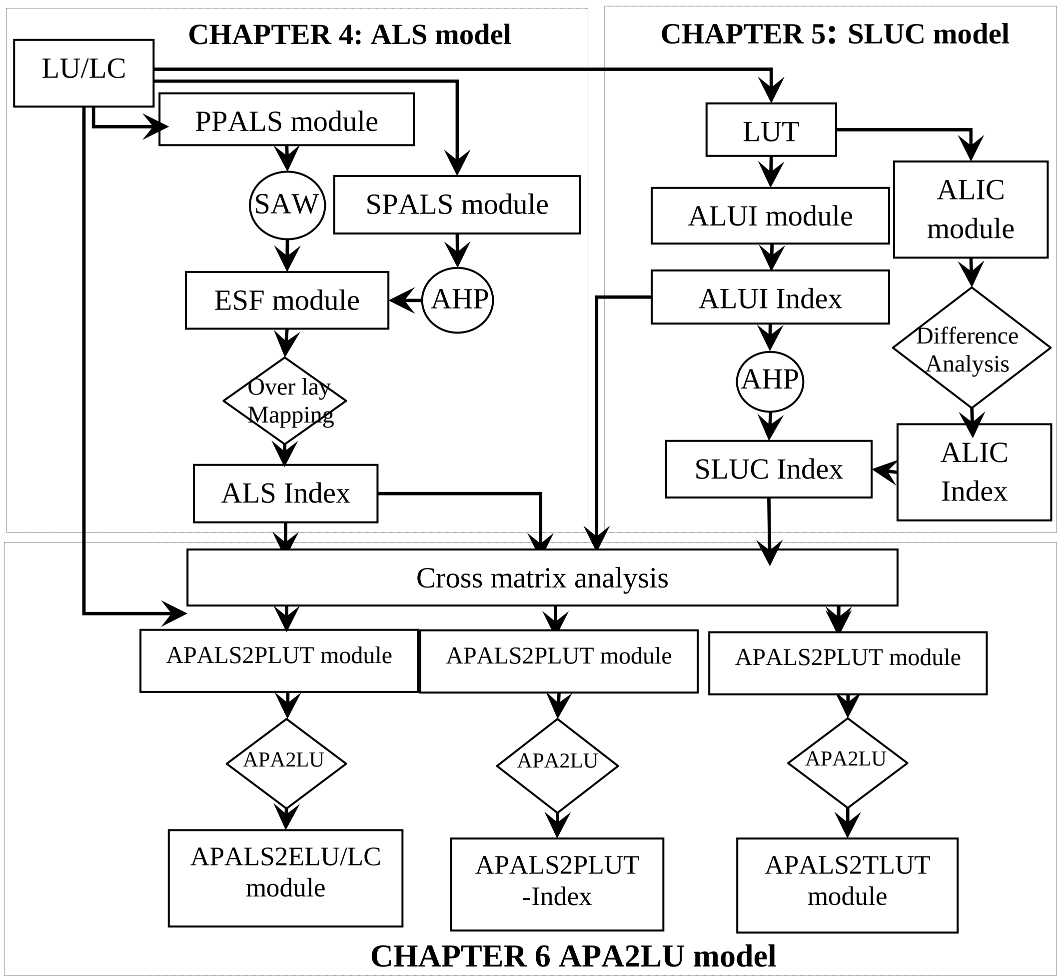
Equipment items	**Function**
1. Notebook	Data collection in field survey
2. Desktop Computer	GIS and RS processing
3. Global Positioning System (GPS)	Input spatial data in field survey
4. Digital camera and sound recorder	Record photograph and sound in field survey
5. Questionnaires	Data surveys and collection of socio-economic data
6. GIS software (Arc GIS V. 9.3)	Process GIS data
7. RS software (ERDAS IMAGIN V 9.0)	Process remotely sensed data
8. Statistics software (SPSS V. 14)	Process socio-economic data

3.2.3 Data collection and data sampling

Data sampling in the study used focus group analysis method based on village and sub-districts unit. The research cluster sampling was a sampling technique where the entire population was divided into groups or clusters and random samples of these clusters were selected. Two thousand five hundred ninety villages were randomly interviewed using sampling size of 1:1 (Village: km^2). As a result, the total populations of 554 villages were divided in to 58 groups of cropping system.

3.3 Conceptual research framework

Evaluation of agricultural land suitability using GIS and remotely sensed data was created by spatial data model with MCDM. It was divided into three parts as shown in the Figure 3.1.



Legend

SAW	Simple Additive Weighting.
AHP	Analytical Hierarchy Process.
PPALS-module	Physical Potential of Agricultural Land Suitability module.
SPALS module	Socio-economic Potential of Agricultural Land Suitability module.
ESF module	Effect of Socio-economic Factor module.
PPALS-Index	Physical Potential of Agricultural Land Suitability Index.
SPALS-Index	Socio-economic Potential of Agricultural Land Suitability Index.
ALS-Index	Agricultural Land Suitability Index.
ALUI module	Agricultural Land Utilization Intensity indexing module.
AULC module	Agricultural Land Utilization Change indexing module.
SLUC module	Stability of Land Utilization Change Index.
APALS2PLUT	Agreement of Potential Agricultural Land Suitability with Present Land Utilization Type.
APALS2TLUT	Agreement of Potential Agricultural Land Suitability with Tendency Agricultural Land Utilization Type.
AALS2ELU/LC	Agreement of Agricultural Land Suitability with Existing LU/LC(lowland rice and longan).

Figure 3.1 Conceptual research frameworks.

3.3.1 This model used GIS technology together with the two stages approach. The first stage of physical of agricultural land suitability was to verily the suitability classification by survey. The first stage of socio-economic potential was also checking the relevance of the kinds and LU. Both of fist stage was presented in map and using GIS overlay technique to produce ALS indexes as the second stage approach.

3.3.2 SLUC model was used to compare the existing land-use in 2007 with the agricultural land use change occurring in the short period (2002-2007) for lowland rice and agricultural land use change occurring in the long period (1997-2007) for longan. The results could explain the stability of agricultural land utilization. The SLUC model consisted of three modules: (1) Agricultural Land utilization Intensity indexing (ALUI module), (2) Agricultural Land Utilization Change indexing (ALUC module), and (3) Stability of Land Utilization Change indexing as (SLUC module).

3.3.3 Agreement of Potential Agricultural Land Utilization model (APA2LU model): The APA2LU model was separately conducted for lowland rice and longan using overlay techniques to generate cross matrix for agreement. Then the agreement results were used in comparison for the agreement by AA2LU model. The APA2LU model consisted of three modules: (1) Agreement of Potential Agricultural Land Suitability with Present Land Utilization Type (APALS2PLUT module), (2) Agreement of Potential Agricultural Land Suitability with Tendency Agricultural Land Utilization Type (APALS2TLUT module), and (3) Agreement of Agricultural Land Suitability with Existing LU/LC (AALS2ELU/LC module).

3.4 Techniques and methods for data preparation and data analysis

In this study standard techniques and methods for data preparation and data analysis were identified into three groups: (1) analysis of remotely sensed data and aerial photographs, (2) analysis of socio-economic data and questionnaires, and (3) analysis of geospatial data.

3.4.1 Analysis of remotely sensed data and aerial photographs

Remotely sensed data from 1997, 2002, and 2007 were used to classify land use and land cover by visual interpretation and digital image processing. The outputs were used in agricultural land suitability model and land use and land cover change detection. The aerial photographs as color orthophotos (2003) were only used for model verification.

3.4.2 Analysis of socio-economic data and questionnaires

Socio-economic data from BMN, crop production data from Office of Agricultural Economics and questionnaires from field survey were imported to geospatial database by using village or sub-district as ID. The spatial database was used in agricultural land suitability model. Standard techniques and methods for data preparation and analysis were applied for socio-economic data and questionnaires including (1) factor analysis techniques and Participatory Action Research (PAR) methods, (2) geostatistics techniques, and (3) AHP techniques of MCDM.

3.4.3 Analysis of geospatial data

Geospatial data collected from various government agencies which were in the form of remote sensed data and socio-economic data were used in agricultural land suitability model. Standard techniques and methods for data preparation and geospatial data analysis included following: (1) MDCM method, (2) geostatistics techniques, and (3) AHP techniques.

CHAPTER IV

EVALUATION OF AGRICULTURAL LAND SUITABILITY

4.1 Introduction

Evaluation of agricultural land suitability was conducted by using physical and socio-economic factors to determine coefficient values of land suitability under Agricultural Land Suitability model (ALS model). Basically, the evaluation of land suitability adopts from principle of A Framework for Land Evaluation (FAO, 1976), Guidelines Land Evaluation for Rainfed agriculture (FAO,1983) and Land Evaluation for Economic Crops (Land Development Department, 1996). However, interpretations of these concepts are rather diverse. In other words, a policy should be evaluated on the main criterion basis of economic crops sustainability, in addition to the traditional criteria of land efficiency (Beek, 1978). Malczewski (2004) claimed that land suitability analysis mostly used MCDM and GIS-based procedure. While spatial information systems, databases, relationships of farmer's, farm managements and farmer's households based on the World Bank's guidelines for Sustainable Land Management (World Bank, 2006) There are important components of agricultural activities in watershed area. Clearly, the spatial MCDM model of relating socio-economic factors can be constructed via negotiations formats between various social groups such as development formats, farmer formats, decision-makers, special interest group, and others (Malczewski, 2004). Thus, GIS based model, which capable for storage, management, manipulation and analysis was used for agricultural land suitability.

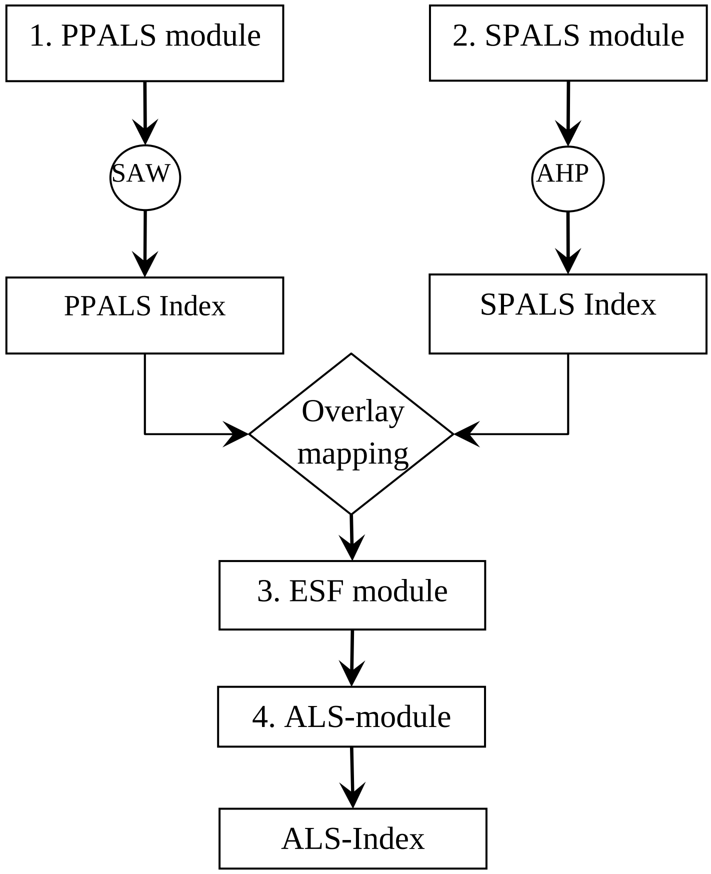
4.2 Objective

Building a model was using the multi MCDM and geostatistical methods that could evaluate agricultural land suitability.

4.3 Agricultural Land Suitability Model (ALS model)

The ALS model was firstly applied two-stage approach for land evaluation included (1) potential physical agricultural land suitability based on A Framework for Land Evaluation (FAO, 1976), Guidelines Land Evaluation for Rainfed agriculture (FAO,1983) and Land Evaluation for Economic Crops (Land Development Department, 1996) and (2) potential socio-economic agricultural land suitability based on World Bank's guidelines for sustainable land management (World Bank, 2006). Then, potential physical and socio-economic land suitability was integrated using GIS technique for optimum agricultural land suitability.

The ALS model was comprised of four modules including (1) Physical Potential of Agricultural Land Suitability (PPALS) module, (2) Socio-economic Potential of Agricultural Land Suitability (SPALS) module, (3) Effect of Socio-economic Factor (ESF) module, and (4) Agricultural Land Suitability (ALS) module as shown in Figure 4.1.



Legend

PPALS-module	Physical Potential of Agricultural Land Suitability module
SPALS module	Socio-economic Potential of Agricultural Land Suitability module
ESF module	Effect of Socio-economic Factor module
ALS-module	Agricultural Land Suitability module
SAW	Simple Additive Weighting
AHP	Analytical Hierarchy Process
PPALS-Index	Physical Potential of Agricultural Land Suitability Index.
SPALS-Index	Socio-economic Potential of Agricultural Land Suitability Index.
ALS-Index	Agricultural Land Suitability Index.

Figure 4.1 Conceptual framework of ALS model.

4.3.1 Physical Potential of Agricultural Land Suitability (PPALS) module

First-stage approach of ALS module was evaluation potential of agricultural land suitability based on bio-physical factors. Under PPALS module, agricultural land suitability potential for lowland rice and longan was evaluated based on Land Use Requirement (LUR) (crop requirement, management requirement and conservation requirement), Land Quality (LQ), Land Characteristic (LC) (climate, topography, infrastructure, water resources, and hazard) and Land Utilization Type (land use and land cover in 2007). The PPALS module consisted of three main suitability components as (1) suitability based on LUR and LQ (2) suitability based on LC and Land Utilization Type (LUT), and (3) potential physical agricultural land suitability as shown in Figure 4.2.

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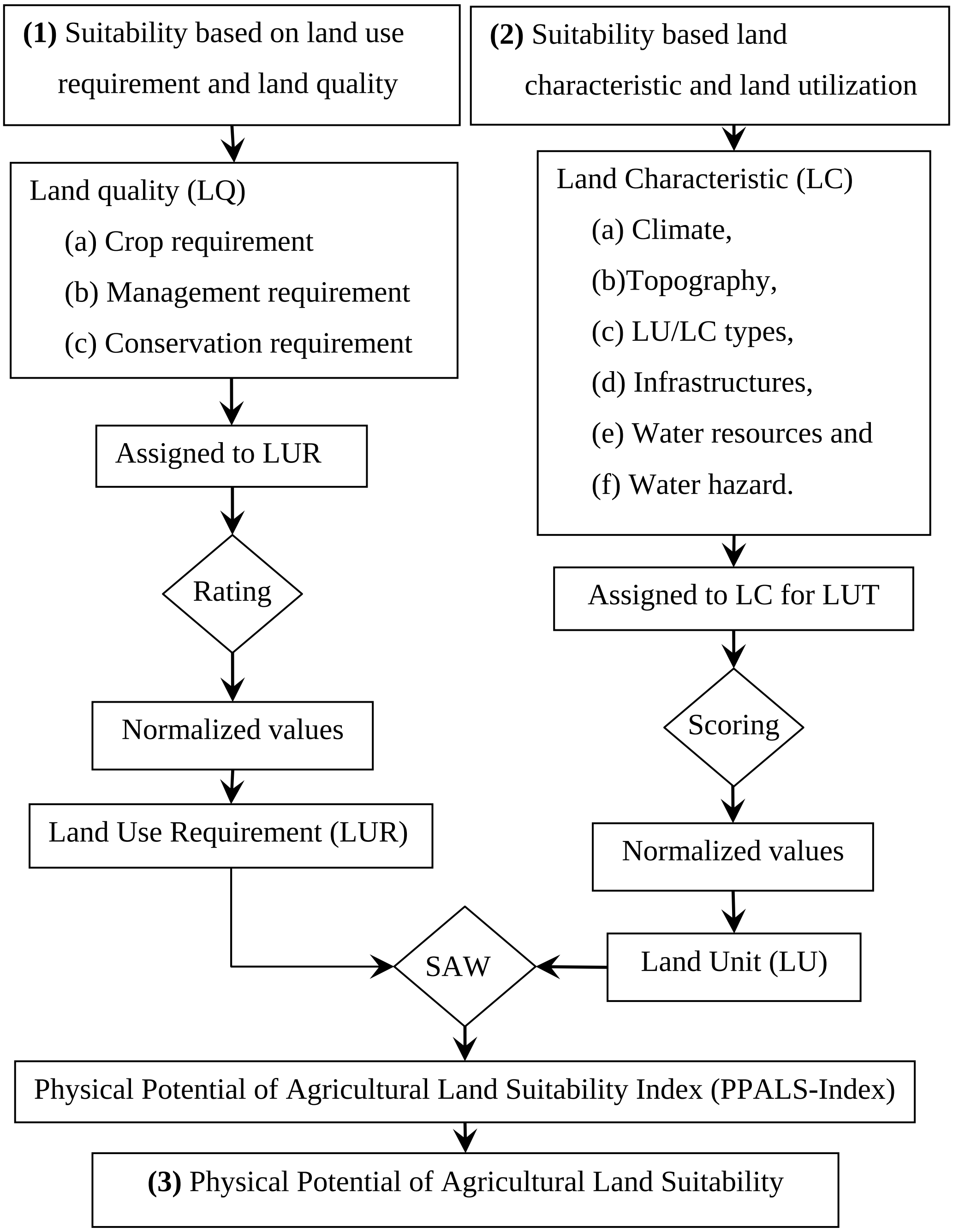


Legend

LUT	Land utilization Type
LUR	Land Use Requirement
SAW	Simple Additive Weighting

Figure 4.2 Workflow of PPALS module.

The three main suitability components could be described in the followings:

(1) Suitability based on Land Use Requirement and Land Quality:

LUR in terms of crop requirement, management requirement and conservation requirement for lowland rice and longan firstly identified and evaluated based on LQ with diagnostic factor from soil properties of soil series (Land Development Department, 2006). LUR and LQ comprised:

(a) Crop requirement,

1) Oxygen availability (LQ_1),

2) Nutrient availability (LQ 2),

3) Nutrient retention (LQ 3),

4) Rooting condition (LQ 4),

5) Excess of salts (LQ 5),

6) Soil toxicities (LQ 6),

(b) Management requirement,

7) Soil workability (LQ 7),

8) Potential for Mechanizations (LQ 8) and

(c) Conservation requirement

9) Soil erosions (LQ 9).

Then, factor rating of LUR for lowland rice and longan were assigned to LU with normalized values as suitability classes (S1, S2, S3, N1, and N2). Details of factor rating of each LQ were summarized as shown Tables A.1, A.2, and A.3 in Appendix A.

(2) Suitability based on Land Characteristic and Land Utilization Type:

LUR in terms of bio-physical suitability for lowland rice and longan was evaluated on LC and LUT. Detail of LC and LUT were summarized as in the followings:

(a) Climate,

1) Temperature (LC1),

2) Moisture availability (LC2),

(b) Topography,

3) Slope (LC3),

(c) Infrastructures,

4) Accessibility (LC4),

(d) Water resources,

5) Water body (LC5),

6) Stream (LC6),

7) Irrigation project (LC7),

(e) Water hazard,

8) Flood hazard (LC8),

(f) LU/LC types,

9) Agricultural area (LC9) and

10) Non-agricultural area (LC10).

Then, factor rating of LUR according to LC were assigned to LU with normalized values as suitability classes (S1, S2, S3 N1, and N2). All selected LQ and LC for suitability calculation of lowland rice and longan in this study were listed as shown in Table 4.1 (See criteria map for land characteristics in Appendix: B).

(3) Physical potential of agricultural land suitability:

Physical potential of agricultural land suitability was evaluated using Simple Additive Weighting (SAW) method. Here factor rating of LUR based on LQ and LC for LUT (lowland rice and longan) were applied to each LU of soil series data. Physical potential of agricultural land suitability for lowland rice and longan were separately calculated by equations 4.1 and 4.2, respectively.

Physical potential of agricultural land suitability for lowland rice:

$$\text{PPALSrice} = \sum_{i=1}^{9}\sum_{j=1}^{10} \text{LU[(LUR-LQi-rice)][(LUR-LCj-rice)]} \qquad (4.1)$$

Physical potential of agricultural land suitability for longan:

$$\text{PPALSlongan} = \sum_{i=1}^{9}\sum_{j=1}^{10} \text{LU[(LUR-LQi-longan)][(LUR-LCj-longan)]} \qquad (4.2)$$

Where,

PPALS-Index$_{rice}$	is indexing value of physical potential of agricultural land suitability for lowland rice.
PPALS -Index$_{longan}$	is indexing value of physical potential of agricultural for index for longan.
LU	is the land unit based on soil series types
[(LUR$_{\text{-LQi-rice}}$)]	is rating of LUR based on ith LQ of soil properties (LQ_1, $LQ_{2,}$ LQ_3…LQ_9) to LU for lowland rice
[(LUR$_{\text{-LCj-rice}}$)]	is rating of LUR based on jth the LC of soil properties (LC_1, $LC_{2,}$ LC_3…LC_{10}) to LU for lowland rice

$[(LUR_{-LQi-longan})]$ is rating of the land use requirement based on i^{th} Land Quality of soil properties (LQ_1, LQ_2, LQ_3…LQ_9) to Land Unit (LU) for longan

$[(LUR_{-LCj-longan})]$ is rating of the land use requirement based on j^{th} land characteristic of soil properties (LC_1, LC_2, LC_3…LC_{10}) to Land Unit (LU) for longan

Therefore, ranking physical potential of agricultural land suitability value for lowland rice and longan were generated with value of 0 to 100. These values were then normalized to new values varied between 0 and 1 (all values divide by 100) and reclassified into 5 classes for physical potential of agricultural land suitability as shown in Table 4.2.

Table 4.1 Evaluation criteria and rating value of LCs and LQ for lowland rice and longan.

Map layers of physical attributes (LC)	Score (100) LU_{ij}[3] = (x_i)	Land Use Requirement (LQ)											
			(a) Crop requirement							(b)Management requirement		(c)Conservation requirement	
		Weighting (LUR_j)	1.Temperature(LQ_x)	2 Moisture availability (LQ_x)	3.Oxygen availability (LQ_1)	4.Nutrient availability (LQ_2)	5.Nutrient retention (LQ_3)	6. Rooting condition (LQ_4)	8.Excess of salts (LQ_5)	9.Soli toxicities (LQ_6)	10.Soil workability (LQ_7)	11.Potential for mechanizations (LQ_8)	12.Erosion (LQ_9)	Weight Sum
		w_j	$w1_x$	$w1_x$	$w1_1$	$w1_2$	$w1_3$	$w1_4$	$w1_5$	$w1_6$	$w1_7$	$w1_8$	$w1_9$	100
			Rating[1] of LUR for lowland rice[2] or longan[3]											
(a) Climate	i													
1 Temperature (LC_1)	x_1	w_1	x	x										x
2 Moisture availability (LC_2)	x_2	w_2	x											x
(b) Topography														
3 Slope (LC_3)	x_3	w_3							x		x		x	x
(c) Infrastructures														
4 Accesses (LC_4)	x_4	w_4										x	x	x
(d) Water resources														
5 Water body (LC_5)	x_5	w_5	x											x
6 Stream (LC_6)	x_6	w_6	x											x
7 Irrigation project (LC7)	x7	w7		x				x						x

Table 4.1 Evaluation criteria and rating value of LCs and LQ for lowland rice and longan. (Continued)

Map layers of physical attributes (LC)	Score (100) LU_{ij}[3]	Land Use Requirement (LQ)												
			(a)Crop requirement								(b) Management requirement		(b)Conservation requirement	
		Weighting (LUR_j)	1.Temperature(LQ_x)	2 Moisture availability (LQ_x)	3.Oxygen availability (LQ_1)	4.Nutrient availability (LQ_2)	5.Nutrient retention (LQ_3)	6. Rooting condition (LQ_4)	8.Excess of salts (LQ_5)	9.Soli toxicities (LQ_6)	10.Soil workability (LQ_7)	11.Potential for mechanizations (LQ_8)	12.Erosion (LQ_9)	Weight Sum
		w_j	$w1_x$	$w1_x$	$w1_1$	$w1_2$	$w1_3$	$w1_4$	$w1_5$	$w1_6$	$w1_7$	$w1_8$	$w1_9$	100
			Rating[1] of LUR for lowland rice[2] or longan[3]											
(e) Hazard														
8 Flood Hazard(LC_8)	x_8	w_8						x						x
(f) LU/LC types														
9 Agricultural area (LC_9)	x_9	w_9	x	x	x	x	x	x	x	x	x	x	x	x
10 Non agricultural area (LC_{10})	x_{10}	w_{10}											x	x
Toal	100													100

Note: [1], [2] and [3] see detail in Appendix A

Table 4.2 Physical potential of agricultural land suitability classes for lowland rice and longan.

PPALS-Index		Description	Ranking importance value
S_1	Highly suitable	Land having no, or insignificant limitations to the given type	>0.80
S_2	Moderately suitable	Land having minor limitations to the given type	0.60 to 0.79
S_3	Marginally suitable	Land having moderate limitations to the given type	0.40 to 0.59
N_1	Currently not suitable	Land having severe limitations that preclude the given type of use, but can be improved by specific management	0.20 to 0.39
N_2	Permanently not suitable	Land that have so severe limitations that are very difficult to be overcome	<0.19

Source: Suitability classes base on FAO (1975).

4.3.2 Socio-economic Potential of Agricultural Land Suitability (SPALS) module

Second-stage approach of ALS module was to evaluate land potential for agricultural land suitability based on socio-economic factors at local level. This module applied AHP rule of MCDM method. All socio-economic factors were compared against each other in a pair-wise compare son matrix. This is a measurement to express the relative preference among the factors and weighting value of each factor. The socio-economic agricultural land suitability for lowland rice and longan was evaluated on LUR for socio-economic dimension including LUT, Agricultural Land Use Intensity (ALUI) from field survey in year 2007, and Socio-economic Status (SS) from BMN between 1997 to 2007. Basically, socio-economic attributes from Land Evaluation for Agricultural Development by Beek (1978) and Guideline of the Sustainable Land Management of World Bank (2006) were reviewed and selected with some modification for this module as in the following.

(A) Land Evaluation for Agricultural Development by Beek (1978)

(1) Cropping system,

(B) World Bank's Guidelines for Sustainable Land Management

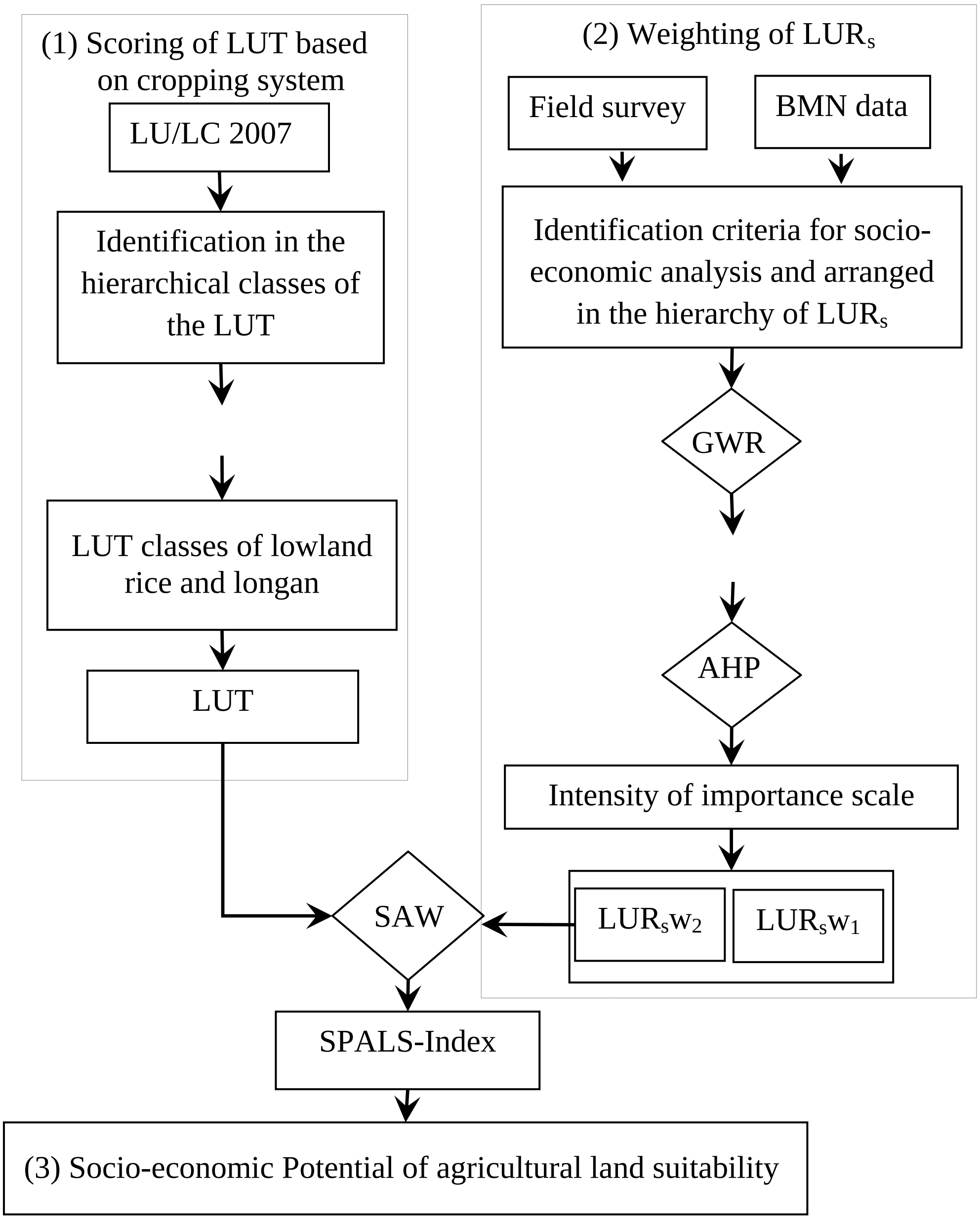
(1) Land properties,

(2) Management properties and

(3) Farmer properties.

Under SPALS module, land use and land cover types in 2007 were firstly reclassified for LUT and assigned score value according to cropping system as suggested by Beek (1978). Data from field survey in 2007 was used to define weighting value to Land Utilization Requirement of socio-economic (LURs) in the study area that occurred at present time. Furthermore, BMN data in 1997, 2002, and 2007 from Community Development Department were also used to define weight value to LURs in the study area that occurred in past time. At the end, potential of socio-economic agricultural land suitability was calculated by multiplication of LUT value and LURs.

SPALS module divided into three main components as (1) Scoring of LUT based on Cropping System, (2) Weighting of socio-economic LUR based on field survey and BMN data and (3) potential of socio-economic agricultural land suitability as shown in Figure 4.3.



Legend

⊕ = Normalized values.
LURs = Land Use Requirement for socio-economic.
LUT = Land Utilization Type.
AHP = Analytical Hierarchy Process.
SAW = Simple Additive Weighting.
LUR_sw_1 = weighting value of present socio-economic land use requirement for low land rice.
LUR_sw_2 = weighting value of past socio-economic land use requirement for low land rice.

Figure 4.3 Workflow of SPALS module.

(1) Scoring of LUT based on Cropping System

Land Use/Land Cover (LU/LC) data in 2007 which were extracted from remotely sensed data, were firstly reclassified to LUT for 5 classes as: 1) Agricultural area Type-1 (strong to very strong importance), 2) Agricultural area Type-2 (moderate to strong importance), 3) Agricultural area Type-3 (moderate importance), 4) NA1 Non-Agricultural area (currently not agricultural area) and 5) Non-Agricultural area (permanently not agricultural area). All 5 classes were then given a score based on LUT for lowland rice and longan as shown in Table 4.3 and 4.4, respectively.

Table 4.3 Hierarchical classes of LUT for lowland rice in 2007.

LUT Classes	Land Utilization Type[1/]	Score[2/]
1. Cropping system area (A_1, A_2, and A_3)		
1.1 Agricultural area Type-1 (strong to very strong importance)	Transplanted paddy field, abandoned paddy, and transplanted paddy field/mixed orchard, transplanting paddy field + bush fallow and bush fallow.	>0.80
1.2 Agricultural area Type-2 (moderately to strong importance)	Mixed field crop-scrub, grass and scrub, mixed orchard, longan-mixed field crop, longan-scrub, longan-transplanted paddy field, longan/scrub, longan, mixed field crop, mixed orchard-disturbed	0.60 to 0. 79

Table 4.3 Hierarchical classes of LUT for lowland rice in 2007. (Continued)

LUT Classes	Land Utilization Type[1]	Score[2]
	deciduous forest, mixed orchard-mixed field crop, mixed orchard/disturbed deciduous forest, mixed forest plantation and mixed field crop-longan.	
1.3 Agricultural area Type-3 (marginally importance)	Grass, scrub, grass and scrub-mixed field crop.	0.40 to 0. 59
2. NA : Non Agricultural area		
2.1 NA_1 (currently not agricultural area)	cattle farm house, poultry farm house, livestock, capital intensity, labor intensity, environmental impact, associated forestry deciduous dipterocarp forest, deciduous forest, disturbed deciduous forest, disturbed deciduous forest-longan, disturbed deciduous forest-mixed orchard, hill evergreen forest, hill evergreen forest-tropical pine forest, mixed deciduous forest, mixed deciduous forest-deciduous dipterocarp forest and mixed swidden cultivation.	0.39 to 0.20

Table 4.3 Hierarchical classes of LUT for lowland rice in 2007. (Continued)

LUT Classes	Land Utilization Type[1]	Score[2]
2.1 NA_2 (permanently not agricultural area)	city, town, commercial and service, lowland, village, high land village, factory, golf course, allocated land project, industrial estate, institutional land, mine, recreation area and lake and reservoir.	<0.19

Note: [1] land use in 2007.

[2] level of land utilization intensity values for agriculture in under Appendix A Table A.6.

Table 4.4 Hierarchical classes of the LUT for longan in 2007.

LUT Classes	Land Utilization Type[1]	Score[2]
1. Cropping system Area (A_1, A_2, and A_3)		
1.1 Agricultural area Type-1 (strong to very strong importance)	longan, longan-mixed field crop, and longan-scrub.	0.80 to 1.00
1.2 Agricultural area Type-2 (moderate to strong importance)	Mixed orchard, longan-transplanted paddy field, longan/scrub, grass and scrub, mixed orchard-disturbed deciduous forest, mixed orchard-mixed field crop and mixed orchard/disturbed deciduous forest.	0.60 to 0.79
1.3 Agricultural area Type-3 (moderate importance)	Disturbed deciduous forest-mixed orchard, disturbed deciduous forest-longan, mixed field crop, mixed field crop-longan, mixed field crop-scrub, grass and scrub, scrub, grass and scrub-mixed field crop, lowland village-longan, lowland village-mixed orchard, lowland village/longan/mixed orchard, bush fallow, transplanted paddy field,	0.40 to 0.59

Table 4.4 Hierarchical classes of the LUT for longan in 2007. (Continued)

LUT Classes	Land Utilization Type[1]	Score[2]
2. NA : Non Agricultural Area		
2.1 NA1 (non-agricultural area with non-permanent)	Poultry farm house and cattle farm house.	0.39 to 0.20
2.2 NA2 (non-agricultural area with permanent)	City, town, commercial, service, lowland village, high land village, allocated land project, factory, golf course, industrial estate, institutional land, mine, recreation area, mixed swidden cultivation, hill evergreen forest, hill evergreen forest-tropical pine forest, deciduous dipterocarp forest, deciduous forest, disturbed deciduous forest, mixed deciduous forest, mixed deciduous forest-deciduous dipterocarp forest, mixed forest plantation, reservoir and lake.	0.19 to 0.00

Note: [1] land use in 2007.

[2] level of land utilization intensity values for agriculture in Appendix A Table A.6.

(2) Weighting of LURs based on field survey and BMN data

Both socio-economic data form field survey in 2007 and BMN data in 1997, 2002, and 2007 from CDD were analyzed for socio-economic LUR for lowland rice and longan. The three main criterias with eight sub-criteria as recommendation by World Bank (2006) were considered as shown in Table 4.5. However, weighting of socio-economic LUR form field survey in 2007 and BMN data in 1997, 2002, and 2007 from CDD were separately processed.

In weighting of LURs from field survey in 2007, socio-economic attribute Table 4.5 from 544 villages as sampling points were firstly interpolated by using GWR technique to represent socio-economic factors in polygon based on coefficient of determination value (R2). Then, weight values of each socio-economic factor based on scale intensity of important (Table 4.6) were assigned by interviewing from 58 focus groups.

While weighting of LURs from BMN data in 1997, 2002, and 2007 and all values of socio-economic factors were firstly averaged and interpolated by using GWR technique to represent socio-economic factors in polygon based on coefficient of determination value (R2). Then, weighting values of each socio-economic factor were assigned by compare with standard value, if average value is more than standard value, weight value should be “+” sign and if average value is less than standard value, weight value should be “-” sign.

Scoring and weighting values in socio-economic of agricultural land suitability calculation for lowland rice and longan were presented in Table 4.7 and Table 4.8 (see also criteria map in APPENDIX D).

Table 4.5 Hierarchical criteria for socio-economic analysis of LURs.

Goal	**Criteria**[1]	**Sub-criteria**[2]
Socio-economic agricultural land suitability	(1) Land properties	(A) Agricultural nutrient balance and present farm practices (B) Yields
	(2) Management properties	(C) Fertilizers management (D) Farm pest management (E) Farm management and marketing (F) Agricultural soil conservation management (G) Irrigation management
	(3) Farmer properties	(H) Whole household farm management

Note: [1] FAO Framework (1976) and World Bank (2006).
[2] BMN database in 2007 and field survey with questionnaire in 2007.

Table 4.6 Importance scale for pair-wise comparison.

Importance scale	Definition[1]
1	Equal importance
2	Equal to moderately importance
3	Moderate importance
4	Moderate to strong importance
5	Strong importance
6	Strong to very strong importance
7	Very strong importance
8	Very to extremely strong importance
9	Extreme importance

Note: [1] Saaty (1980).

Table 4.7 Scoring and weighting values for existing land-use with LUR_s for lowland rice using SAW method.

	LU/LC TYPES	LUT Score (x_{ij})	Socio-economic potential of agricultural land utilization	1.Land properties		2. Management properties					3. Farmer properties
				(A) Agricultural nutrient balance and present farm practices	(B) Crop yields	(C) Fertilizers management	(D) Farm pest management	(E) Farm management and marketing	(F) Agricultural soil conservation management	(G) Irrigation management	(H) Whole household farm management
			LUR_sw1j	+0.98	+ 0.91	+0.21	+0.97	- 0.04	+0.44	+0.45	+0.98
			LUR_sw2j	-0.49	+0.02	+0.75	+0.1	+0.1	-0.56	-0.38	+0.1
			w_j(overall)	w_j^{1} Total =1.00		w_j^{2} Total =1.00					w_j^{3} Total =1.00
1	Scrub, Grass and scrub	0.45	w_1	x						x	x
2	Bush fallow	0.65	w_2	x						x	x
3	Cattle farm house	0.60	w_3	x	x	x	x				x
4	Poultry farm house	0.30	w_4	x	x	x	x				x
5	Lowland rice	1.00	w_5	x	x	x	x	x	x	x	x
6	Longan	0.45	w_6	x	x	x	x	x	x	x	x
7	Village	0.10	w_7				x	x	x		x
8	High land village	0.10	w_8				x	x	x	x	x
9	Allocated land project	0.00	w_9						x		x
10	City, town, commercial and service	0.00	w_{10}						x		x
11	Deciduous forest	0.20	w_{11}							x	
12	Mixed deciduous forest,	0.10	w_{12}							x	

Table 4.7 Scoring and weighting values for existing land-use with LUR_s for lowland rice using SAW method. (Continued)

	LU/LC TYPES	**LUT Score (x_{ij})**	Socio-economic potential of agricultural land utilization	**1.Land properties** (A) Agricultural nutrient balance and present farm practices	(B) Crop yields	**2. Management properties** (C) Fertilizers management	(D) Farm pest management	(E) Farm management and marketing	(F) Agricultural soil conservation management	(G) Irrigation management	**3.Farmer properties** (H) Whole household farm management
			$LUR_s w1_j$	+0.02	+ 0.92	+0.65	+0.41	- 0.21	+0.09	+0.97	+0.11
			$LUR_s w2_j$	-0.97	+0.09	+0.9	+0.29	+0.98	-0.10	-0.07	+0.16
			w_j(overall)	$w_j^{1\rfloor}$Total =1.00		$w_j^{2\rfloor}$ Total =1.00					$w_j^{3\rfloor}$ Total =1.00
13	Mixed orchard	0.10	w_{13}						x		
14	Mixed swidden cultivation	0.10	w_{14}						x		
15	Hill evergreen forest	0.10	w_{15}						x		
16	Recreation area	0.10	w_{16}						x		x
17	Factory	0.00	w_{17}			x		x	x		x
18	Golf course	0.00	w_{18}			x		x	x		x
19	Industrial estate	0.00	w_{19}			x		x	x		x
20	Institutional land	0.00	w_{20}			x		x	x		x
21	Mine	0.00	w_{21}			x					
22	Lake	0.00	w_{22}							x	x
23	Reservoir	0.00	w_{23}							x	x

Note: $w_j^{1\rfloor}$ = (A+B), $w_j^{2\rfloor}$ = (C+D+E+F+G), $w_j^{3\rfloor}$ = H, LUI data in field survey in 2007 and SS data in 1997 to 2007.

Table 4.8 Scoring and weighting values for existing land-use with LUR_s for longan using SAW method.

				1.Land properties		2. Management properties					3. Farmer properties
	LU/LC TYPES	**LUT Score (x_{ij})**	Socio-economic potential of agricultural land utilization	(A) Agricultural nutrient balance and present farm practices	(B) Crop yields	(C) Fertilizers management	(D) Farm pest management	(E) Farm management and marketing	(F) Agricultural soil conservation management	(G) Irrigation management	(H) Whole household farm management
			$LUR_s w1j$	+0.02	+ 0.92	+0.65	+0.41	- 0.21	+0.09	+0.97	+0.11
			$LUR_s w2j$	-0.97	+0.09	+0.9	+0.29	+0.98	-0.10	-0.07	+0.16
			w_j(overall)	w_j^{1} Total =1.00		w_j^{2} Total =1.00					w_j^{3} Total =1.00
1	Scrub, Grass and scrub	0.55	w_1	x						x	
2	Bush fallow	0.65	w_2	x						x	
3	Cattle farm house	0.60	w_3	x	x	x	x				x
4	Poultry farm house	0.30	w_4	x	x	x	x				x
5	Lowland rice	0.45	w_5	x	x	x	x	x	x	x	x
6	Longan	1.00	w_6	x	x	x	x	x	x	x	x
7	Village	0.10	w_7				x	x	x		x
8	High land village	0.55	w_8				x	x	x	x	x
9	Allocated land project	0.00	w_9						x		x
10	City, town, commercial and Service	0.00	w_{10}						x		x
11	Deciduous forest	0.35	w_{11}							x	
12	Mixed deciduous forest,	0.20	w_{12}							x	

55

Table 4.8 Scoring and weighting values for existing land-use with LUR_s for longan using SAW method. (Continued)

	LU/LC TYPES	**LUT Score (x_{ij})**	Socio-economic potential of agricultural land utilization	**1.Land properties** (A) Agricultural nutrient balance and present farm practices	**1.Land properties** (B) Crop yields	**2. Management properties** (C) Fertilizers management	**2. Management properties** (D) Farm pest management	**2. Management properties** (E) Farm management and marketing	**2. Management properties** (F) Agricultural soil conservation management	**2. Management properties** (G) Irrigation management	**3.Farmer properties** (H) Whole household farm management
			LURw1j	+0.98	+ 0.91	+0.21	+0.97	- 0.04	+0.44	+0.45	+0.98
			LURw2j	-0.97	+0.09	+0.75	+0.1	+0.1	-0.56	-0.38	+0.1
			w_j(Overall)	$w_j^{1\rfloor}$Total =1.00		$w_j^{2\rfloor}$ Total =1.00					$w_j^{3\rfloor}$ Total =1.00
13	Mixed orchard	0.65	w_{13}						x		
14	Mixed swidden cultivation	0.10	w_{14}						x		
15	Hill evergreen forest	0.10	w_{15}						x		
16	Recreation area	0.00	w_{16}						x		x
17	Factory	0.00	w_{17}			x		x	x		x
18	Golf course	0.00	w_{18}			x		x	x		x
19	Industrial estate	0.00	w_{19}			x		x	x		x
20	Institutional land	0.00	w_{20}			x		x	x		x
21	Mine	0.00	w_{21}			x					
22	Lake	0.00	w_{22}							x	x
23	Reservoir	0.00	w_{23}							x	x

Note: $w_j^{1\rfloor}$ = (A+B), $w_j^{2\rfloor}$ = (C+D+E+F+G), $w_j^{3\rfloor}$ = H, LUI data in field survey in 2007 and SS data in 1997 to 2007.

(3) Socio-economic potential of agricultural land suitability

Socio-economic potential of agricultural land suitability was evaluated using SAW method. The score of LUT (based on land use and land cover in 2007) and weight of LURs for present situation (LURs wj1) and BMN data in 1997, 2002, and 2007 for past situation (LURs wj2) were applied to each LUT unit of land use and land cover data. Socio-economic of agricultural land suitability for lowland rice and longan were separately calculated by equation 4.3 and 4.4, respectively.

Socio-economic potential of agricultural land suitability for lowland rice:

$$SPALS_{rice} = \sum_{i=1}^{23}\sum_{j=1}^{8} LUT_{xi\ -rice}[(LURs_{w1j\text{-}rice})]\ [(LURs_{w2j\text{-}rice})] \qquad (4.3)$$

Socio-economic potential of agricultural land potential for longan:

$$SPALS_{longan} = \sum_{i=1}^{23}\sum_{j=1}^{8} LUT_{xi\ longan}[(LURs_{w1j\text{-}longan})]\ [(LURs_{w2j\text{-}longan})] \qquad (4.4)$$

Where,

$SPALS\text{-}Index_{rice}$ is the value of socio-economic of potential agricultural land suitability index for lowland rice.

$SPALS\ \text{-}Index_{longan}$ is the value of socio-economic of potential agricultural land suitability index for longan.

$LUT_{xi\text{-}rice}$ is scoring value of LUT unit consisting of i^{th} land use and land cover types for lowland rice.

$LUT_{xi\text{-}longan}$ is scoring value of LUT unit consisting of i^{th} land use and land cover types for longan.

[(LURs$_{w1j\text{-}rice}$)] is weighting value of present socio-economic LUR for lowland rice.

[(LURs$_{w2j\text{-}rice}$)] is weighting value of past socio-economic LUR for lowland rice.

[(LUR$_{sw1j\text{-}longan}$)] is weighting value of present socio-economic LUR for longan.

[(LURs$_{w2j\text{-} longan}$)] is weighting value of past socio-economic LUR for longan.

4.3.3 Effects of Socio-economic Factor (ESFI) module

Under ESF module, effect values as positive and negative sign were calculated by comparing between SPALS index and PPALS index to identify effect of PSALS index to PPASL index.

In principle, "If SPALS index is higher than PPASL index, and then PSALS index gives positive effect to PPASL index. In contrast, if SPALS index is lower than PPASL index, then SPALS index gives negative effect to PPASL index." In addition, "If PSALS index is equal to PPASL index, and then SPALS index gives no effect to PPASL index"

These socio-economic effects play important role in Agricultural Land Suitability model. The ESF for lowland rice and longan were calculated by using equation 4.5 and 4.6, respectively as in the following:

ESFI for lowland rice:

$$ESFI_{rice} = [(SPALS_{-rice}) - (PPALS_{-rice})]*0.01 \quad (4.5)$$

ESFI for longan:

$$ESFI_{longan} = [(SPALS_{-longan}) - (PPALS_{-longan})]*0.01 \quad (4.6)$$

Where,

$ESFI_{rice}$	is the effect of socio-economic factor index for lowland rice.
$ESFI_{longan}$	is the effect of socio-economic factor index for longon.
$PPALS_{rice}$	is the value of physical potential of agricultural land suitability index for lowland rice.
$PPALS_{longan}$	is the value of physical potential of agricultural land suitability index for longan.
$SPALS_{rice}$	is the value of socio-economic potential of agricultural land suitability index for lowland rice.
$SPALS_{longan}$	is the value of socio-economic potential of agricultural land suitability index for longan.

The values of ESF index for lowland rice and longan vary between -1 to +1 (include 0). These values were reclassified into 5 classes as shown in Table 4.9.

Table 4.9 Classification of ESFI index.

ESFI-Index	Definition	Ranking of importance value
EFSI-1	SPALS index gives highly positive effect to PPASL index	+0.50 to +1.00
EFSI-2	SPALS index gives moderately positive effect to PPASL index	+0.01 to +0.49
EFSI-3	SPALS index gives non effect to PPASL index	0.00
EFSI-4	SPALS index gives moderately negative effect to PPASL index	-0.01 to -0.49
EFSI-5	SPALS index gives highly negative effect to PPASL index	-0.50 to -1.00

4.3.4 Agricultural Land Suitability (ALS) module

The ALS module was an integration of two stages approach of agricultural land suitability of PPALS index and SPALS index with ESFI index. In other word, ALS module was an integral module between bio-physical factors and LC and socio-economic factors that were extracted from socio-economic data obtaining from field survey and secondary data. The ALS index for lowland rice and longan were calculated by equation 4.7 and 4.8.

Agricultural land suitability for lowland rice:

$$ALSrice = [[(PPALSrice)] + [(SPALSrice)(ESFIrice + 1)]]*0.5 \quad (4.7)$$

Agricultural land suitability for longan:

$$ALSlongan = [[(PPALSlongan)] + [(SPALS\ longan)(ESFIlongan + 1)]]*0.5 \quad (4.8)$$

Where,

$ALS\text{-}Index_{rice}$ is the value of agricultural land suitability index for lowland rice.

$ALS\text{-}Index_{longan}$	is the value of agricultural land suitability index for longan.
$PPALS\text{-}Index_{rice}$	is the value of physical potential of agricultural land suitability index for lowland rice.
$PPALS\text{-}Index_{rice}$	is the value of physical potential of agricultural land suitability index for longan.
$SPALS\text{-}Index_{rice}$	is the value of socio-economic potential of agricultural land suitability index for lowland rice.
$SPALS\ \text{-}Index_{longan}$	is the value of socio-economic potential of agricultural land suitability index for longan.
$ESFI\ Index_{rice}$	is the value of socio-economic factor for lowland rice.
$ESFI\ Index_{longan}$	is the value of socio-economic factor effect for longan.

Thus, ranking values of agricultural land suitability for lowland rice and longan were generated with value between 0 to 100. These values were then normalized to new values varied between 0 and 1 (all values divide by 100) and reclassified into 5 classes as shown in Table 4.10.

Table 4.10 Classification of agricultural land suitability index.

ALS-Index	Definition	Ranking importance value
S1	Highly suitable	>0.80
S2	Moderately suitable	0.60-0.79
S3	Marginally suitable	0.40-0.59
N1	Currently not suitable	0.20-0.39
N2	Permanently not suitable	<0.19

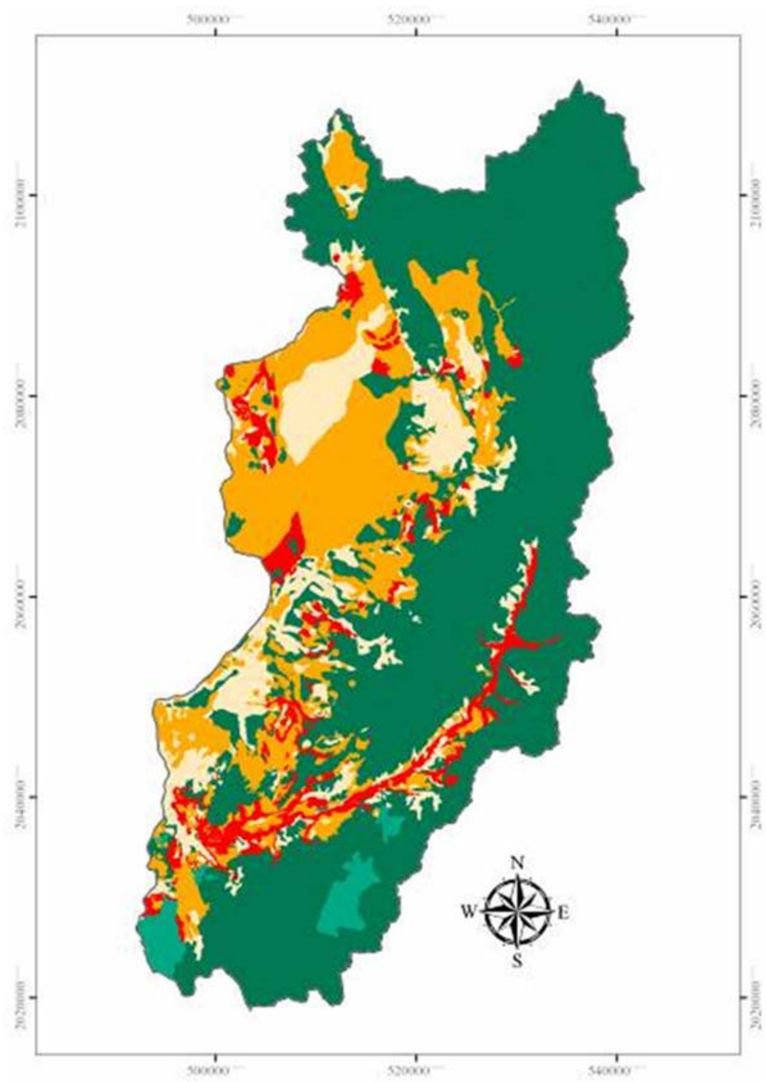
4.4 Results

Based on four modules of ALS model for lowland rice and longan were here explained into 4 parts as Potential agricultural land suitability (PPALS), Socio-economic Potential of agricultural land suitability (PSALS), Effect of Socio-economic factor index (ESFI) and Agricultural land suitability (ALS).

4.4.1 Physical Potential of Agricultural Land Suitability (PPALS)

(1) PPALS for lowland rice

The results shown that in the most physical potential of agricultural land suitability class was currently not suitable for lowland rice, it covers the area about 1,586.74 sq. km (58.81%) and it distributed mostly over hills and mountains landform. In contrast, highly and moderate suitable areas for lowland rice were situated in flood plain and alluvial and covering the area of 735.89 sq. km or 27.27% of the total area as shown in Figure 4.4.



Physical potential of agricultural land suitability classes (PPALS)

S_1: Highly suitable

S_2: Moderately suitable

S_3: Marginally suitable

N_1: Currently not suitable

N_2: Permanently not suitable

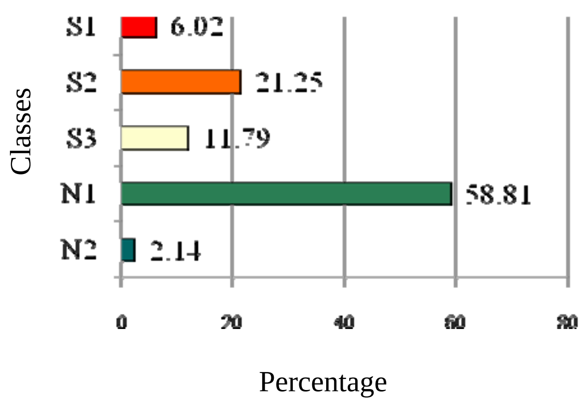
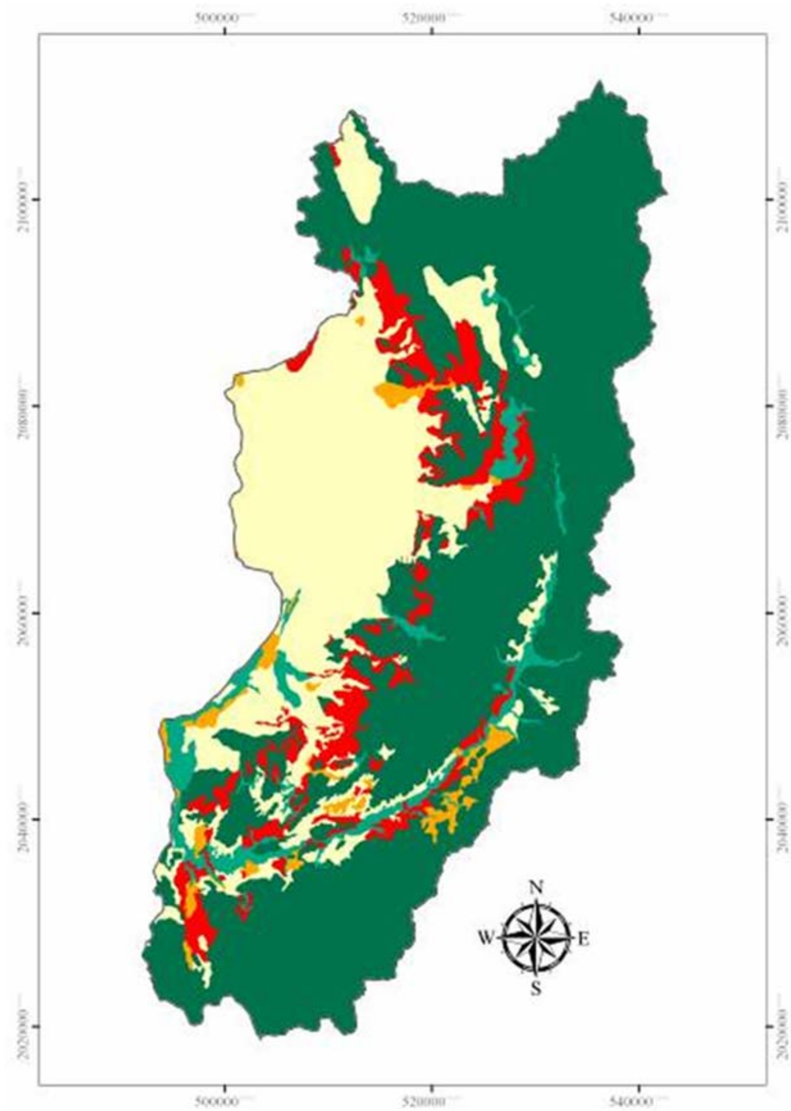


Figure 4.4 PPALS for lowland rice.

(2) PPALS for longan

Physical potential of agricultural land suitability for longan was shown in Figure 4.5.

The results shown that most of the physical potential of agricultural land suitability classes were marginally unsuitable for longan, It covered area of 1,577.90 sq. km (58.48%) and distributed mostly over hills and mountains landform. In contrast, highly and moderate suitable areas were situated in semi-recent terrace and old riverine alluvium and covering the area of 275.78 sq. km (10.22%).



Potential physical agricultural land suitability classes for longan

S_1: Highly suitable

S_2: Moderately suitable

S_3: Marginally suitable

N_1: Currently not suitable

N_2: Permanently not suitable

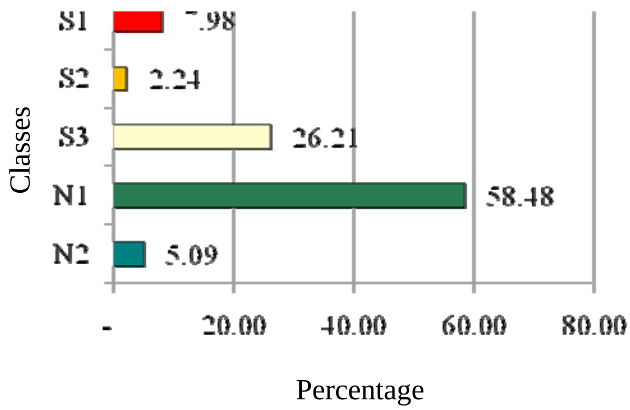


Figure 4.5 PPALS for longan.

Distributions of land use and land cover classes in the study area were shown in Figure 4.6. and Table 4.11 (Detail of accuracy assessment of land use/land cover in 2007 was shown in APPENDIX E).

Table 4.11 Area and percentage of land use and land cover in 2007.

No	Land use and land cover	Area in sq. km	Percent
1	Scrub and grass	1.94	0.07
2	Bush fallow	4.32	0.16
3	Cattle farm house	0.14	0.01
4	Poultry farm house	0.22	0.01
5	Lowland rice	510.80	18.99
6	Longan	348.24	12.94
7	Village	128.13	4.76
8	High land village	4.98	0.19
9	Allocated land project	12.67	0.47
10	City, town, commercial and service	24.59	0.91
11	Deciduous dipterocarp forest	796.91	29.63
12	Mixed deciduous forest	710.18	26.41
13	Mixed orchard	8.39	0.31
14	Mixed swidden cultivation	0.16	0.01
15	Hill evergreen forest	66.03	2.46
16	Recreation area	1.14	0.04
17	Factory	4.20	0.16
18	Golf course	2.60	0.10
19	Industrial estate	3.28	0.12
20	Institutional land	28.66	1.07
21	Mine	1.92	0.07
22	Lake	1.66	0.06
23	Reservoir	28.12	1.05
	Total	2,689.28	100.00

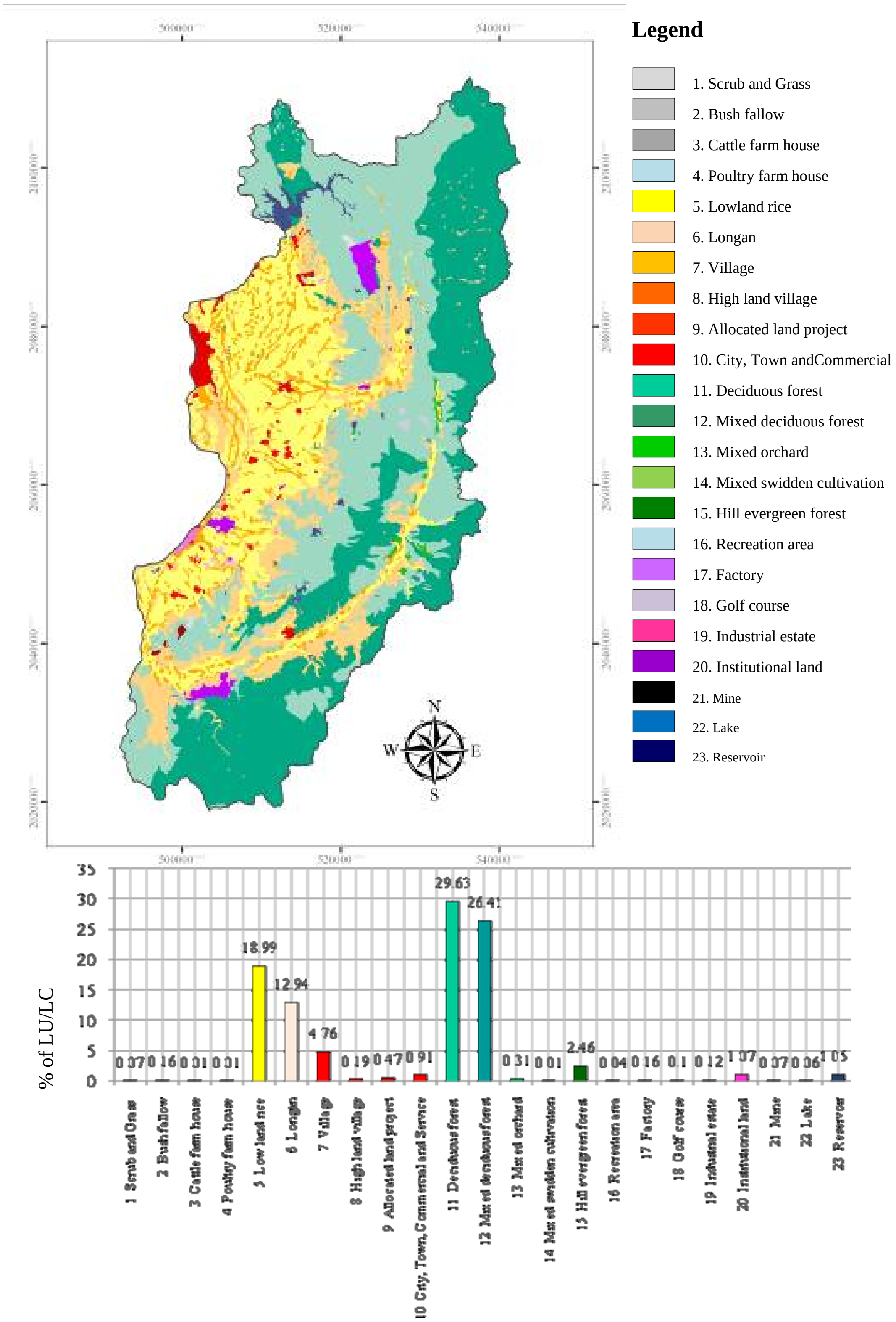


Figure 4.6 Land Use /Land Cover in 2007.

4.4.2 Socio-economic Potential of Agricultural Land Suitability (SPALS)

Results of socio-economic potential of agricultural land suitability consisted of two parts: 1) Scoring LUT based on cropping system and 2) Socio-economic potential of agricultural land suitability

(1) Scoring LUT based on cropping system

LUT for lowland rice and longan ware classified based on land use and land cover in 2007 into 5 classes. The results indicated that major distribution of LUT class for lowland rice and longan were permanently not agricultural area which were derived from forest classes and covering area of 1,640.45 sq. km (60.80%) and 1,097.23 sq. km (40.8%), respectively as shown in Figures 4.7 and 4.8.

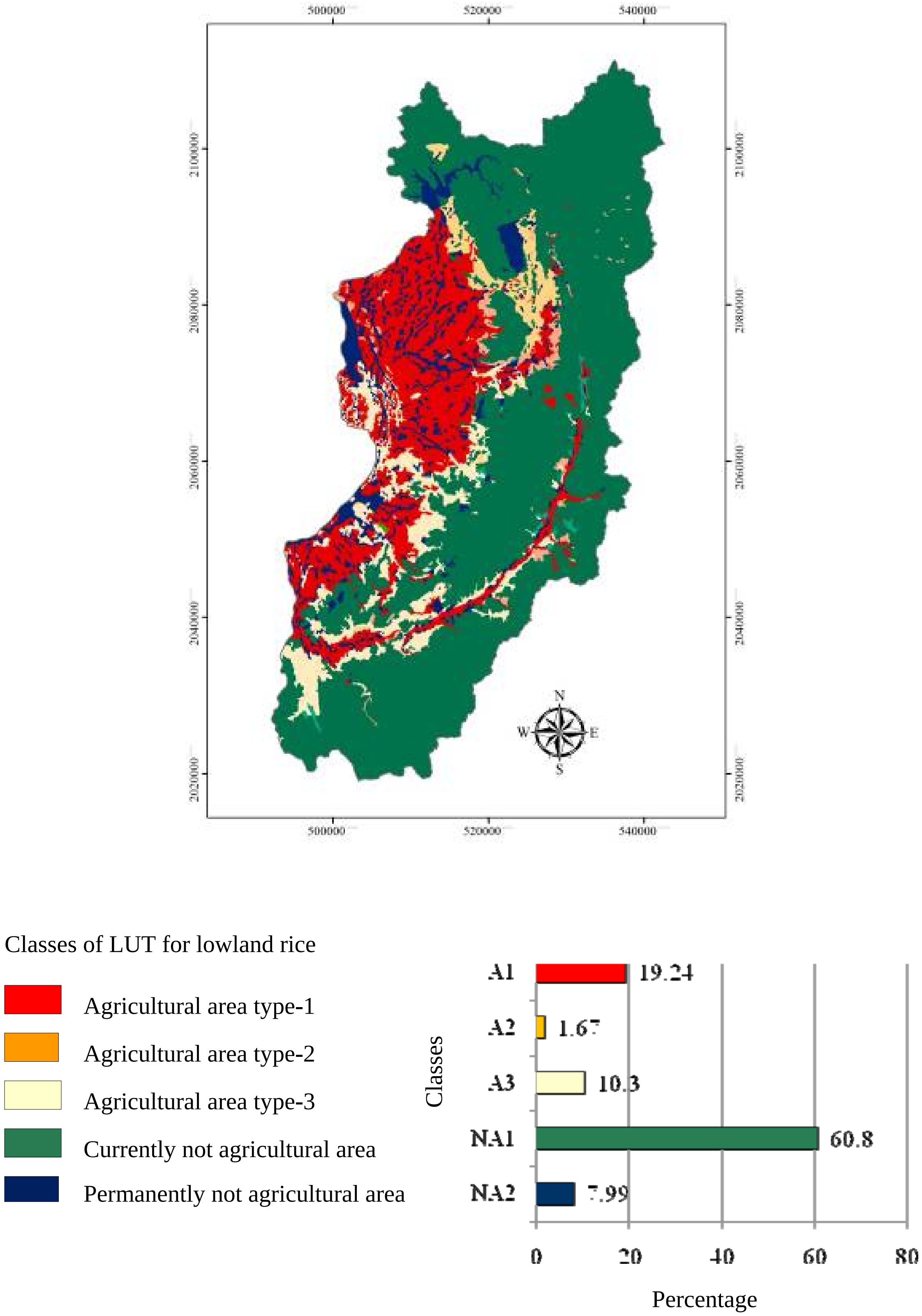


Figure 4.7 Classes of LUT for lowland rice in 2007.

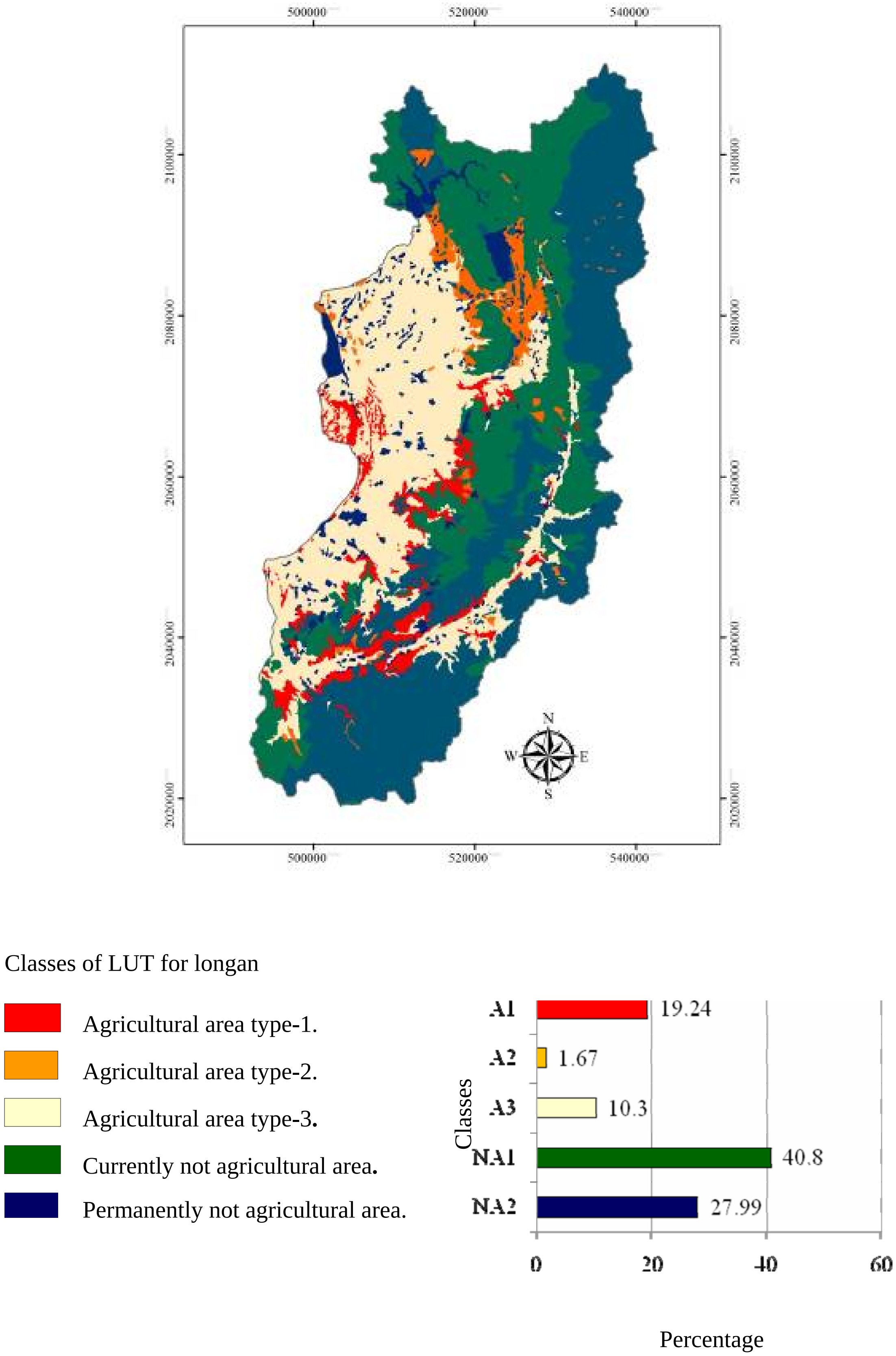
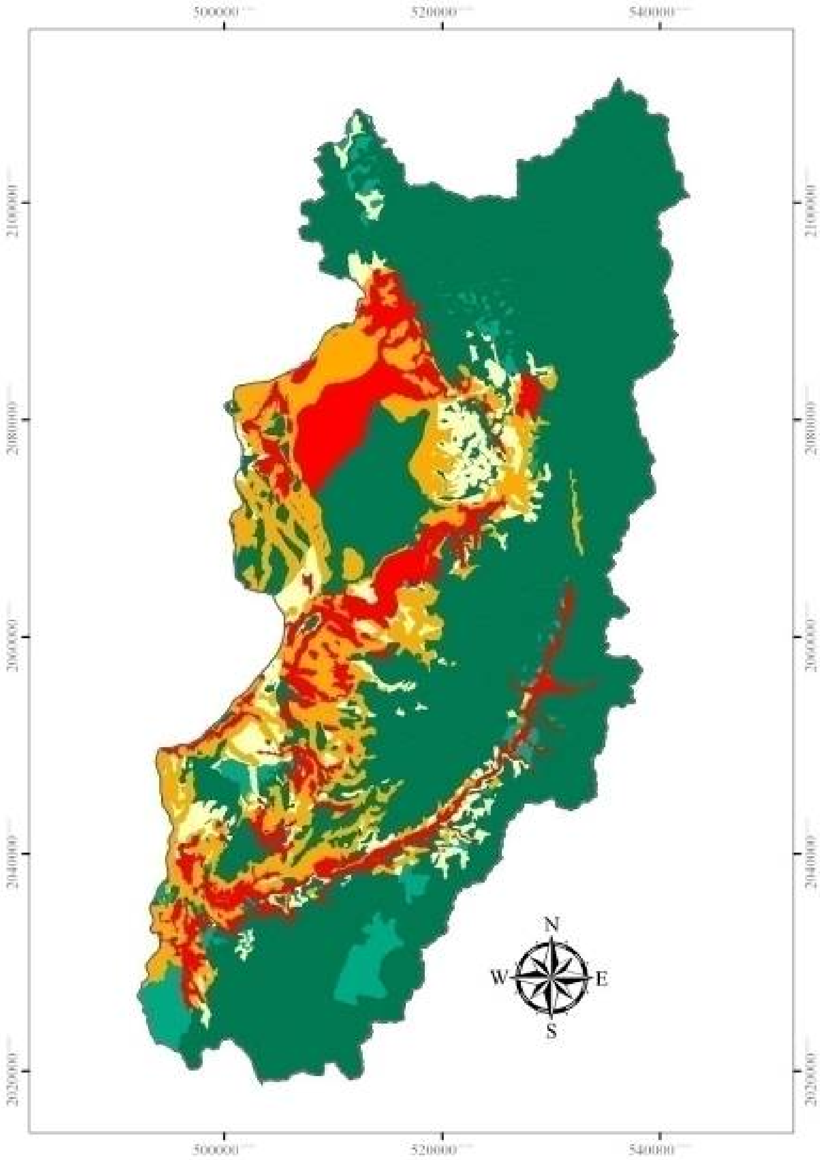


Figure 4.8 Classes of LUT for longan in 2007.

Socio-economic potential of agricultural land suitability for lowland rice and longan were generated by combining of LUT and socio-economic LUR. The distribution of socio-economic potential of agricultural land suitability for lowland rice and longan were shown in Figures 4.9 and Figure 4.10, respectively.

The result indicated that most of socio-economic potential of agricultural land suitability class for lowland rice was currently not suitable area. It coved area of 1,701.89 sq. km (63.07%) and distributed mostly over hills and mountains landform. In contrast, highly and moderate suitable areas for lowland rice were situated in flood plain, alluvial fans and old alluvial terrace and fans and they covering area of 719.94 sq. km (26.68%) of the total area.

For longan, it was found that most of socio-economic potential of agricultural land suitability class was marginally suitable area. It coved area about 1,432.39 sq. km (53.09%) and distributed mostly over hills and mountains landform. In contrast, highly and moderate suitable areas were situated in flood plain, alluvial fans and old alluvial terrace and fans and covering area of 550.19 sq. km (20.39%).



Classes of SPALS for lowland rice

S_1: Highly suitable.

S_2: Moderately suitable.

S_3: Marginally suitable.

N_1: Currently not suitable.

N_2: Permanently not suitable.

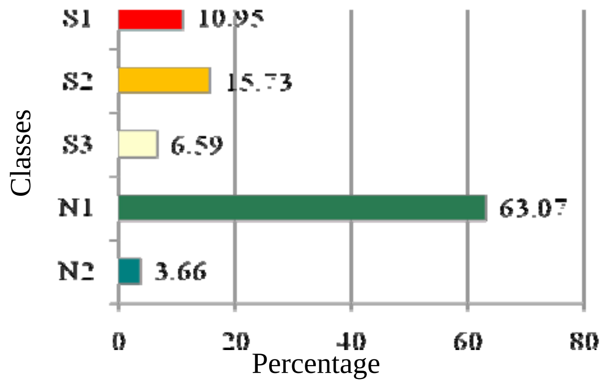
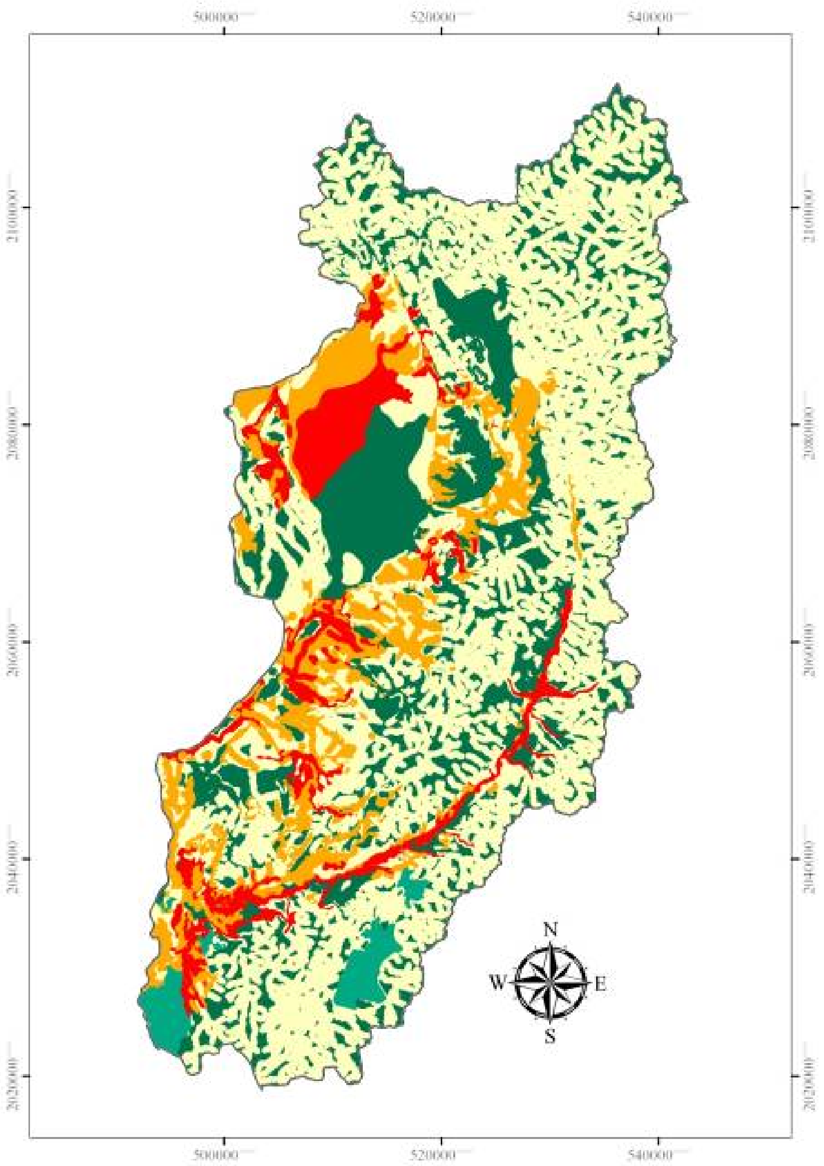


Figure 4.9 Classes of SPALS for lowland rice.



Classes of SPALS for longan

- S_1: Highly suitable.
- S_2: Moderately suitable.
- S_3: Marginally suitable.
- N_1: Currently not suitable.
- N_2: Permanently not suitable.

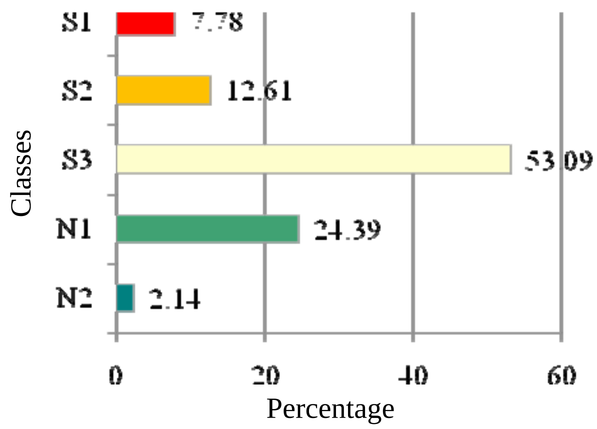


Figure 4.10 Classes of SPALS for longan.

4.4.3 ESF index

The results showed the effect of socio-economic factor on bio-physical factors for lowland rice and longan could be explained in positive, neutral and and negartive effects as shown in Figuers 4.11 and 4.12, respeclily.

For lowland rice, higher precentage of ESFI classes were in moderately negative effect (37.98%) and highly negative effect (24.67%) whereas the positive effect found mostly in moderrate positive effect (30.70%).

For longan , highest precentage of ESFI classes were in moderately positive effect (57.79%) whereas the negative effect found mostly in highly negartive effect classes (24.67%).

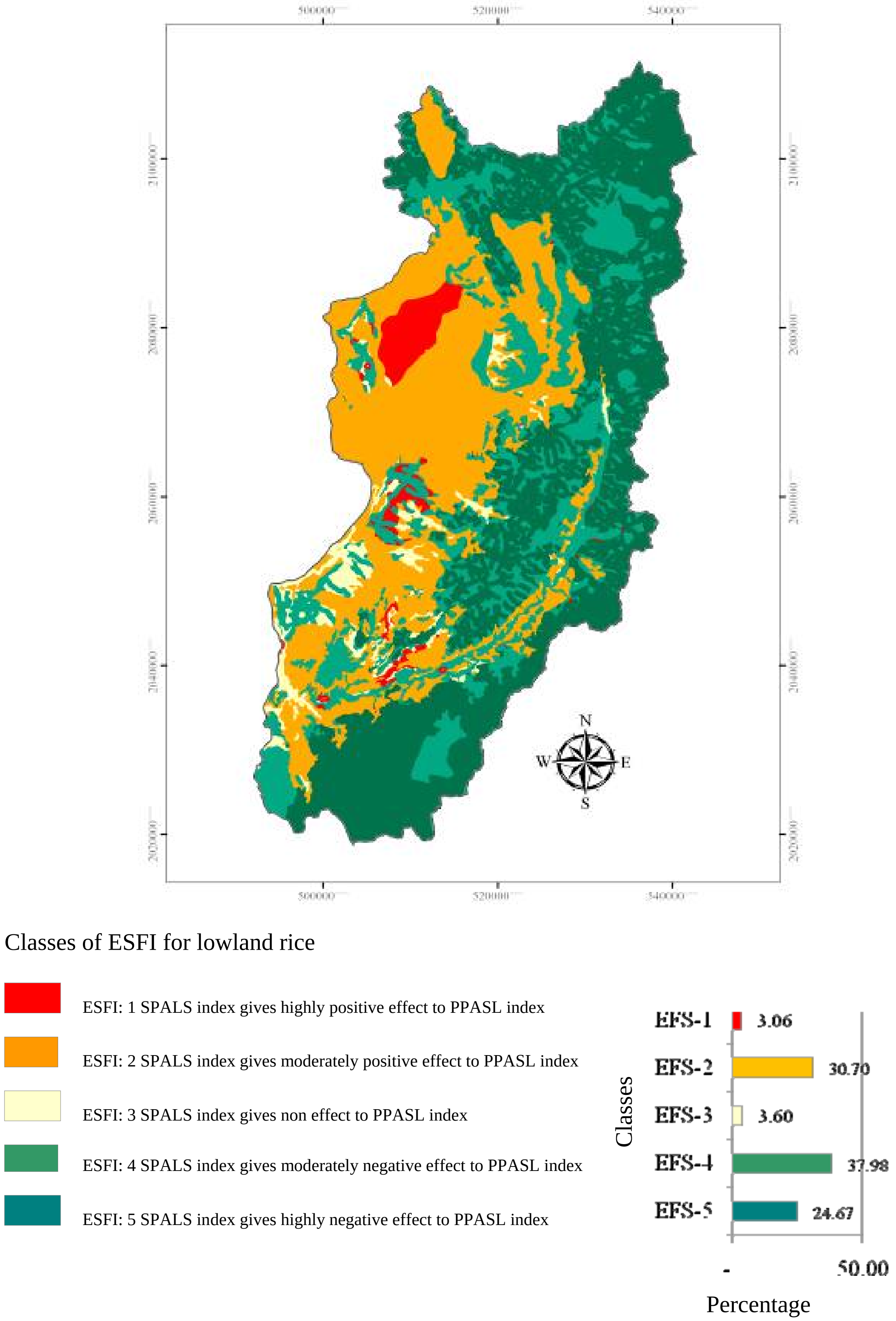
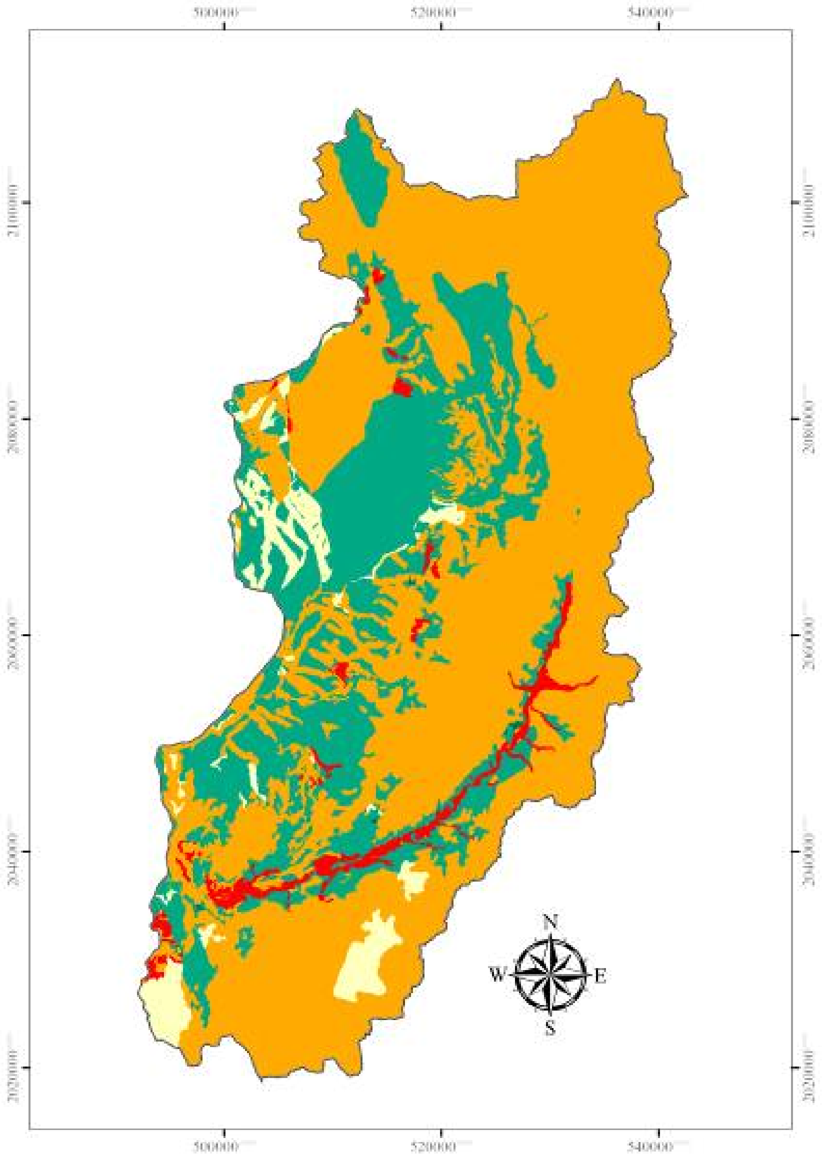


Figure 4.11 Classes of ESFI for lowland rice.



Classes of ESFI for longan

ESFI: 1 SPALS index gives highly positive effect to PPASL index

ESFI: 2 SPALS index gives moderately positive effect to PPASL index

ESFI: 3 SPALS index gives non effect to PPASL index

ESFI: 4 SPALS index gives moderately negative effect to PPASL index

ESFI: 5 SPALS index gives highly negative effect to PPASL index

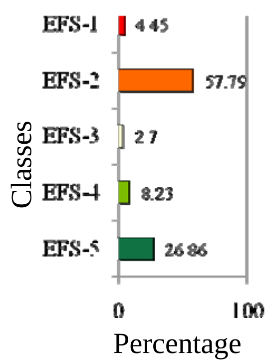


Figure 4.12 Classes of ESFI for longan.

4.4.4. Agricultural land suitability (ALS)

Under ALS model, agricultural land suitability was evaluated from PPALS and SPALS indexes.

(1) ALS for lowland rice

The results of ALS for lowland rice were pointed out that most of agricultural land suitability class was permanently unsuitable covering area of 1,530.90 sq. km (56.74%) and distributed mostly over hills and mountains landform. In contrast, highly and moderate suitable areas for lowland rice were situated in flood plain and alluvial and they covering area of 274.84 sq. km (10.22%) as shown in Figure 4.13.

(2) ALS for longan

The results of ALS for longan were found that most of agricultural land suitability class was not suitable for longan covering area of 1,725.99 sq. km (64.18%) and distributed mostly over hills and mountains landform. In contrast, highly and moderate suitable areas for longan were situated in old alluvial terraces and fans and covering area of 465.50 sq. km (7.13%) as shown in Figure 4.14.

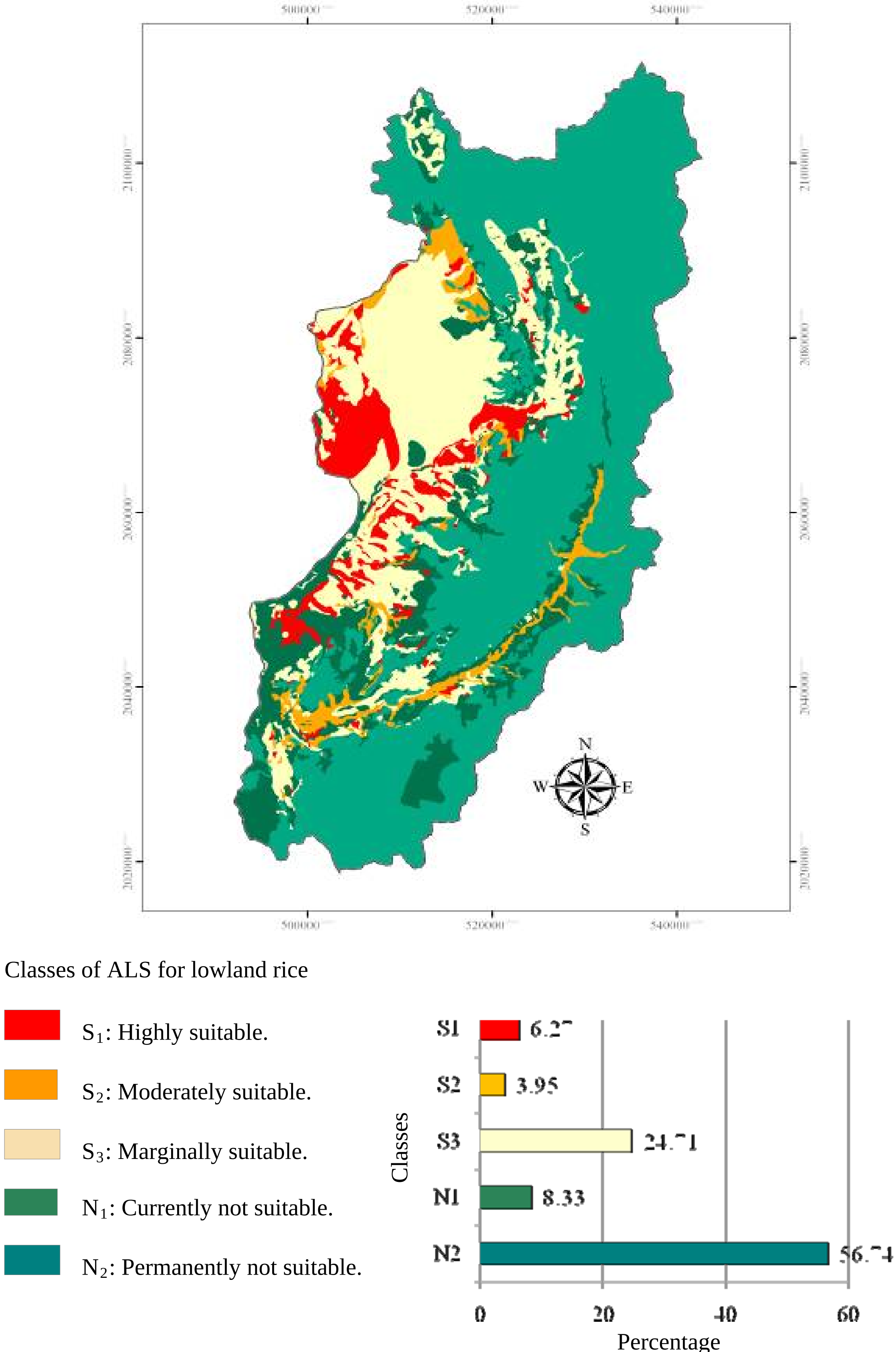
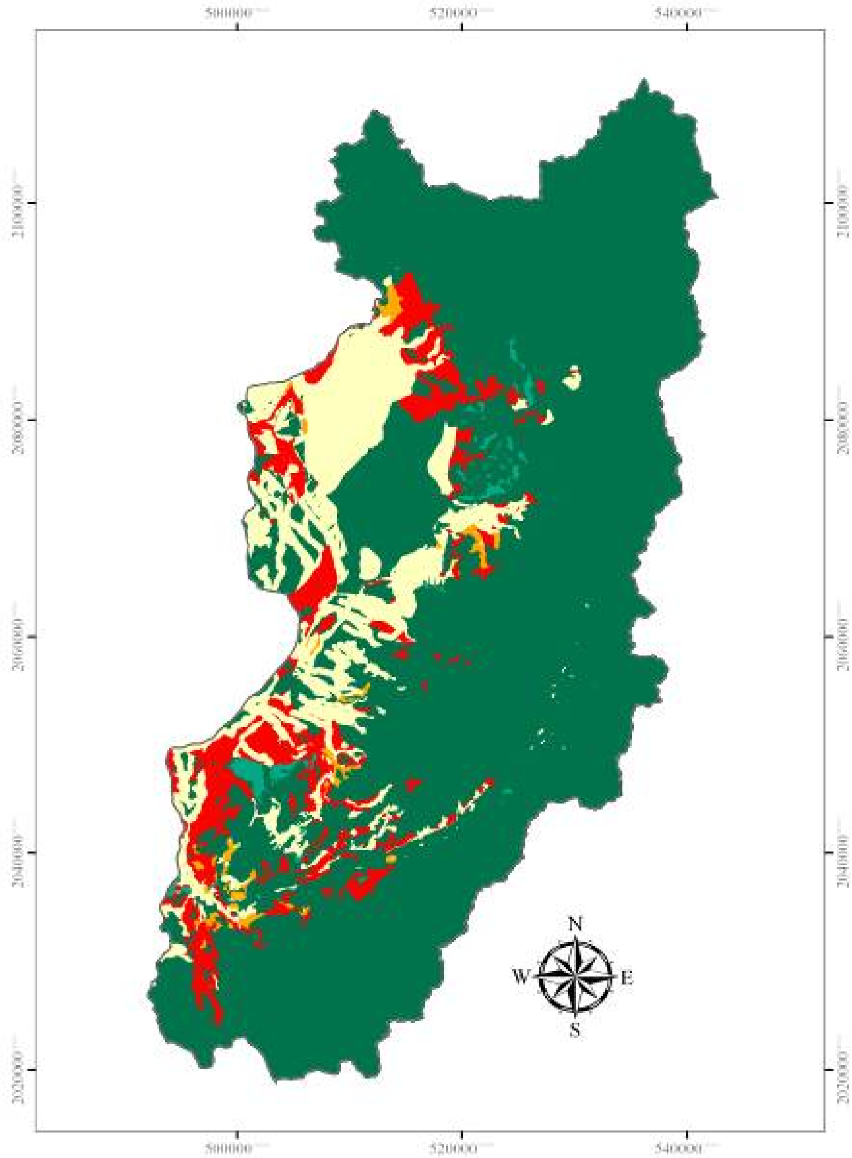


Figure 4.13 Classes of ALS for lowland rice.



Classes of ALS for longan

S_1: Highly suitable.

S_2: Moderately suitable.

S_3: Marginally suitable.

N_1: Currently not suitable.

N_2: Permanently not suitable.

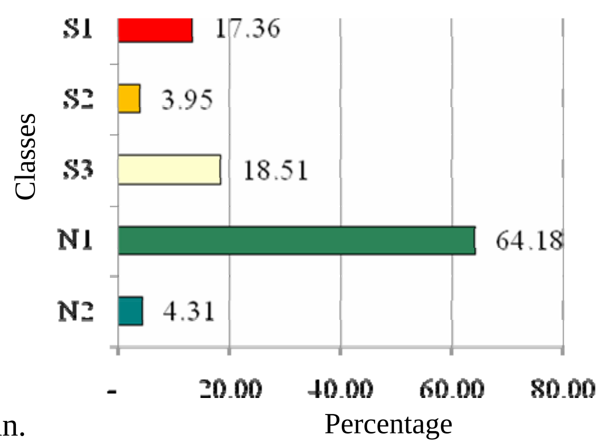


Figure 4.14 Classes of ALS for longan.

4.5 Conclusions

4.5.1 Physical potential agricultural land suitability (PPALS)

Most of physical potential of agricultural land suitability class for lowland rice and longan which distributed over hills and moraines landform, were both clarified in marginally unsuitable covering are of 58.81% and 53.09% of total area, respectively.

Whereas highly and moderate suitability classes for lowland rice (27.27%) were higher than longan (10.22%). These classes for lowland rice distributed in semi-recent terrace and old reverine alluvium while for longan situated in flood plain, alluvial fan and old alluvial terrace and fans.

4.5.2 Socio-economic Potential Agricultural Land Suitability (SPLAS)

Most of socio-economic potential of agricultural land suitability class for lowland rice and longan which distributed over hills and mountain landform were both classified as marginally unsuitable covering area of 63.07% and 53.09%, respectively. Highly and moderate suitable areas for longan which situated in semi-recent terrace and old reverine alluvium, whereas lowland rice distributed in flood plain, alluvial fans and old alluvial terrace and fans.

4.5.3 Effect of Socio-economic factor index (ESFI)

It was found that for longan was in the moderate positive effect (57.79%) whereas for lowland rice was in the moderate negative effect (37.98%) that was represented effect values in overall area as positive for longan and negative for lowland rice.

4.5.4 Agricultural land suitability (ALS)

Most of agricultural land suitability class for lowland rice and longan which distributed over hills and moraines landform was both clarified in marginally unsuitable covering are of 56.74% and 69.87% of total area respectively. Highly and moderate suitable areas for longan while situated in semi-recent terrace and old reverine alluvium, covered 7.31% of total area. These areas the same classes for lowland rice were found higher which had only 6.87% of total area and distributed in old alluvial terraces and fan.

4.6 Discussions

The results concluded that PPALs and SPALS module gave similar results for lowland rice and longan which were likely more than 50% of unsuitable classes. This could be explained in term of physical properties that both lowland rice and longan grown in unsuitable areas such as hill and mountains. Whereas the outputs of ESFI module produced positive classes for longan (62.24%) but negative classes for lowland rice (72.65%). Because the longan growing areas were growing in farmers own land and having expertise on growing them whereas most lowland rice growing areas were in the rent farm and having less expertise of growing rice. However the overall results as ALS indexes for both lowland rice and longan were fallen in the unsuitable classes as 65.07% and 68.49%, respectively. This meant that overall physical and socio-economic factors were not suitable for both lowland rice and longan.

CHAPTER V

STABILITY EVALUATION OF AGRICULTURAL LAND UTILIZATION CHANGE

5.1 Introduction

The Stability of Land Utilization Change Model (SLUC model) for stability of agricultural land utilization based on intensity of agricultural land utilization and recent past-to-present land use change. SLUC model applied MCDM method with AHP and geostatistical technique to integrate spatial database and stability indicators for agricultural land utilization of lowland rice and longan. A framework for land evaluation of FAO (1976) and sustainable land management of World Bank (2006) were used as a guideline for intensity of agricultural land utilization. The BMN database in 2007, existing land use types in 2007 and field data collection were used in the process of SLUC model.

5.2 Objective

To build up a model that can evaluate stability of agricultural land utilization based on existing land use in 2007 and recent past-to-present of land use change, for lowland rice and longan cropping system using MCDM methods.

5.3 Stability of Land Utilization Change model (SLUC model)

Basically, SLUC model will compare the existing land use in 2007 with agricultural land use change occurring in the short period (2002-2007) for lowland rice and agricultural land use change occurring in the long period (1997-2007) for longan. Results will explain stability of agricultural land utilization. SLUC model consisted of three modules: (1) Agricultural Land Utilization Intensity Indexing (ALUI module), (2) Agricultural Land Utilization Change indexing module (ALUC module), and (3) Stability of Land Utilization Change indexing module as (SLUC module) shown in Figure 5.1.

5.3.1 Agricultural Land Utilization Intensity indexing module (ALUI module)

Landsat-TM data (25 November 2007) was classified for existing land use type 2007 by digital image processing and visual interpretation and it was verified by field observation and comparison with high resolution image of IKONOS 2002. The existing land use type 2007 will be normalized by intensity of agricultural land utilization for lowland rice and longan using AHP method as shown in Figure 5.2.

The intensity of agricultural land utilization was classified into 8 groups based on a Framework for Land Evaluation of FAO (1976) as shown in the following:

(a) Agricultural nutrient balance and present farm practices,

(b) Crop yields,

(c) Fertilizers management,

(d) Farm pest management,

(e) Farm management and marketing,

(f) Agricultural soil conservation management,

(g) Irrigation management and

(h) Whole household farm management.

This intensity of agricultural land utilization was compatible with Sustainable land Management of World Bank (2006) as shown in Appendix D. In this study the intensity of agricultural land utilization for lowland rice will be extracted from socio-economic potential agricultural land utilization while longan will be extracted both from BMN database in 2007 and questionnaire field survey in 2007. The socio-economic potential for agricultural land utilization included (1) capital intensity, (2) cropping system, (3) economic information, (4) environment impact, (5) farm operations, (6) infrastructure, (7) irrigation infrastructure, (8) irrigation method, (9) labour intensity, (10) land tenure, (11) livestock, (12) markets, (13) material inputs, (14) power extent of human, (15) size and shape farms, (16) technical skills, (17) water rights, (18) water supply, and (19) yield. The relationship between intensity of agricultural land utilization and socio-economic potential for agricultural land utilization was summarized as shown in Table 5.1.

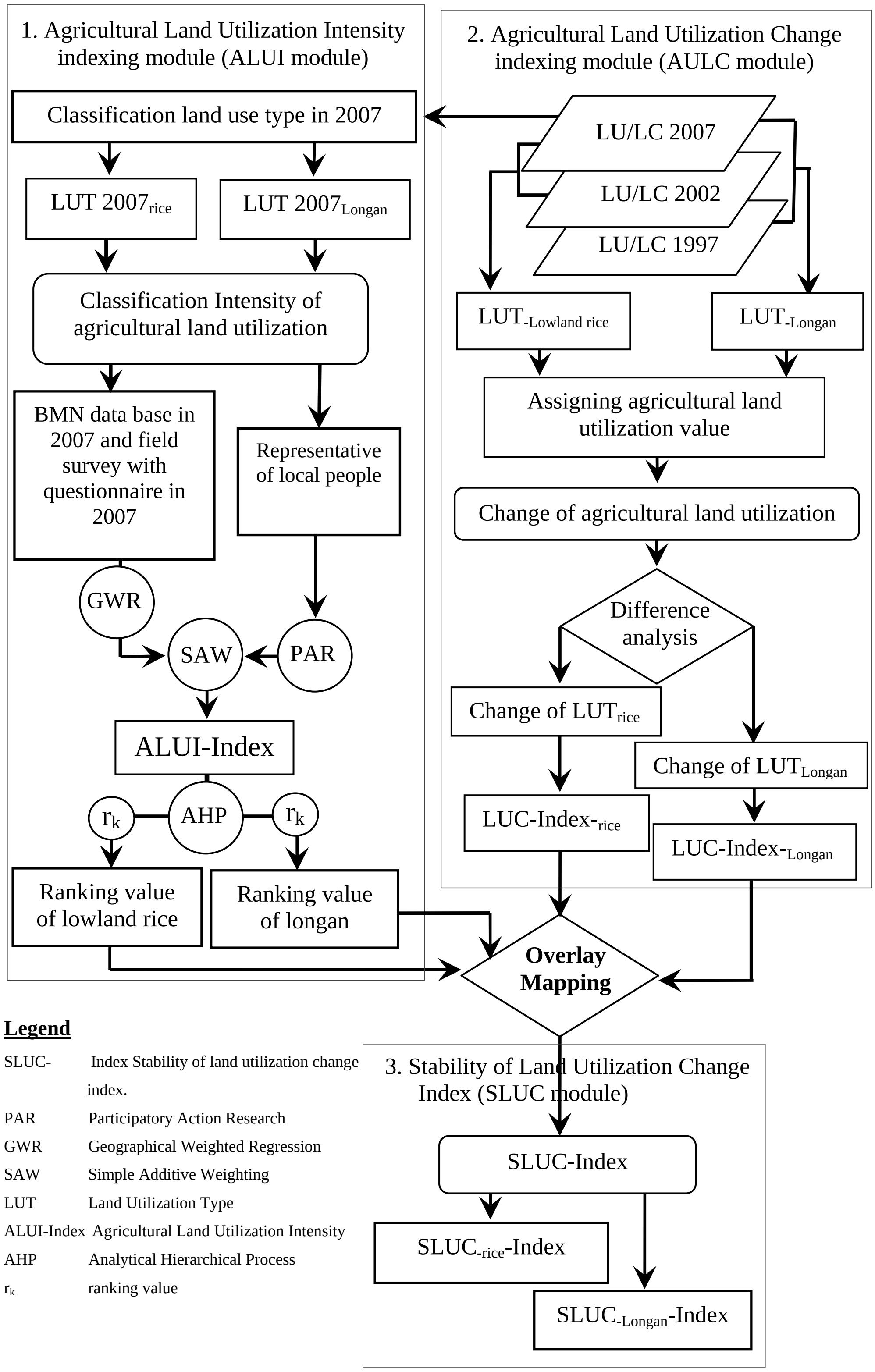


Figure 5.1 Component of SLUC model.

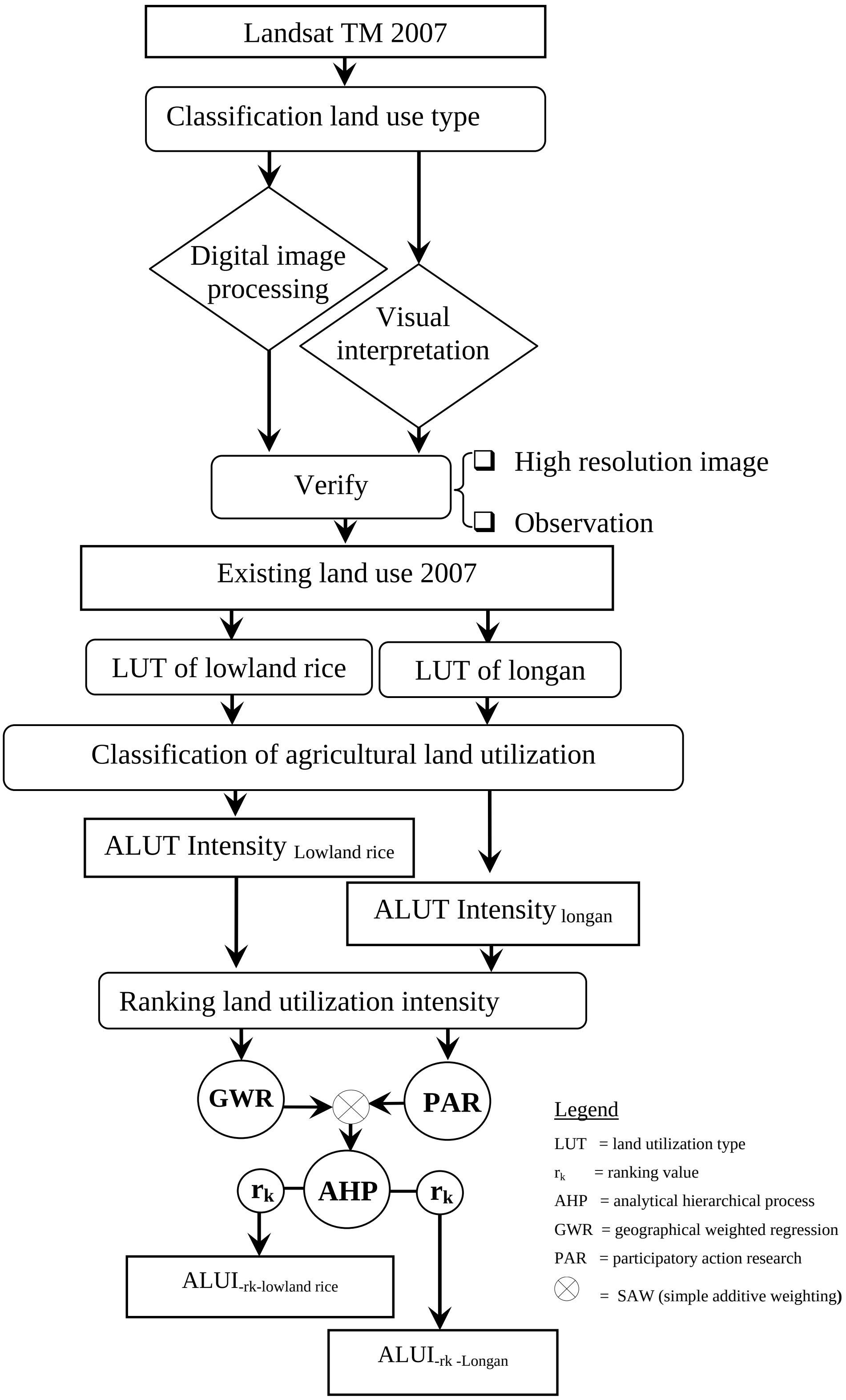


Figure 5.2 Workflow of ALUI module.

Table 5.1 Intensity of agricultural land utilization and socio-economic potential for agricultural land utilization.

Agricultural land utilization Intensity [1]		**Socio-economic potential for agricultural land utilization**[2]	
(A)	Agricultural nutrient balance and present farm practices	(1)	Cropping system
		(2)	Labour intensity
		(3)	Farm operations
		(4)	Size and shape farms
(B)	Crop yields	(5)	Yields and production.
(C)	Fertilizers management	(6)	Material inputs
(D)	Farm pest management	(7)	Technical skills
(E)	Farm management and marketing	(8)	Infrastructure
		(9)	Markets
(F)	Agricultural soil conservation management	(10)	Environment al impact
(G)	Irrigation management	(11)	Irrigation infrastructure
		(12)	Irrigation method
		(13)	Water supply
(H)	Whole household farm management	(14)	Capital intensity
		(15)	Economic information
		(16)	Land tenure
		(17)	Livestock
		(18)	Power extent of human
		(19)	Water rights

Note: [1] FAO Framework (1976) and World Bank (2006).
[2] BMN database in 2007 and field survey with questionnaire in 2007.

Under this module, normalization of Agricultural Land Utilization Intensity index (ALUI-index) for lowland rice and longan were parallel processed in 2 steps.

Step 1: Normalization of existing land use for lowland rice and longan with socio-economic data.

Existing land use types in 2007 were firstly normalized with socio-economic factors for agricultural land utilization using SAW method. Then, the existing land use types in 2007 will be assigned score values (0-100) and weight value (0-100) based on 19 socio-economic factors for agricultural land utilization in 8 groups of agricultural land utilization intensity as shown in Table 5.2 and Table 5.3, respectively. Afterword values of land utilization intensity were generated between 0 and 1 using equation 5.1 and 5.2.

Agricultural Land Utilization Intensity index for lowland rice:

$$\text{ALUI-Index}_{rice} = \sum_{i=1}^{23} \sum_{j=1}^{8} (\text{LUI}_{rice-2007})(\text{LUT}_{rice-2007}) \quad (5.1)$$

Agricultural Land Utilization Intensity index for longan:

$$\text{ALUI-Index}_{longan} = \sum_{i=1}^{23} \sum_{j=1}^{8} (\text{LUI}_{longan-2007})(\text{LUT}_{longan-2007}) \quad (5.2)$$

Where,

ALUI-Index_{rice} is agricultural land utilization index for lowland rice.

ALUI-Index_{rice} is agricultural land utilization index for longan.

$LUI_{rice\ -2007}$ is land utilization value intensity for lowland rice in 2007 (LUT = f_x (LUI_A, LUI_B, LUI_C,…LUI_H)). These values were then normalized to new values vary between 0 and 1 (all value divide by 100).

$LUI_{longan\text{-}2007}$ is land utilization intensity value for lowland rice in 2007 (LUT = f_x (LUI_A, LUI_B, LUI_C,…LUI_H)). These values were then normalized to new values vary between 0 and 1 (all value divide by 100).

$LUT_{rice\text{-}2007}$ is land utilization type value for lowland rice in 2007.

$LUT_{longan\text{-}2007}$ is land utilization type value for longan in 2007.

Step 2: Ranking of the ALUI-indexes for lowland rice and longan.

Rankling of the ALUT-index were normalized again using AHP techniques of MCDM method. The importance value given by local people were interpolated by using the GWR and multiplied with each layer of land utilization intensity between 1 and 9. The LUI will then generate ranking value as shown in Table 5.4. Finally, ALUI-indexes based on ranking values for lowland rice and longan were identified.

Table 5.2 Assigning scores and weighting values for normalization of each ALUI for lowland rice using SAW method.

ITEM	LU/LC TYPES	**Score (S_{ij})**	**$w_{(1)}$**	(1) Cropping w_1= 0.25	(2) Labour intensity w_1= 0.25	(3) Farm operations w_1= 0.25	(4) Size and shape farms w_1 = 0.25	(5) Yields and production w_1 = 1.00	(6) Material inputs w_1 = 1.00	(7) Technical skills w_1 = 1.00	(8) Infrastructure w_1= 0.50	(9) Markets w_1 = 0.50	10) Environment Impact w_1 = 1.00	(11) Irrigation infrastructure w_1 = 0.33	(12) Irrigation method w_1 = 0.33	(13) Water supply w_1= 0.33	14) Capital intensity w_1 = 0.16	(15) Economic information w_1 = 0.16	(16) Land tenure w_1 = 0.16	(17) Livestock w_1= 0.16	(18) Power extent of human w_1 = 0.16	(19) Water rights w_1 = 0.16
			$w_{(2)}$	**A**				**B**	**C**	**D**	**E**		**F**	**G**			**H**					
				0.40				0.70	0.60	0.98	0.99		0.50	0.27			0.15					
1	Scrub and Grass	0.45	w_1	x		x	x	x	x				x					x	x	x		
2	Bush fallow	0.65	w_2	x		x	x	x	x				x				x	x	x	x		
3	Cattle farm house	0.30	w_3						x	x							x		x	x		
4	Poultry farm house	0.30	w_4						x	x							x		x	x		
5	Lowland rice	1.00	w_5	x	x	x	x	x	x	x			x	x	x	x	x	x	x	x	x	x
6	Longan	0.45	w_6	x	x	x	x	x	x	x			x	x	x	x	x	x	x	x	x	x
7	Village	0.10	w_7		x		x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
8	High land village	0.10	w_8		x		x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
9	Allocated land project	0.00	w_9							x	x	x	x				x					
10	City, commercial and Service	0.00	w_{10}							x	x	x	x									

Table 5.2 Assigning scores and weighting values for normalization of each ALUI for lowland rice using SAW method. (Continued)

ITEM	LU/LC TYPES	Score (S_{ij})	$w_{(1)}$	(1) Cropping w_1= 0.25	(2) Labour intensity w_1= 0.25	(3) Farm operations w_1= 0.25	(4) Size and shape farms w_1 = 0.25	(5) Yields and production w_1 = 1.00	(6) Material inputs w_1 = 1.00	(7) Technical skills w_1 = 1.00	(8) Infrastructure w_1= 0.50	(9) Markets w_1 = 0.50	10) Environment Impact w_1 = 1.00	(11) Irrigation infrastructure w_1 = 0.33	(12) Irrigation method w_1 = 0.33	(13) Water supply w_1= 0.33	14) Capital intensity w_1 = 0.16	(15) Economic information w_1 = 0.16	(16) Land tenure w_1 = 0.16	(17) Livestock w_1= 0.16	(18) Power extent of human w_1 = 0.16	(19) Water rights w_1 = 0.16
			$w_{(2)}$	**A**				**B**	**C**	**D**	**E**		**F**	**G**			**H**					
				0.40				0.70	0.60	0.98	0.99		0.50	0.27			0.15					
11	Deciduous forest	0.35	w_{11}										x									
12	Mixed deciduous forest	0.10	w_{12}										x									
13	Mixed orchard/Disturbed deciduous forest	0.10	w_{13}										x									
14	Mixed swidden cultivation	0.10	w_{14}										x									
15	Hill evergreen forest	0.10	w_{15}										x									
16	Recreation area	0.10	w_{16}										x									
17	Factory	0.00	w_{17}						x	x		x					x					
18	Golf course	0.20	w_{18}										x									
19	Industrial estate	0.00	w_{19}						x	x		x					x					
20	Institutional land	0.00	w_{20}						x	x		x					x					
21	Mine	0.00	w_{20}										x									

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Table 5.2 Assigning scores and weighting values for normalization of each ALUI for lowland rice using SAW method. (Continued)

ITEM	LU/LC TYPES	Score (S_{ij})	$w_{(1)}$	(1) Cropping w_1= 0.25	(2) Labour intensity w_1= 0.25	(3) Farm operations w_1= 0.25	(4) Size and shape farms w_1 = 0.25	(5) Yields and production w_1 = 1.00	(6) Material inputs w_1 = 1.00	(7) Technical skills w_1 = 1.00	(8) Infrastructure w_1= 0.50	(9) Markets w_1 = 0.50	10) Environment Impact w_1 = 1.00	(11) Irrigation infrastructure w_1 = 0.33	(12) Irrigation method w_1 = 0.33	(13) Water supply w_1= 0.33	14) Capital intensity w_1 = 0.16	(15) Economic information w_1 = 0.16	(16) Land tenure w_1 = 0.16	(17) Livestock w_1= 0.16	(18) Power extent of human w_1 = 0.16	(19) Water rights w_1 = 0.16
			$w_{(2)}$	**A**				**B**	**C**	**D**	**E**		**F**	**G**			**H**					
				0.40				0.70	0.60	0.98	0.99		0.50	0.27			0.15					
22	Lake	0.10	w_{21}							x				x	x	x						x
23	Reservoir	0.00	w_{23}							x				x	x	x						x

where:

A Agricultural nutrient balance and present farm practices

B Crop yields

C Fertilizers management

D Farm pest management

E Farm management and marketing

F Agricultural soil conservation management

G Irrigation management

H Whole household farm management

x Applied score and weight values

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Table 5.3 Assigning scores and weighting values for normalization of each ALUI for longan using SAW method.

	LU/LC TYPES	Score (S_{ij})	$w_{(1)}$	(1) Cropping w_1= 0.25	(2) Labour intensity w_1= 0.25	(3) Farm operations w_1= 0.25	(4) Size and shape farms w_1 = 0.25	(5) Yields and production w_1 = 1.00	(6) Material inputs w_1 = 1.00	(7) Technical skills w_1 = 1.00	(8) Infrastructure w_1= 0.50	(9) Markets w_1 = 0.50	10) Environment Impact w_1 = 1.00	(11) Irrigation infrastructure w_1 = 0.33	(12) Irrigation method w_1 = 0.33	(13) Water supply w_1= 0.33	14) Capital intensity w_1 = 0.16	(15) Economic information w_1 = 0.16	(16) Land tenure w_1 = 0.16	(17) Livestock w_1= 0.16	(18) Power extent of human w_1 = 0.16	(19) Water rights w_1 = 0.16
			$w_{(2)}$	**A**				**B**	**C**	**D**	**E**		**F**	**G**			**H**					
				0.31				0.83	0.04	0.49	0.39		0.72	0.80			0.43					
1	Scrub and Grass	0.55	w_1	x		x	x	x	x				x					x	x	x		
2	Bush fallow	0.65	w_2	x		x	x	x	x				x				x	x	x	x		
3	Cattle farm house	0.30	w_3						x	x							x		x	x		
4	Poultry farm house	0.30	w_4						x	x							x		x	x		
5	Lowland rice	0.45	w_5	x	x	x	x	x	x	x			x	x	x	x	x	x	x	x	x	x
6	Longan	1.00	w_6	x	x	x	x	x	x	x			x	x	x	x	x	x	x	x	x	x
7	Village	0.10	w_7		x		x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
8	High land village	0.10	w_8		x		x		x	x	x	x	x	x	x	x	x	x	x	x	x	x
9	Allocated land project	0.00	w_9							x	x	x	x				x					
10	City, commercial and Service	0.00	w_{10}							x	x	x	x									

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Table 5.3 Assigning scores and weighting values for normalization of each ALUI for longan using SAW method. (Continued)

	LU/LC TYPES	Score (S_{ij})	$w_{(1)}$	(1) Cropping w_1= 0.25	(2) Labour intensity w_1= 0.25	(3) Farm operations w_1= 0.25	(4) Size and shape farms w_1 = 0.25	(5) Yields and production w_1 = 1.00	(6) Material inputs w_1 = 1.00	(7) Technical skills w_1 = 1.00	(8) Infrastructure w_1= 0.50	(9) Markets w_1 = 0.50	10) Environment Impact w_1 = 1.00	(11) Irrigation infrastructure w_1 = 0.33	(12) Irrigation method w_1 = 0.33	(13) Water supply w_1= 0.33	14) Capital intensity w_1 = 0.16	(15) Economic information w_1 = 0.16	(16) Land tenure w_1 = 0.16	(17) Livestock w_1= 0.16	(18) Power extent of human w_1 = 0.16	(19) Water rights w_1 = 0.16
			$w_{(2)}$	**A**				**B**	**C**	**D**	**E**		**F**	**G**			**H**					
				0.31				0.83	0.04	0.49	0.39		0.72	0.80			0.43					
11	Deciduous forest	0.35	w_{11}										x									
12	Mixed deciduous forest	0.10	w_{12}										x									
13	Mixed orchard/Disturbed deciduous forest	0.65	w_{13}										x									
14	Mixed swidden cultivation	0.10	w_{14}										x									
15	Hill evergreen forest	0.10	w_{15}										x									
16	Recreation area	0.10	w_{16}										x									
17	Factory	0.00	w_{17}						x	x		x					x					
18	Golf course	0.20	w_{18}										x									
19	Industrial estate	0.00	w_{19}						x	x		x					x					
20	Institutional land	0.00	w_{20}						x	x		x					x					
21	Mine	0.00	w_{20}										x									

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Table 5.3 Assigning scores and weighting values for normalization of each ALUI for longan using SAW method. (Continued)

	LU/LC TYPES	Score (S_{ij})	$w_{(1)}$	(1) Cropping w_1= 0.25	(2) Labour intensity w_1= 0.25	(3) Farm operations w_1= 0.25	(4) Size and shape farms w_1 = 0.25	(5) Yields and production w_1 = 1.00	(6) Material inputs w_1 = 1.00	(7) Technical skills w_1 = 1.00	(8) Infrastructure w_1= 0.50	(9) Markets w_1 = 0.50	10) Environment Impact w_1 = 1.00	(11) Irrigation infrastructure w_1 =	(12) Irrigation method w_1 = 0.33	(13) Water supply w_1= 0.33	14) Capital intensity w_1 = 0.16	(15) Economic information w_1 = 0.16	(16) Land tenure w_1 = 0.16	(17) Livestock w_1= 0.16	(18) Power extent of human w_1 = 0.16	(19) Water rights w_1 = 0.16
				A				**B**	**C**	**D**	**E**		**F**	**G**			**H**					
			$w_{(2)}$	0.31				0.83	0.04	0.49	0.39		0.72	0.80			0.43					
22	Lake	0.10	w_{21}							x				x	x	x						x
23	Reservoir	0.00	w_{23}							x				x	x	x						x

where:

A	Agricultural nutrient balance and present farm practices	F	Agricultural soil conservation management
B	Crop yields	G	Irrigation management
C	Fertilizers management	H	Whole household farm management
D	Farm pest management	**x**	Applied score and weight values
E	Farm management and marketing		

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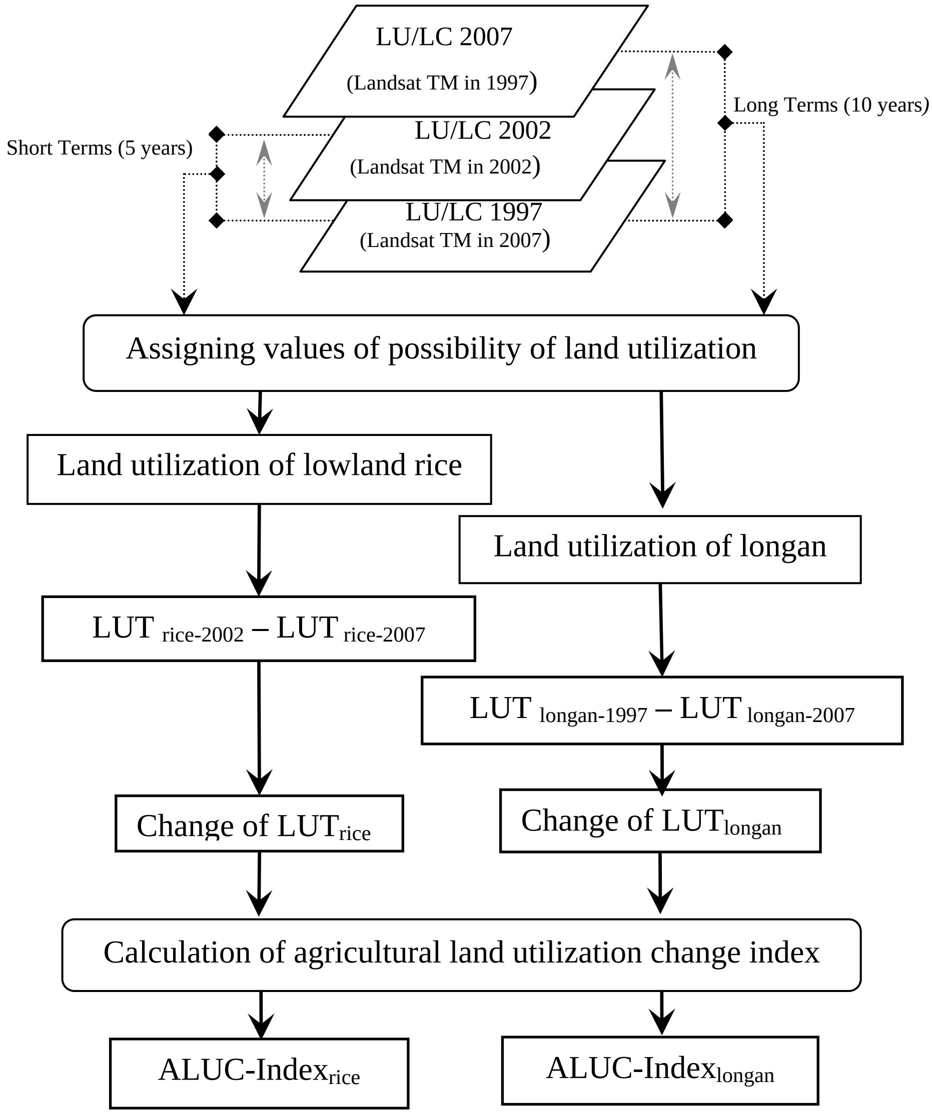
Table 5.4 Classes of importance level for land utilization index.

ALUI-Index	Definition	Ranking importance value
ALUI-0	Not importance	0-9
ALUI-1	Equal importance	10-19
ALUI-2	Equal to moderately importance	20-29
ALUI-3	Moderate importance	30-39
ALUI-4	Moderate to strong importance	40-49
ALUI-5	Strong importance	50-59
ALUI-6	Strong to very strong importance	60-69
ALUI-7	Very strong importance	70-79
ALUI-8	Very to extremely strong importance	80-89
ALUI-9	Extreme importance	90-100

5.3.2 Agricultural Land Utilization Change index module (ALUC module) for lowland rice and longan

Land use classes in 1997, 2002, and 2007 were classified from Landsat-TM data taken in corresponding years by digital image processing. Visual interpretations were used to calculate agricultural land utilization change indexes using normalization and overlay techniques (Figure 5.3). Change of land utilization for lowland rice as short time cropping system and longan as long time cropping system were identified from land use data between 2002 and 2007 and between 1997 and 2002, respectively.



Legend

ALUCindex	Agricultural Land Utilization Change index.
Change of LUT_{rice}	is land utilization change lowland rice.
Change of LUT_{longan}	is land utilization change for longan.
$LUT_{rice-2002}$	is land utilization value for lowland rice in 2002.
$LUT_{rice-2007}$	is land utilization value for lowland rice in 2007.
$LUT_{longan-1997}$	is land utilization value for longan in 1997.
$LUT_{longan-2007}$	is land utilization value for longan in 2007

Figure 5.3 Workflow of ALUC module.

Under this module, ALUC-Indexes for lowland rice and longan were parallel procssed in 3 steps as follows:

Step 1: Assigning agricultural land utilization value for lowland rice and longan:

Land use change classes in 1997, 2002 and 2007 were assigned values (0-100) for possibility of land utilization in short time (between 2002 and 2007) for lowland rice (0-100) and long time (between 1997 and 2007) for longan as shown in Table 5.5 and Table 5.6.

Step 2: Change of agricultural land utilization:

Changes of land utilization for lowland rice and longan were separately calculated by the following equation 5.3 and 5.4.

For low land rice:

$$\text{Change of } LUT_{rice} = LUT_{rice\text{-}2002} - LUT_{rice\text{-}2007} \tag{5.3}$$

For longan:

$$\text{Change of } LUT_{longan} = LUT_{longan\text{-}1997} - LUT_{longan\text{-}2007} \tag{5.4}$$

Where,

Change of LUTrice is land utilization change lowland rice.

Change of LUTlongan is land utilization change for longan.

LUTrice - 2002 is land utilization value for lowland rice in 2002.

LUTrice - 2007 is land utilization value for lowland rice in 2007.

LUTlongan - 1997 is land utilization value for longan in 1997.

LUTlongan - 2007 is land utilization value for longan in 2007.

Table 5.5 Assigning important values to land utilization for lowland rice.

NO	LU/LC Type	LU/LC in 2002	LU/LC in 2007
1	Scrub, Grass and scrub	0.45	0.45
2	Bush fallow	0.65	0.65
3	Cattle farm house	0.30	0.30
4	Poultry farm house	0.30	0.30
5	Lowland rice	1.00	1.00
6	Longan	0.45	0.45
7	Village	0.10	0.10
8	High land village	0.10	0.10
9	Allocated land project	0.00	0.00
10	City, town, commercial and Service	0.00	0.00
11	Deciduous forest	0.20	0.20
12	Mixed deciduous forest,	0.10	0.10
13	Mixed orchard/Disturbed deciduous forest	0.10	0.10
14	Mixed swidden cultivation	0.10	0.10
15	Hill evergreen forest	0.10	0.10
16	Recreation area	0.00	0.00
17	Factory	0.00	0.00
18	Golf course	0.00	0.00
19	Industrial estate	0.00	0.00
20	Institutional land	0.00	0.00
21	Mine	0.00	0.00
22	Lake	0.20	0.20
23	Reservoir	0.10	0.10

Table 5.6 Assigning important values to land utilization for longan.

NO	LU/LC Type	LU/LC in 1997	LU/LC in 2007
1	Scrub, Grass and scrub	0.55	0.55
2	Bush fallow	0.65	0.65
3	Cattle farm house	0.30	0.30
4	Poultry farm house	0.30	0.30
5	Lowland rice	0.45	0.45
6	Longan	1.00	1.00
7	Village	0.10	0.10
8	High land village	0.55	0.55
9	Allocated land project	0.00	0.00
10	City, town, commercial and Service	0.00	0.00
11	Deciduous forest	0.35	0.35
12	Mixed deciduous forest,	0.20	0.20
13	Mixed orchard/Disturbed deciduous forest	0.65	0.65
14	Mixed swidden cultivation	0.10	0.10
15	Hill evergreen forest	0.10	0.10
16	Recreation area	0.00	0.00
17	Factory	0.00	0.00
18	Golf course	0.00	0.00
19	Industrial estate	0.00	0.00
20	Institutional land	0.00	0.00
21	Mine	0.00	0.00
22	Lake	0.00	0.00
23	Reservoir	0.00	0.00

Each different values of LUT for lowland rice and longan ware rescaled to abolish minus value by additive change values with absolute value of it's minimum value. Basically, new values vary between 0 and 100. These values were then normalized to new values between 0 and 1 (all value divide by 100). The values imply about possibility of land utilization change for lowland rice in short time and longan in long time.

Step 3: Calculation of agricultural land utilization change index:

Land utilization change indexes for lowland rice and longan were separately calculated to evaluate the tendency of land utilization change by equation 5.5 and 5.6.

Agricultural Land utilization change index for low land rice:

$$\text{ALUC - Index}_{\text{rice}} = \frac{(\text{Change of LUT}_{\text{rice}} - \text{Change of LUT}_{\text{longan}})}{(\text{Change of LUT}_{\text{rice}} + \text{Change of LUT}_{\text{longan}})} \quad (5.5)$$

Agricultural land utilization change index for longan:

$$\text{ALUC - Index}_{\text{longan}} = \frac{(\text{Change of LUT}_{\text{longan}} - \text{Change of LUT}_{\text{rice}})}{(\text{Change of LUT}_{\text{longan}} + \text{Change of LUT}_{\text{rice}})} \quad (5.6)$$

Where,

$\text{ALUC-Index}_{\text{rice}}$ is agricultural land utilization change index for low land rice.

$\text{ALUC-Index}_{\text{longan}}$ is agricultural land utilization change index for longan.

$\text{Change of LUT}_{\text{rice}}$ is change of land utilization for low land rice.

$\text{Change of LUT}_{\text{longan}}$ is change of land utilization for longan.

This step ranking value of land utilization change (value -1 to +1) will be generating for lowland rice and longan as shown in the Tables 5.7 and 5.8.

Table 5.7 Classes of ALUI index for lowland rice (tendency of change from lowland rice to longan or vice versa).

ALUC Index	Definition	Ranking importance
$ALUC_{-1-rice}$	Very highly change to longan	-0.70 to -1.00
$ALUC_{-2-rice}$	High change to longan	-0.40 to -0.69
$ALUC_{-3-rice}$	Moderate change to longan	-0.20 to -0.39
$ALUC_{-4-rice}$	Less change to lowland rice	-0.09 to +0.19
$ALUC_{-5-rice}$	Equal change to lowland rice and longan	0.00 to +0.05 and 0.00 to -0.05
$ALUC_{-6-rice}$	Less stability to lowland rice	+0.09 to +0.19
$ALUC_{-7-rice}$	Moderate stability to lowland rice	+0.20 to +0.39
$ALUC_{-8-rice}$	High stability to lowland rice	+0.40 to +0.69
$ALUC_{-9-rice}$	Very highly stability to lowland rice	+0.70 to +1.00

Table 5.8 Classes of ALUI index for longan (tendency of change from lowland rice to longan or vice versa).

ALUC Index	Definition	Ranking importance
$ALUC_{-1\ longan}$	Very highly change to lowland rice	>-0.70 to -1.00
$ALUC_{-2\ longan}$	High change to lowland rice	-0.40 to -0.69
$ALUC_{-3\ longan}$	Moderate change to lowland rice	-0.20 to -0.39
$ALUC_{-4\ longan}$	Less change to lowland rice	-0.09 to +0.19
$ALUC_{-5\ longan}$	Equal change to longan and lowland rice	0.00 to +0.05 and 0.00 to -0.05
$ALUC_{-6\ longan}$	Less stability to longan	+0.09 to +0.19
$ALUC_{-7\ longan}$	Moderate stability to longan	+0.20 to +0.39
$ALUC_{-8\ longan}$	High stability to longan	+0.40 to +0.69
$ALUC_{-9\ longan}$	Very highly stability to longan	+0.70 to +1.00

5.3.3 Stability of land utilization change module (SLUC module).

Under trend of land utilization change module, both ALUI index and ALUC index for longan will be used to calculate of agricultural land utilization stability for lowland rice and longan. Then, the SAW technique was applied to identify agricultural land utilization stability based on scoring and weighting values which were represented by ALUI index and ALUC index. Stability of land utilization change index (SLUC index) for lowland rice and longan were separately calculated by using equation 5.6 and 5.7, respectively:

Stability of land utilization change index for lowland rice

$$\text{SLUC - Index}_{\text{rice}} = \sum_{ii=1}^{n} \text{ALUI - Index}_{\text{i-rice}} \left(\text{ALUC}_{\text{-j-rice}}\right) \qquad (5.6)$$

Stability of land utilization change index for longan:

$$\text{SLUC - Index}_{\text{longan}} = \sum_{ii=1}^{n} \text{ALUI - Index}_{\text{i-longan}} \left(\text{ALUC}_{\text{-j-longan}}\right) \qquad (5.7)$$

Where:

SLUC-Index$_{\text{rice}}$	is stability of land utilization change index for lowland rice
SLUC-Index$_{\text{longan}}$	is stability of land utilization change index for longan
ALUI-Index$_{\text{-j-rice}}$	is agricultural land utilization intensity index for lowland rice.
ALUI-Index$_{\text{-j-longan}}$	is agricultural land utilization intensity index for longan.
ALUC-Index$_{\text{-ij-rice}}$	is agricultural land utilization change index for lowland rice.
ALUC-Index-ij-rice	is agricultural land utilization change index for longan.

Afterward, each SLUC-Index for lowland rice and longan was rescaled to abolish minus value by additive change values with absolute value of it’s minimum value.

The new values of SLUC-Index for lowland rice and longan vary between 0 and 100. These values were normalized to new values between 0 and 1 and they were then categorized into 9 classes for representative stability of agricultural land utilization change index as shown in Table 5.9. SLUC-Index for lowland rice and longan in this study were identified. These values imply about stability of agricultural land utilization change based on socio-economic factors.

Table 5.9 Classes of stability of land utilization change index for lowland rice and longan.

SLUC Index	Definition	Ranking importance value
SLUC-1	Very high (in negative)	-0.75 to -1.00
SLUC-2	High changed (in negative)	-0.50to -0.74
SLUC-3	Moderate changed (in negative)	-0.25 to -0.49
SLUC-4	Less changed (in negative)	-0.01 to -0.24
SLUC-5	Unchanged	0.00
SLUC-6	Less stability (in positive)	+0.01 to +0.24
SLUC-7	Moderate stability (in positive)	+0.25 to +0.49
SLUC-8	High stability (in positive)	+0.50to +0.74
SLUC-9	Very highly stability (in positive)	+0.75 to +1.00

5.4 Results

Stability evaluation results of 3 modules in the agricultural land utilization change could be described according to each module in the SLUC model Figure 5.1.

5.4.1 AULI module

The agricultural land utilization intensity values of lowland rice had minimum value of 0.00, and maximum value of 0.85, mean value of 21.83 and a standard deviation of 18.16. The most important class for agricultural land utilization intensity is equal importance ALUI-1 covering 64.28% of the study area. It implied that the intensity of agricultural land utilization in low terraces hills, and mountains for lowland rice was very low. However, it was found that intensity of agricultural land utilization for lowland rice is rather high in alluvial fan as shown in Figure 5.4.

While, the agricultural land utilization intensity values of longan had minimum value of 0.00, maximum value of 0.90.5, with mean value of 28.35 and standard deviation of 18.49. The most important class for agricultural land utilization intensity is equal importance (ALUI-1) covering 57.52% of the study area. It implies that the intensity of agricultural land utilization in low terraces hills and mountains for longan was very low. However, it was found that in dissected erosion surface of hills and low terraces area, agricultural land utilization intensity for longan was rather high as shown in Figure 5.5.

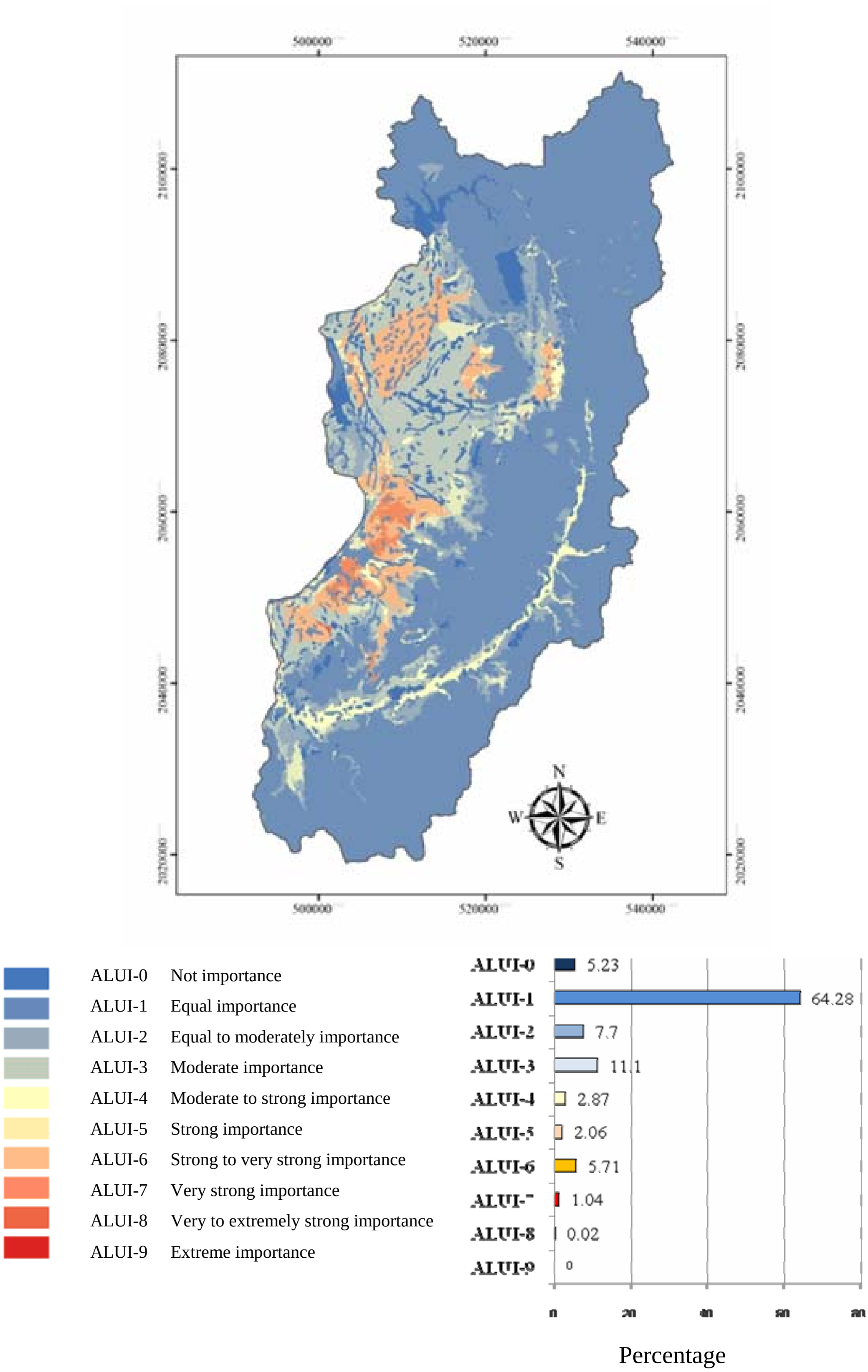


Figure 5.4 Results of ALUI-Index for lowland rice.

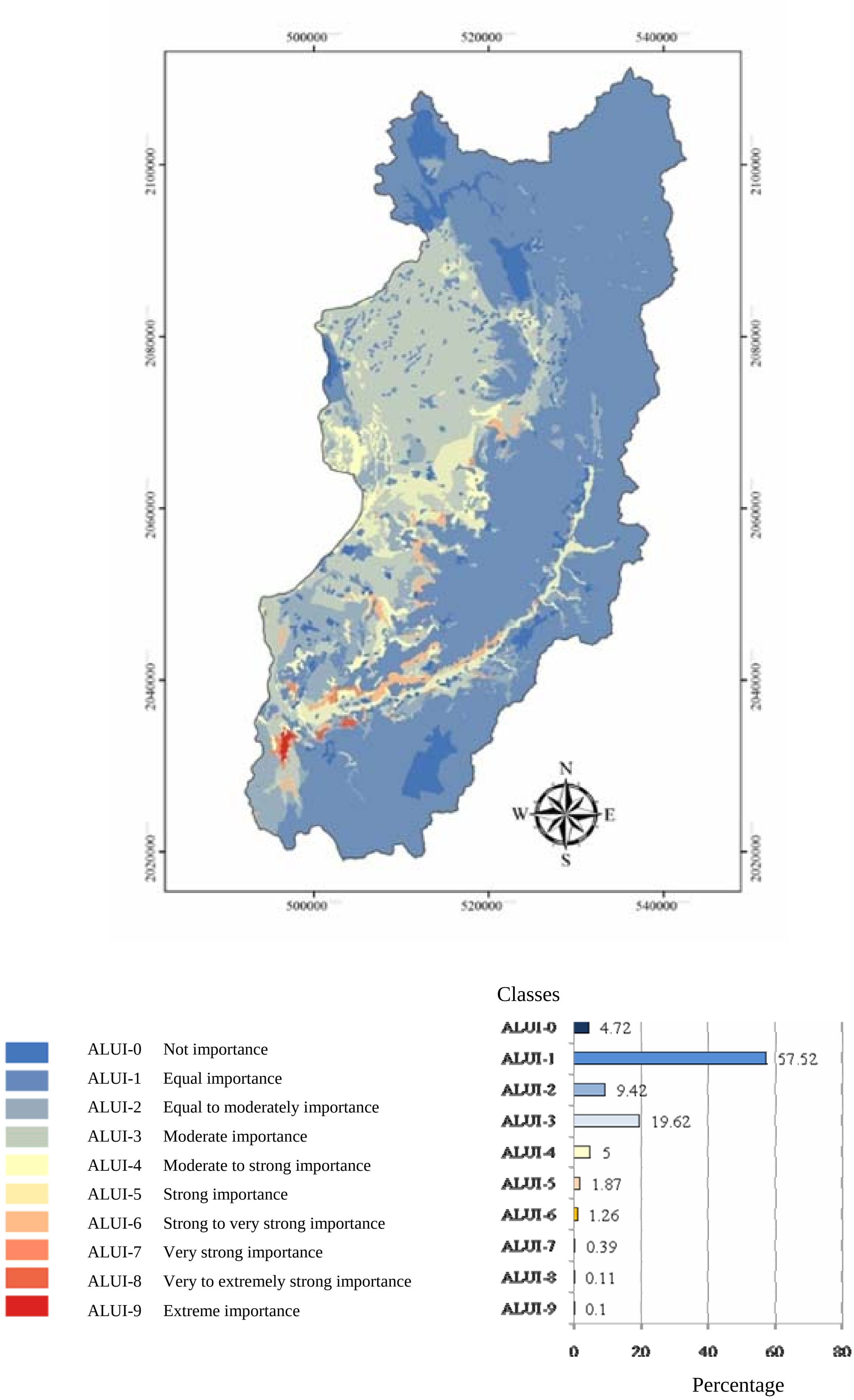


Figure 5.5 Results of ALUI-Index for longan.

5.4.2 ALUC module

The agricultural land utilization change of lowland rice had mean value of +0.8 and standard deviation of +0.26. The most important class for agricultural land utilization change is equal change to longan and to lowland rice (LUC5-rice) that covering 68.87% of the study area. It implied that agricultural land utilization change in dissected erosion surface and hills, low terraces and hills, and mountains for lowland rice and longan was very low. However, it was found that agricultural land utilization changes for lowland rice (ALUC-7, ALUC-8, and ALUC-9) were found in alluvial fan, semi-recent terrace, old riverine alluvium and old alluvium terraces and fans as shown in Figure 5.6.

While, the ALUC index of longan had mean value of +0.09 and standard deviation of +0.48. The most important class for agricultural land utilization change for longan was equal change (LUC5-longan) covering area of 83.74% of the study area. It implied that change of agricultural land utilization for longan and lowland rice in the study area is very low. These areas distributed overall in the whole the study area whereas change of agricultural land utilization for longan (ALUC-7, ALUC-8, and ALUC-9) were found in dissected erosion surface and hills as shown in Figure 5.7.

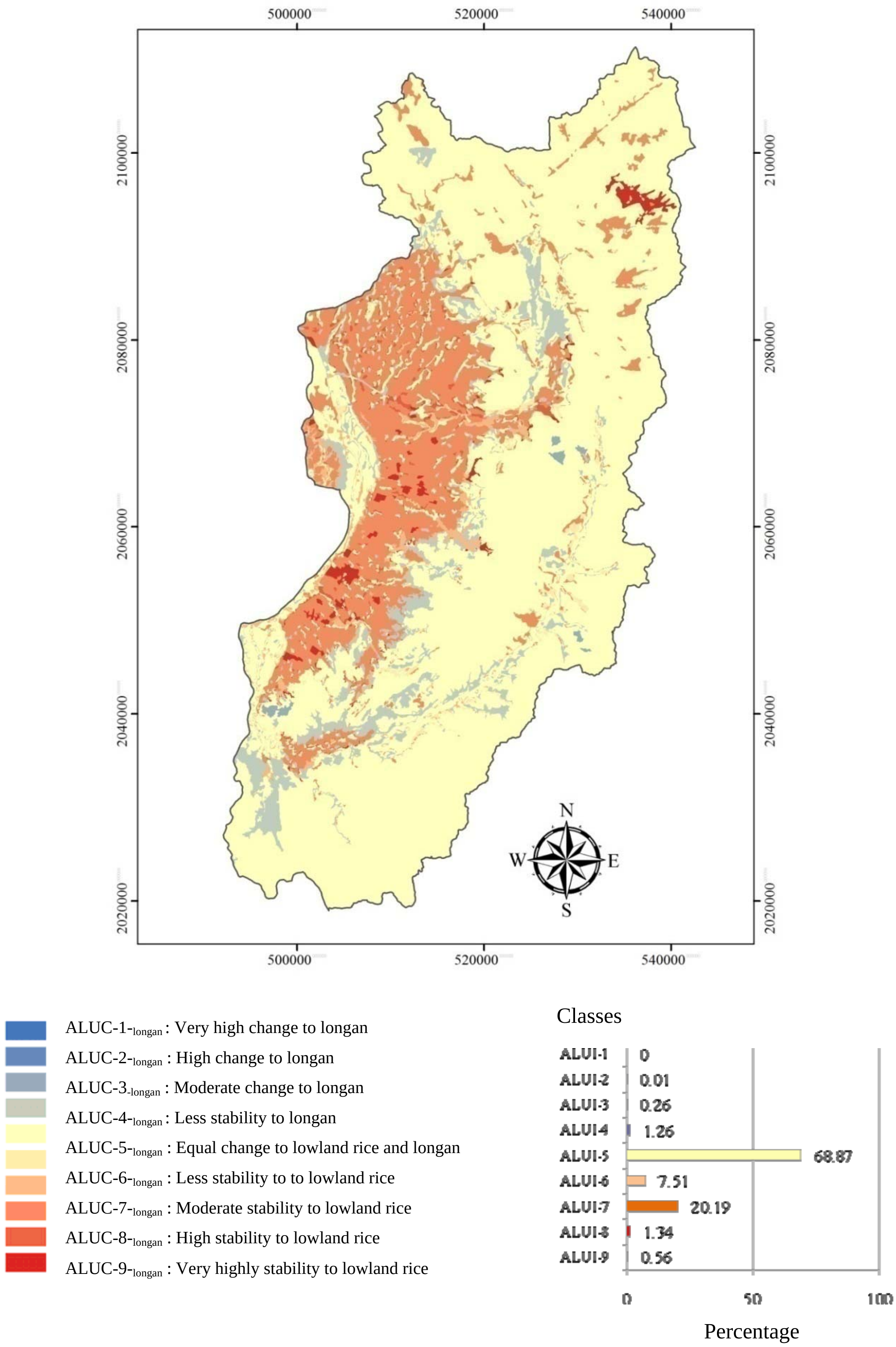


Figure 5.6 Results land utilization change-index for lowland rice.

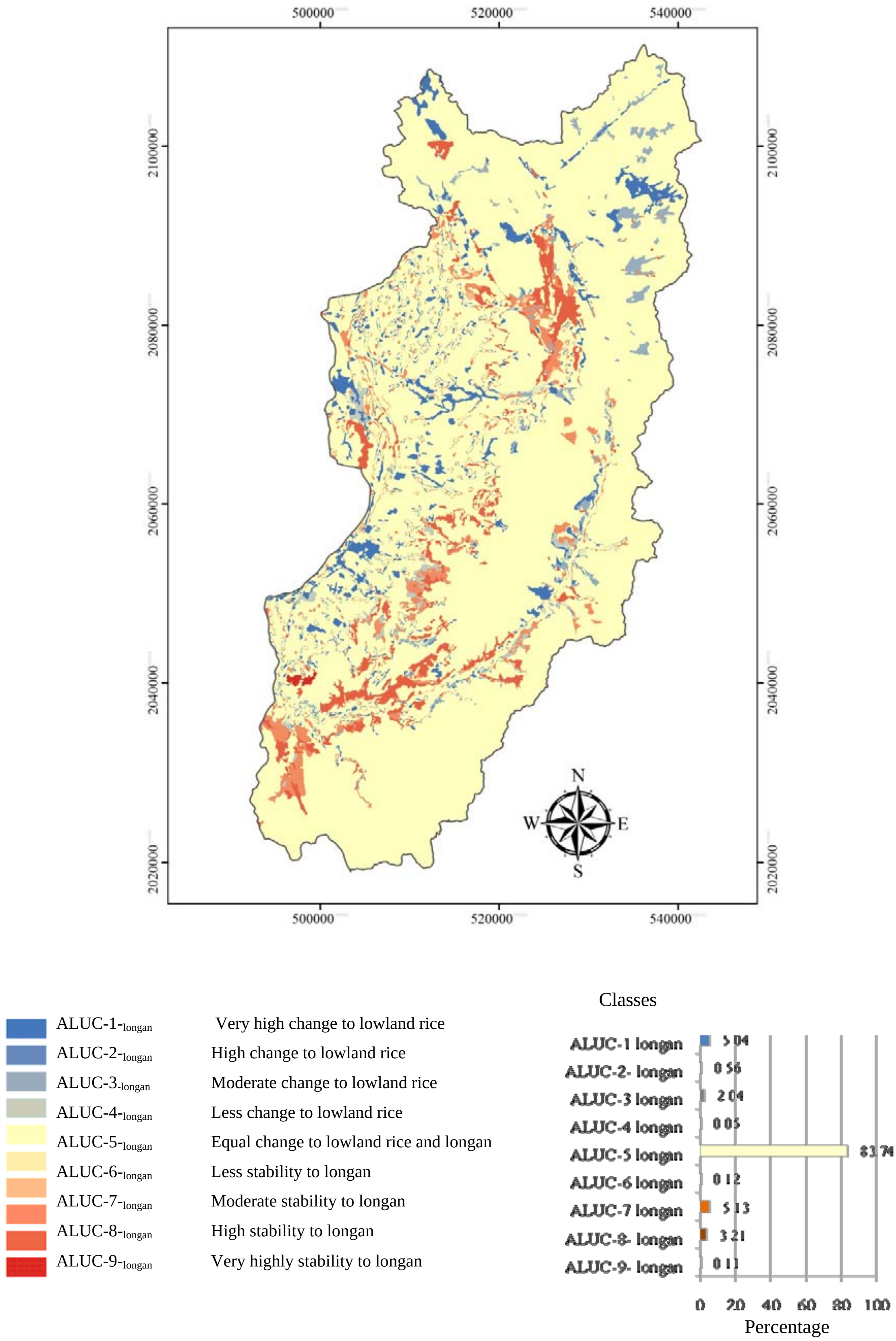


Figure 5.7 Results of land utilization change-index for longan.

5.4.3 SLUC module

The stability of land utilization change of lowland rice had minimum value of 0.00, maximum value of 0.67 with mean value of 0.12 and standard deviation of 0.10. The most important class for the stability of agricultural land utilization change for lowland rice was very high change (SLUC-1) covering 72.12% of the study area. It implied that stability and land utilization change of lowland rice was very low. However, high and very high stability of agricultural land utilization change for lowland rice (SLUC-8 and SLUC-9) were found in old riverine alluvium as shown in Figure 5.8.

The stability of land utilization change of longan had minimum value of 0.00, maximum value of 0.69 mean value of 0.16 and standard deviation of 0.13. The most important class for stability agricultural land utilization change of longan was very high change (SLUC-1) covering 43.30%. It indicated that the stability of agricultural land utilization change of longan was very low. However, it was found that high and very high stability of agricultural land utilization change for longan (SLUC-8 and SLUC-9) were found in dissected erosion surface and hills as shown in Figure 5.9.

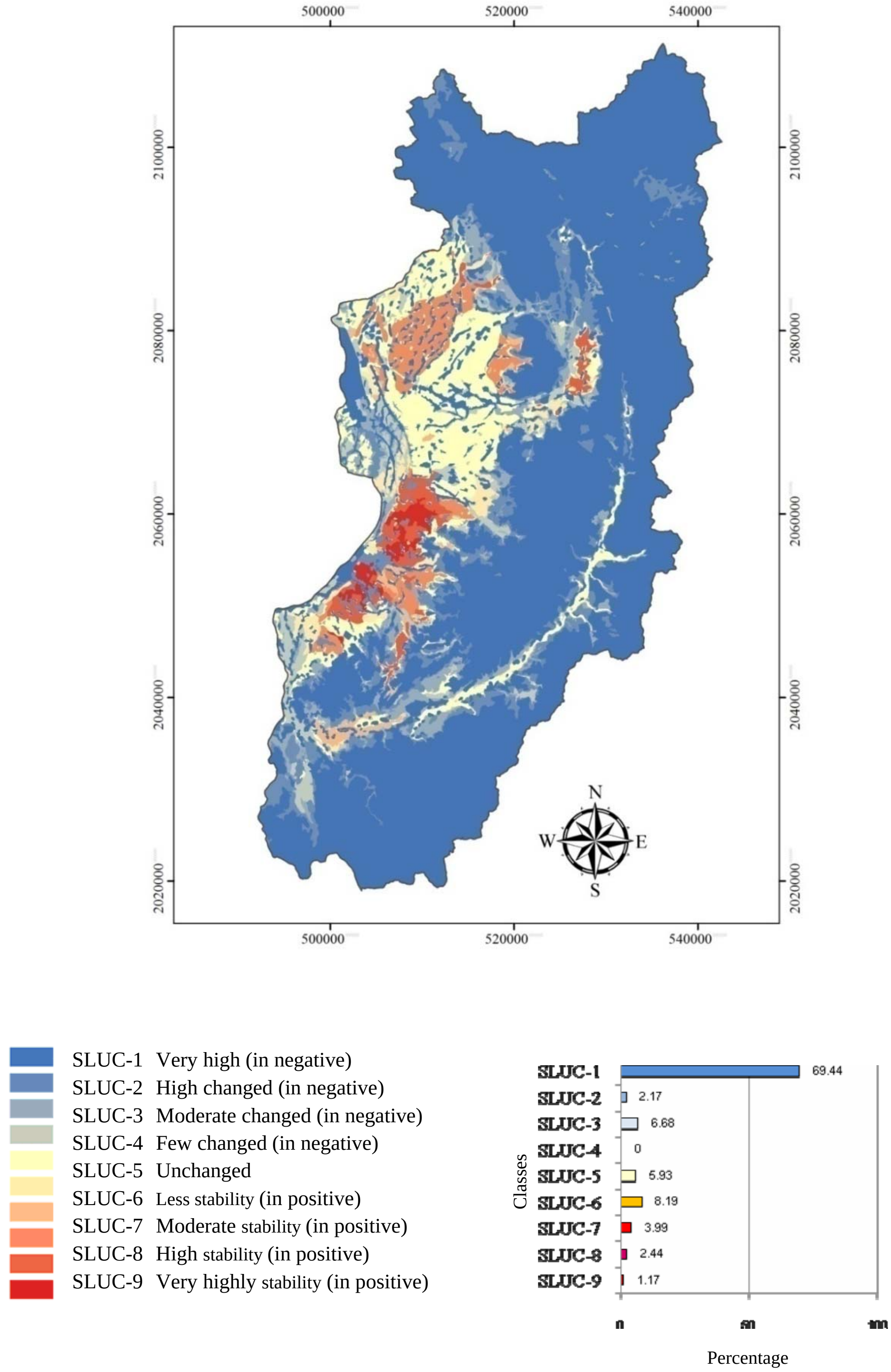


Figure 5.8 Results of SLUC-Index for lowland rice.

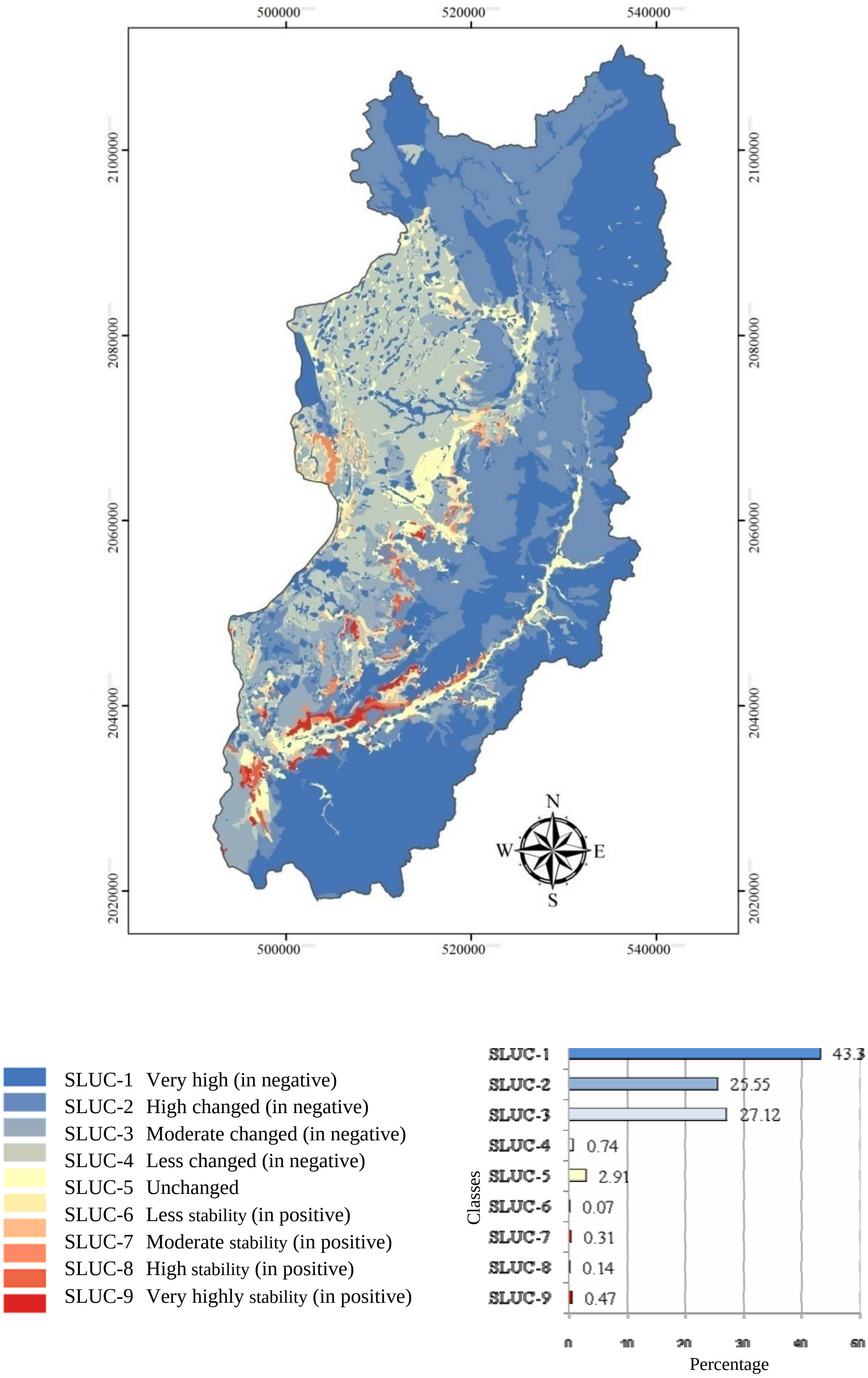


Figure 5.9 Results of SLUC-Index for longan.

5.5 Conclusions

Agricultural Land Utilization Intensity

Intensity of agricultural land utilization for lowland rice were very low. Most land forms were low terraces hills, and mountains they situated in alluvial fan. The most important class for agricultural land utilization intensity for longan was equal importance and intensity of agricultural land utilization was very low but they most situated in dissected erosion surface hills and low terraces areas due to limitation of the terrain for lowland rice.

Agricultural Land Utilization Change

ALUC for lowland rice was very low. It was found that change areas of agricultural land utilization for lowland rice taken place in alluvial fan, semi-recent terrace, old riverine alluvium and old alluvium terraces and fans. The most important class for agricultural land utilization change was equal change to longan and to lowland rice (LUC5-rice) and ALUC for longan was very low. It was found that changes of agricultural land utilization for longan low (ALUC-7, ALUC-8, and ALUC-9) taken place in dissected erosion surface and hills.

Stability of Land Utilization Change

SLUC for lowland rice was very low in the study area. However, high and very high stability of agricultural land utilization change for lowland rice (SLUC-8 and SLUC-9) were also found in old riverine alluvium and SLUC for longan was very low in the study area. Whereas, high and very high stability of agricultural land utilization change for longan (SLUC-8 and SLUC-9) were also found in dissected erosion surface and hills.

5.6 Discussion

The overall results were presented in SLUC-Indexes which could be explained the land stability for both lowland rice and longan. If we combined classes of SLUC-1, SLUC-2 and SLUC-3 together, this clearly demonstrated that lowland rice areas (SLUC- Indexes 78.29%) were having more stability than longan (SLUC-Indexes 95.97%). Because longan areas were suitable to change to non agricultural areas such as city, town, factory, golf courses etc. due to situated in non-flood areas but lowland rice which situated in the flood areas, was unsuitable to change from agricultural areas to non agricultural areas.

CHAPTER VI

AGREEMENT OF POTENTIAL AGRICULTURAL LAND SUITABILITY AND TENDENCY OF LAND UTILIZATION

6.1 Introduction

In general, agricultural land suitability is evaluated by using physical and socio-economic factors for specific land utilization type according to land quality and land characteristics. The potential agricultural land suitability was directly applied for land use planning without verifying the result. Therefore the Agreement of Potential Agricultural Land Utilization model (APA2LU model) will be used to investigate the potential agricultural land suitability and the tendency of use at present.

6.2 Objective

To build a model that could investigated the agreement between the potential agricultural land suitability and tendency of land utilization at present.

6.3 Agreement of Potential Agricultural Land Utilization model (APA2LU model)

The APA2LU was separately conducted for lowland rice and longan using overlay techniques to generate cross matrix for agreement. Then the agreement results were used to compare in the agreement AA2LU model. The model consisted of three modules: (1) Agreement of Potential Agricultural Land Suitability with Present Land Utilization Type (APALS2PLUT module), (2) Agreement of Potential Agricultural Land Suitability with Tendency Agricultural Land Utilization Type (APALS2TLUT module), and (3) Agreement of Agricultural Land Suitability with Existing LU/LC (AALS2ELU/LC module) as shown in Figure 6.1. Details of each model are explained in the following.

6.3.1 Agreement of Potential Agricultural Land Suitability with Present Land Utilization Type (APALS2PLUT module)

Under this module, ALS classes (S1, S2, S3, N1, and N2) and PLUT Classes (A1, A2, A3, NA1, and NA2) were analyzed using simple accuracy and Kappa Analysis. The results were presented in cross matrix and separately calculated agreement using equation 6.1 and 6.2 as APALS2PLUT index for lowland rice and longan.

An equation 6.1 for lowland rice was

$$\text{APALS2PLUT-Index}_{rice} = [\text{ALS}_{rice}] \text{ Cross matrix } [(\text{PLUT}_{rice})$$

An equation 6.2 for longan was

$$\text{APALS2PLUT-Index}_{longan} = [\text{ALS}_{longan}] \text{ Cross matrix } [(\text{PLUT}_{longan})$$

Where,

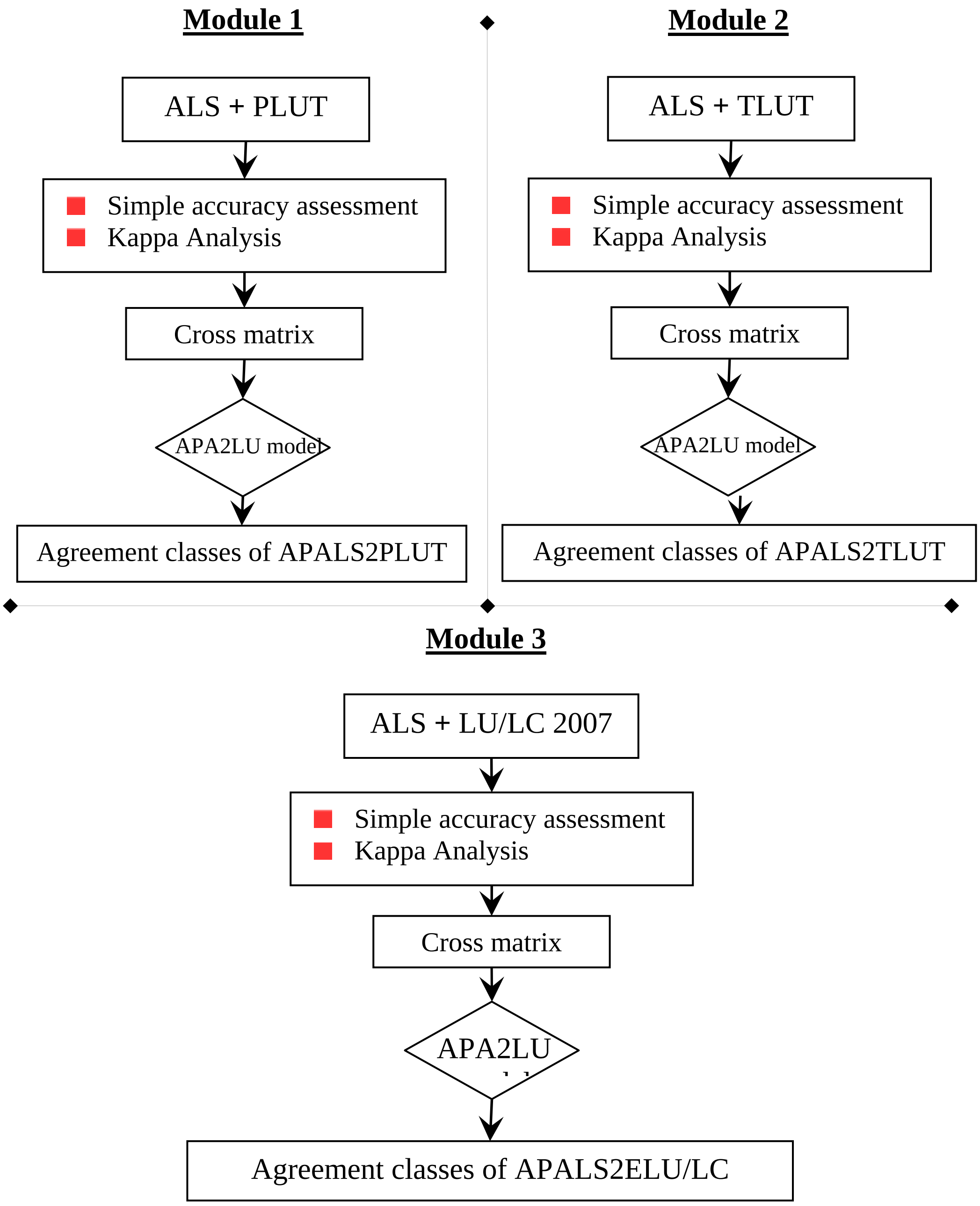
$\text{APALS2PLUT-Index}_{rice}$ is agreement of potential agricultural land suitability with present land utilization type for lowland rice.

APALS2PLUT-Index$_{longan}$	is agreement of potential agricultural land suitability with present land utilization type for longan.
ALS$_{rice}$	is agricultural land suitability index for lowland rice.
ALS$_{longan}$	is agricultural land suitability index for longan.
PLUT$_{rice}$	is the present agricultural land utilization type for lowland rice.
PLUT$_{longan}$	is the present agricultural land utilization type for longan.
Cross matrix	is cross matrix of ALS indexes and PLUT indexes.

Thus, APA2LU model for lowland rice and longan were generated with results of overall accuracy of suitable order and unsuitable order for identify APALS2PLU-Indexes classes of agreement. These values were then reclassified to into 5 new classes. In principle, "if suitable orders are exactly agreement in suitable classes or unsuitable sub-classes gives agreement. In contrast, if suitable orders are in suitable or unsuitable classes not matched gives not agreement." Finally, comparison between ALS classes and PLUT classes within the same order of suitability (S1, S2, and S3) and unsuitability (N1 and N2) and PLUT classes (A1, A2, A3, NA1, and NA2) using results of overall accuracy of suitable order and unsuitable order to identify APALS2PLUT-Indexes classes of agreement as shown in Table 6.1.

Table 6.1 Assigning classes for APALS2PLUT-Indexes.

Type	Classes	Definition	ALS	PLUT
Type 1	Highly agreement in suitable class	ALS and PLUT classes are exactly agreement in suitable sub-classes.	S1, S2, S3	A1 A2 A3
Type 2	Moderately agreement in suitable class	ALS and PLUT classes are in suitable classes but they are not exactly agreement in sub-classes.	S1 S2 S3	A2 and A3 A1and A3 A1 and A2
Type 3	Moderately agreement in unsuitable class	ALS and PLUT classes are in unsuitable classes but they are not exactly agreement in sub-classes.	N1 N2	NA2 NA1
Type 4	Extremely agreement	ALS and PLUT classes are in suitable and unsuitable classes are not matched	S1 S2 S3 N1 N2	NA1 and NA2 NA1 and NA2 NA1 and NA2 A1, A2, and A3 A1, A2, and A3
Type 5	Highly agreement in unsuitable class	ALS and PLUT classes are exactly agreed in unsuitable sub-classes.	N1 N2	NA1 NA2



Legend

[1] TULC	Tendency Land Utilization Type ((PLUT*SLUC[5])).
[2] APALS2PLUT	Agreement of Potential Agricultural Land Suitability with Present Land Utilization Type.
[3] APALS2TLUT	Agreement of Potential Agricultural Land Suitability with Tendency Agricultural Land Utilization Type.
[4] AALS2ELU/LC	Agreement of Agricultural Land Suitability with Existing LU/LC(lowland rice and longan).

Figure 6.1 Work flow of APA2LU model.

6.3.2 Agreement of Potential Agricultural Land Suitability with Tendency of Agricultural Land Utilization Type (APALS2TLUT module).

Under APALS2TLUT module, similarly to APALS2PLUT component of APALS2TLUT module, both ALS and TLUT indexes (PLUT*SLUC-Index) were used to assessing the agreement of the agricultural land suitability classes for lowland rice and longan (See 6.3.1). The results were presented in cross matrix and separately calculated agreement using equation 6.3 and 6.4 as APALS2TLUT index for lowland rice and longan.

An equation 6.3 for lowland rice was:

$$APALS2TLUT\text{-}Index_{rice} = [ALS_{rice}] \text{ Cross matrix } [TLUT_{rice}].$$

An equation 6.4 for lowland rice was:

$$APALS2TLUT\text{-}Index_{longan} = [ALS_{longan}] \text{ Cross matrix } [TLUT_{longan}).$$

Where,

$APALS2TLUT\text{-}Index_{rice}$	is agreement of potential agricultural land suitability with tendency of land utilization type for lowland rice.
$APALS2TLUT\text{-}Index_{longan}$	is agreement of potential agricultural land suitability with tendency of land utilization type for longan.
ALS_{rice}	is agricultural land suitability index for lowland rice.
ALS_{longan}	is agricultural land suitability index for longan.
$TLUT_{rice}$	is the tendency of agricultural land utilization type for lowland rice ($TLUT = [LUT_{rice}*SLUC_{rice}]$).

$TLUT_{longan}$ is the present agricultural land utilization type for longan(TLUT= [LUT_{longan}*$SLUC_{langan}$]).

Cross matrix is cross matrix of ALS indexes and TLUT indexes.

Finally, comparison ALS classes and TLUT classes within the same order of suitability (S1, S2, and S3) and unsuitability (N1 and N2) and PLUT classes (A1, A2, A3, NA1, and NA2) using results of overall accuracy of suitable in order to identify APALS2TLUT classes of agreement as shown in Table 6.2.

Table 6.2 Assigning classes of APALS2TLUT-Indexes.

Type	Classes	Definition	ALS	TLUT
Type 1	Highly agreement in suitable class	ALS and TLUT classes are exactly agreement in suitable sub-classes.	S1, S2, S3	A1 A2 A3
Type 2	Moderately agreement in suitable class	ALS and TLUT classes are in suitable classes but they are not exactly agreement in sub-classes.	S1 S2 S3	A2 and A3 A1and A3 A1 and A2
Type 3	Moderately agreement in unsuitable class	ALS and TLUT classes are in unsuitable classes but they are not exactly agreement in sub-classes.	N1 N2	NA2 NA1
Type 4	Extremely agreement	ALS and TLUT classes are in suitable and unsuitable class not matched	S1 S2 S3 N1 N2	NA1 and NA2 NA1 and NA2 NA1 and NA2 A1, A2 and A3 A1, A2 and A3
Type 5	Highly agreement in unsuitable class	ALS and TLUT classes are exactly agreed in unsuitable sub-classes.	N1 N2	NA1 NA2

6.3.3 Agreement of Agricultural Land Suitability with Existing LU/LC (AALS2ELU/LC module)

Under, AALS2ELU/LC module, the Cross matrix and Kappa Analysis technique were used to identify the agreement of potential agricultural land suitability between ALS classes and existing LULC in 2007 for lowland rice and longan.

Thus, agreement and disagreement were summarized in the area of the error matrix for ALS classes and existing land-use. The overall accuracy of the classification map was determined by dividing the total correct area (sum of the major diagonal) by the total number of area in the error matrix. Then the overall accuracy of Kappa Analysis: (Khat) Coefficients of Agreement were giving the scale of agreement as:

(a) Values greater than 0.80% represented strong agreement or accuracy between the classification map and the ground reference information,

(b) Values between 0.40 to 0.80% represented moderate agreement or accuracy between the classification map and the ground reference information and

(c) Values less than 0.40% represented poor agreement or accuracy between the classification map and the ground reference information.

6.4 Result

The results were explained according to the module as in the followings.

6.4.1 APALS2PLUT module

For lowland rice, overall accuracy was 11.49% and K_{hat} coefficient of agreement was -4.18%. This indicated that the agreement between ALS classes and PLUT classes was very poor as shown in Table 6.3.

However, if we compared agricultural land suitability classes and present land utilization type classes within the same order of suitability (S1, S2, and S3) and unsuitability (N1 and N2) and PLUT classes (A1, A2, A3, NA1, and NA2), it was found that overall accuracy of suitable order was 32.97% and unsuitable order was 6.62% as shown in Figure 6.2.

Table 6.3 Cross matrix of ALS and PLUT classes for lowland rice.

ALS classes	PLUT classes					Total
	A1	**A2**	**A3**	**NA1**	**NA2**	
S1 Highly suitable	90.55	2.16	36.08	36.08	8.42	173.29
S2 Moderately suitable	5.42	0.36	0.2	0.04	5.65	11.67
S3 Marginally suitable	343.97	24.06	111.72	76.2	110.76	666.71
N1 Currently not suitable	80.09	7.51	92.37	88.56	46.94	315.47
N2 Permanently not suitable	5.14	10.87	40.23	1,448.4	17.47	1,522.14
Total	**525.17**	**44.96**	**280.6**	**1,649.3**	**189.24**	**2,689.28**

Note: - Overall accuracy of all classes 11.49%

- Overall accuracy of suitability order 32.97%

- Overall accuracy of unsuitability order 6.62%

- K_{hat} -4.18%

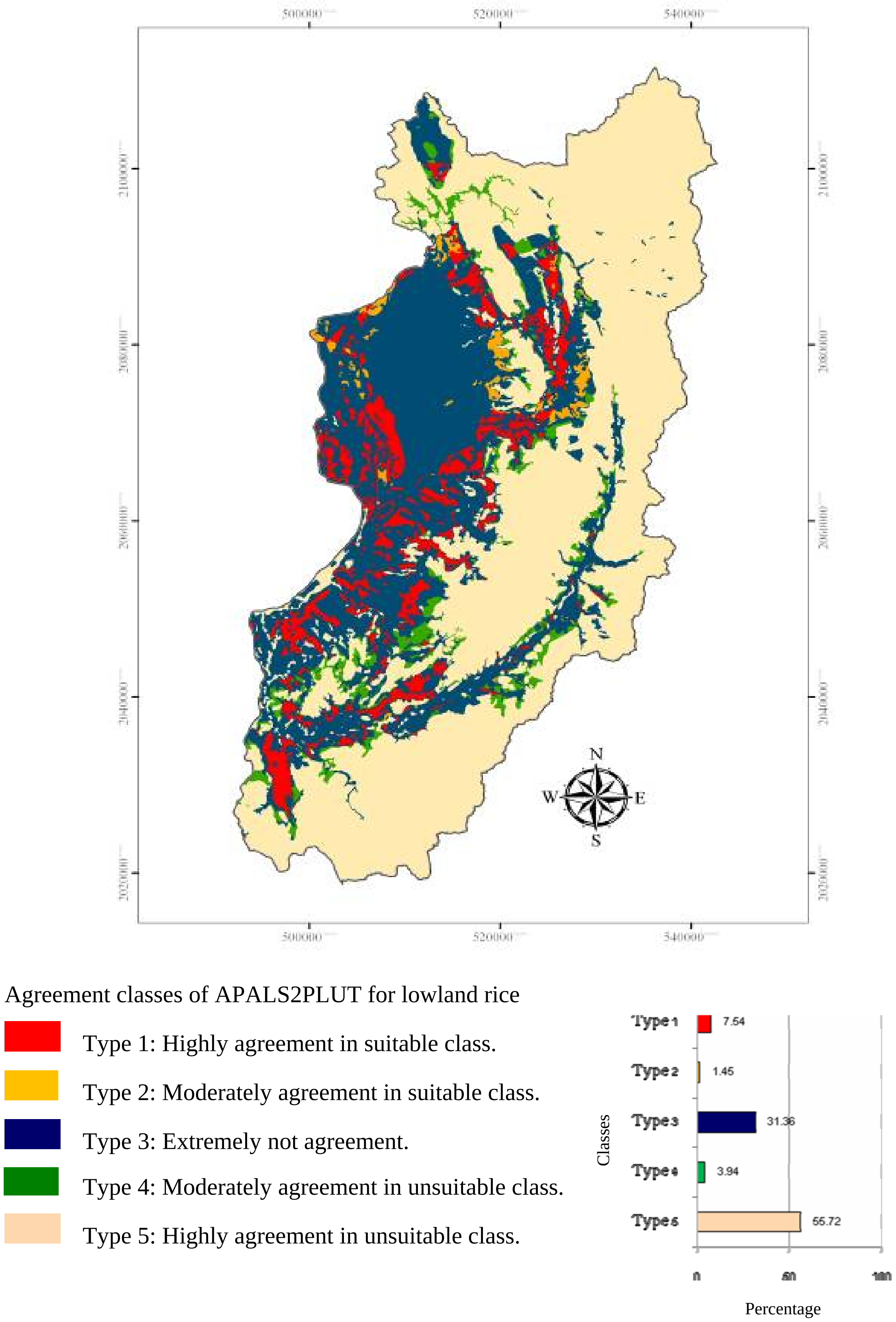


Figure 6.2 Agreement classes of suitability order of ALS and type of PLUT classes for lowland rice.

For longan, the agreement type was rather high. Overall accuracy 67.60% and K_{hat} coefficient of agreement was 38.87%, respectively. The results indicated that the agreement between ALS classes and PLUT classes was higher than lowland rice as shown in Table 6.4. In contrast, if we compared agricultural land suitability classes and present land utilization type classes within the same order of suitability and unsuitability and LUT classes, it was found that overall accuracy of suitable order was 64.99% and unsuitable order was 90.93% as shown in Figure 6.3.

Table 6.4 Cross matrix of ALS and PLUT classes for longan.

ALS classes	PLUT classes					Total
	A1	**A2**	**A3**	**NA1**	**NA2**	
S1 Highly suitable	15.40	2.80	41.90	21.08	9.60	90.78
S2 Moderately suitable	12.70	13.70	60.35	12.28	7.42	106.45
S3 Marginally suitable	51.63	23.61	329.14	51.52	35.14	491.04
N1 Currently not suitable	62.39	50.90	267.93	1,435.86	66.07	1,883.15
N2 Permanently not suitable	5.03	5.00	4.35	79.53	23.95	117.86
Total	**147.15**	**96.01**	**703.67**	**1,600.27**	**142.18**	**2,689.28**

Note : Overall accuracy of all classes 67.60%

Overall accuracy of suitability order 64.99%

Overall accuracy of unsuitability order 90.93%

K_{hat} 38.87%

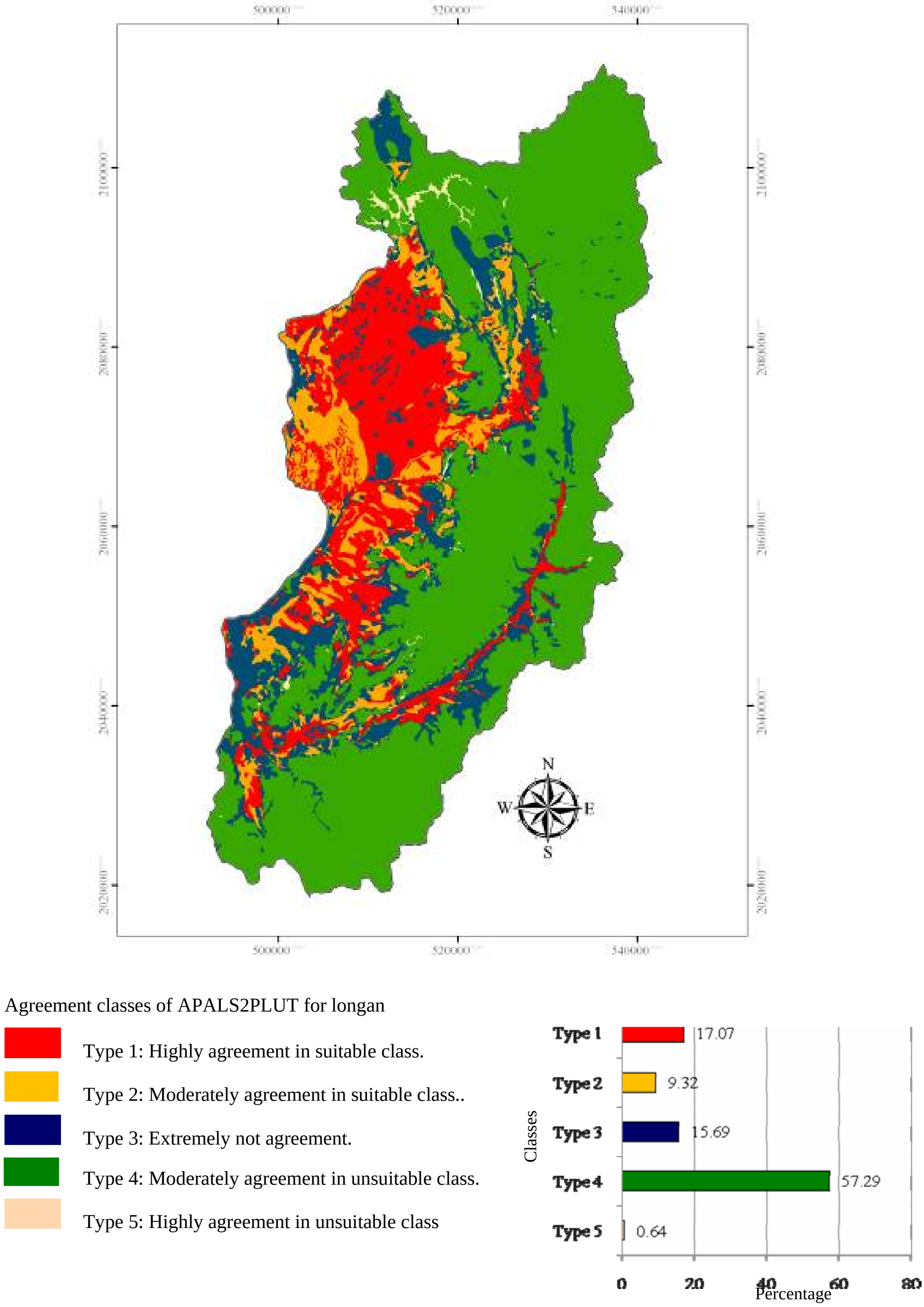


Figure 6.3 Agreement classes of suitability order of ALS and type of PLUT classes for longan.

6.4.2 APALS2TLUT module

For low land rice, overall accuracy and K_{hat} coefficient of agreement were 34.22% and 3.07%, respectively. The agreement between ALS index and TLUT index was very poor as shown in Table 6.5. In contrast, if we compared ALS index and TLUT index within the same order of suitability (S1, S2, and S3) and unsuitability (N1 and N2) and LUT classes (A1, A2, A3, NA1, and NA2), it was found that overall accuracy of suitable order was 36.32% and unsuitable order was 46.55% as shown in Figure 6.4.

Table 6.5 Cross matrix of ALS and tendency TLUT classes for lowland rice.

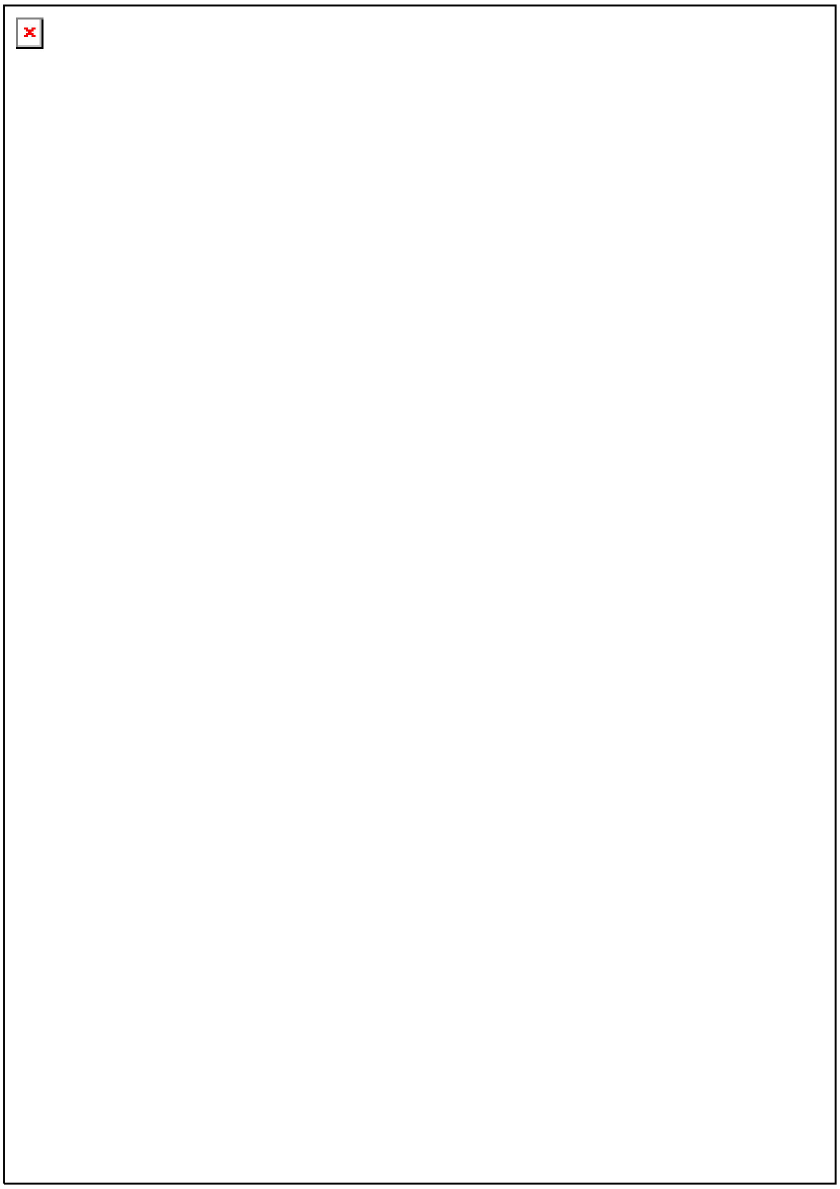
ALS classes	TLUT classes					Total
	A1	A2	A3	NA1	NA2	
S1 Highly suitable	9.45	5.89	5.72	49.2	20.52	90.78
S2 Moderately suitable	7.83	9.09	18.28	53.26	17.99	106.45
S3 Marginally suitable	23.98	35.68	37.01	311.35	83.38	491.4
N1 Currently not suitable	34.97	52.89	43.44	814.28	938.8	1884.38
N2 Permanently not suitable	3.78	4.74	3.11	54.09	50.55	116.27
Total	80.01	108.29	107.56	1,282.18	1,111.24	2,689.28

Note: Overall accuracy of all classes 34.22 %

Overall accuracy of suitability order 36.32 %

Overall accuracy of unsuitability order 46.55 %

K_{hat} - 3.07 %



Agreement classes of APALS2TLUT for longan

Type 1: Highly agreement in suitable class.

Type 2: Moderately agreement in suitable class.

Type 3: Extremely not agreement.

Type 4: Moderately agreement in unsuitable class.

Type 5: Highly agreement in unsuitable class.

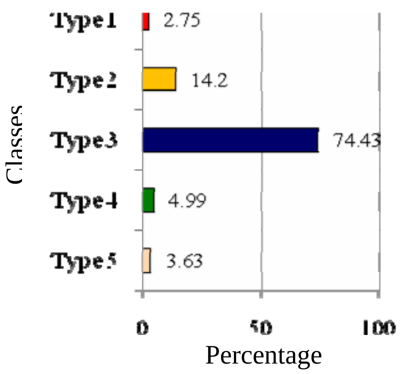


Figure 6.4 Agreement classes as comparison between suitability order of ALS and type of TLUT classes for lowland rice.

For longan, overall accuracy and Khat coefficient of agreement were 62.06% -35.23%, respectively. The agreement between ALS and TLUT classes was higher than lowland rice as shown in Table 6.6. In contrast, if we compared ALS class and TLUT class within the same order of suitability and unsuitability, the overall accuracy of suitable order was only 25.06% and unsuitable order was 88.84% as shown in Figure 6.5.

Table 6.6 Cross matrix of ALS and TLUT classes for longan.

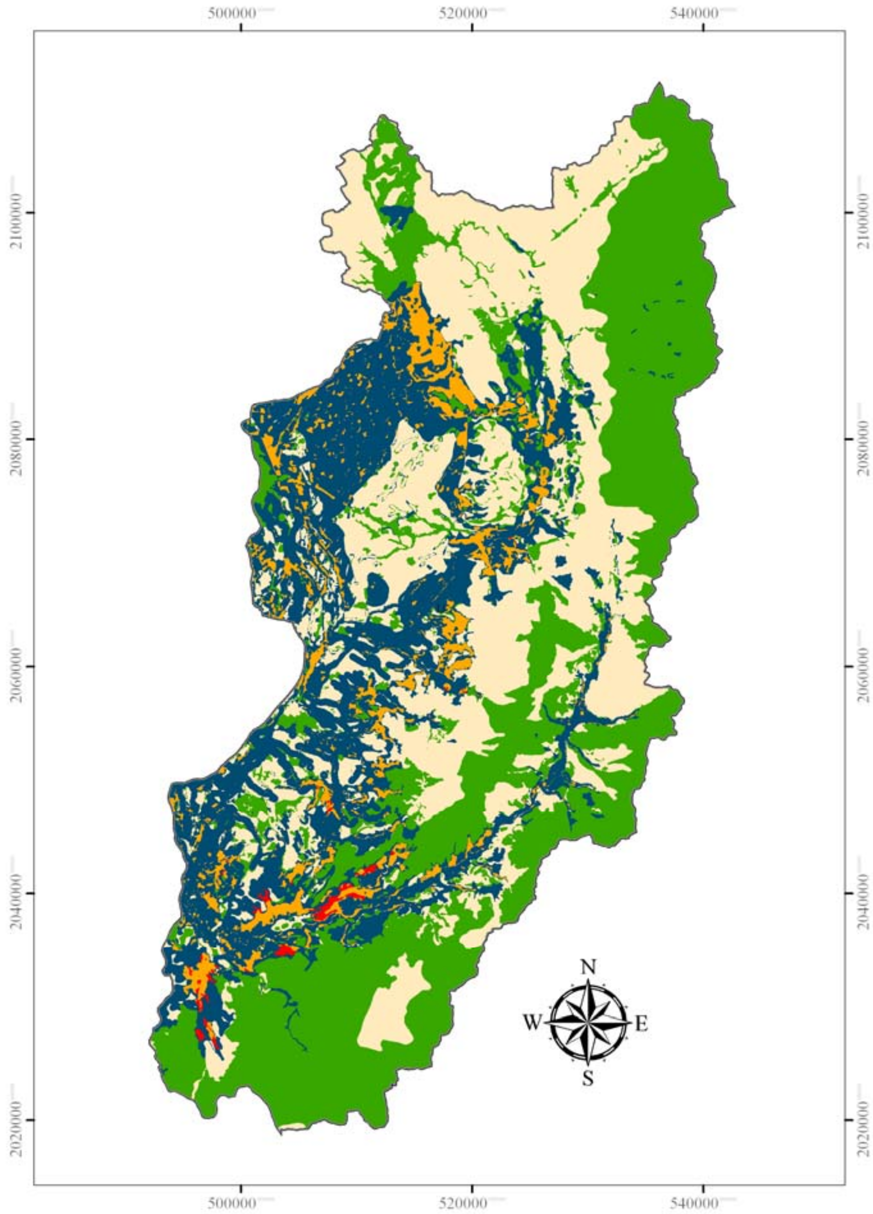
ALS classes	**TLUT classes**					**Total**
	A1	**A2**	**A3**	**NA1**	**NA2**	
S1 Highly Suitable	71.63	12.89	7.64	32.71	44.25	169.12
S2 Moderately Suitable	2.75	1.45	1.55	2.22	5.69	13.66
S3 Marginally Suitable	265.11	52.27	41.38	121.62	186.33	666.71
N1 Currently Not Suitable	45.78	25.38	12.52	97.71	134.09	315.48
N2 Permanently Not Suitable	0.17	1.17	4.89	61.15	1,456.93	1,524.31
Total	385.44	93.16	67.98	315.41	1,827.29	2,689.28

Note : Overall accuracy of all classes 62.06%

Overall accuracy of suitability order 25.06%

Overall accuracy of unsuitability order 88.84%

K_{hat} 35.23%



Agreement classes of APALS2TLUT for longan

Type 1: Highly agreement in suitable class.

Type 2: Moderately agreement in suitable class.

Type 3: Extremely not agreement.

Type 4: Moderately agreement in unsuitable class.

Type 5: Highly agreement in unsuitable class.

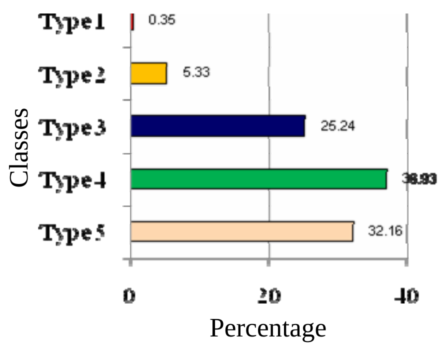
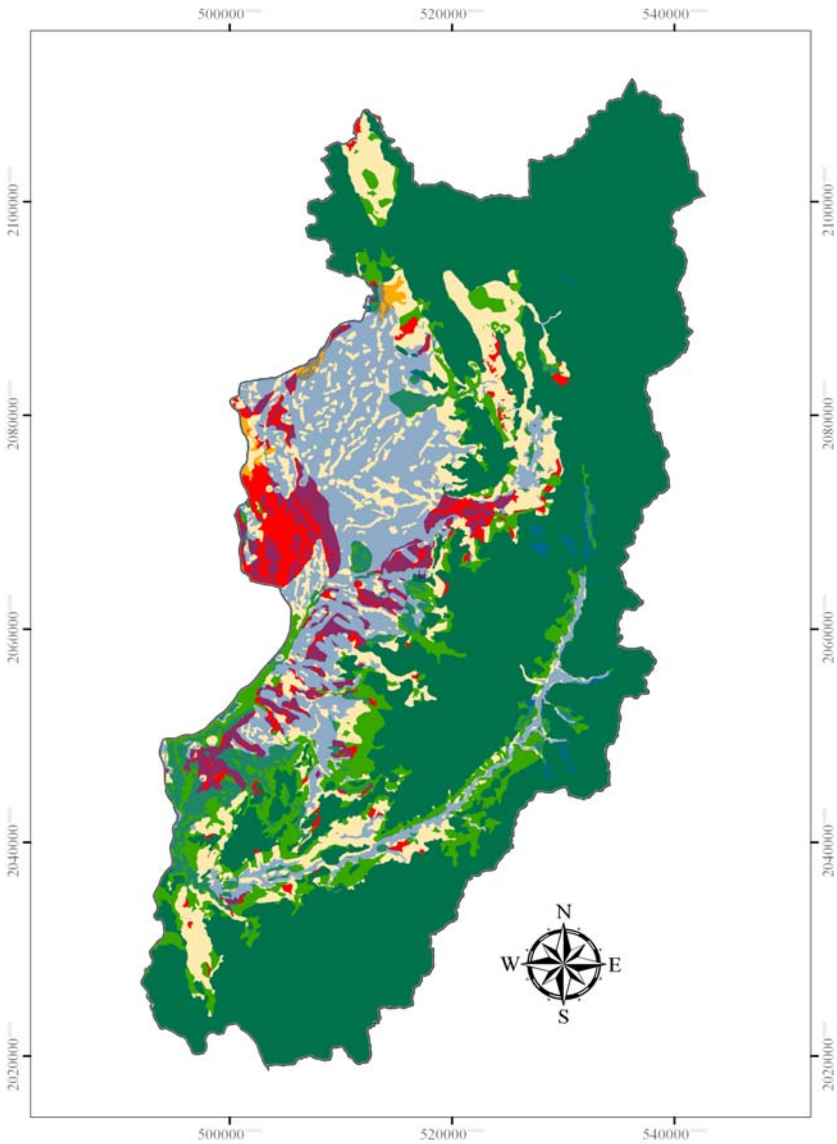


Figure 6.5 Agreement classes as comparison between suitability order ALS and type of TLUT classes for longan.

6.4.3 AALS2ELU/LC module

For lowland rice area, most of existing lowland rice was fallen in marginally suitable class covering area of 338.08 sq. km or about 65.12%. In contrast, some existing lowland rice was fallen in permanently not suitable class which covering area of 5.02 sq. km or about 0.97%. If we compared existing lowland rice with suitability order, the agreement of existing lowland rice with suitable order was 83.86%. This result implied that the accuracy of agricultural land suitability for lowland rice was rather high as shown in Figure 6.6.

For longan area, most of existing longan was fallen in Highly suitable class covering area of 315.01 sq. km or about 90.41%, whereas none of existing longan was fallen in order Not suitable. If we compared existing longan with suitability order, it was indicated the agreement of existing longan with Suitable order was 100%. This result implied that the accuracy of agricultural land suitability for longan is excellent as shown in Figure 6.7.



Agreement classes of AALS2ELU/LC for existing lowland rice in 2007

- lowland rice
- lowland riceand S1 Highly suitable
- S1 Highly suitable
- S2 Moderately suitable
- S3 Marginally suitable
- N1 Currently not suitable
- N2 Permanently not suitable

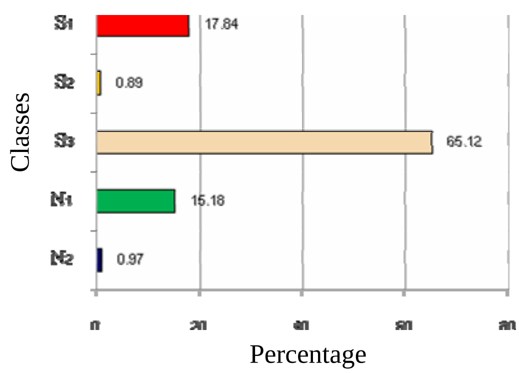


Figure 6.6 Agreement classes between the suitability order of ALS and existing lowland rice area in 2007.

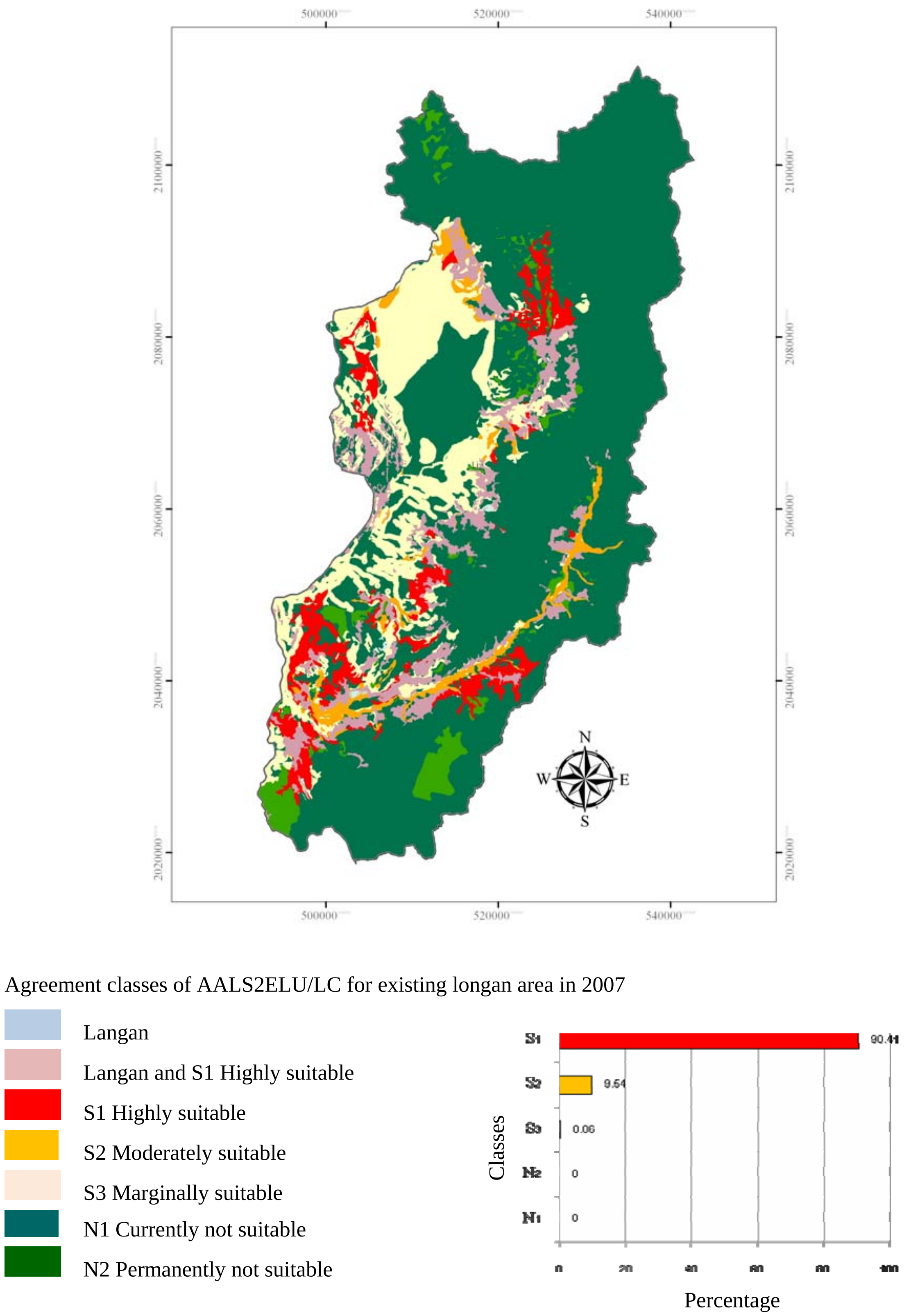


Figure 6.7 Agreement classes between the suitability order of ALS and longan area in 2007.

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6.5 Conclusions

The results of evaluation APA2LU model could be concluded in to 3 parts according to 3 models.

(1) The agreement between ALS and PLUT was very low for lowland rice area whereas the agreement of longan area was rather high.

(2) The agreement between ALS and TLUT classes were very low for lowland rice area but rather high for longan area.

(3) The agreement of agricultural land suitability with lowland rice and longan area in 2007 was indicated that most lowland rice area had fallen in to marginally suitable class (69.87%) in contrast most of longan area was in the most of highly suitable class (90.41%).

6.6 Discussion

Overall results pointed out that tendency agreement of lowland rice was higher than longan. This finding confirmed the results of stability analysis in Chapter V that lowland rice areas had less tendency to changes than longan areas.

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APPENDICES

APPENDIX A

LAND-USE REQUIREMENT FOR LOWLAND RICE AND LONGAN

Table A.1 Factor rating of LQ for lowland rice transplantation, direct, seeding.

Land-Use Requirement (LUR)				Factor rating			
	Land Quality(LQ)	**Diagnostic Factor**	**Unit**	**S1**	**S2**	**S3**	**N**
1	Temperature (t)	Mean temperature in growing period	˚C	20-26	27-30,19-18	31-32,17-16	>32
2	Moisture Availability (m)	Ann. Rainfall	mm.				
		Water requirement in growing period	mm.	450-650	350-450	300-350	<300
3	Oxygen Availability (o)	Soil drainage	Class	5,6	4	3	1.2
4	Nutrient Availability (s)	N (total)	%	>0.2	0.1-0.2	<0.1	
		P	ppm	>25	10-25	<10	
		K	ppm	>60	30-60	<30	
		Organic matter	%	>3	1-3	<1	
		Nutrient Status	Class	VH,H	M	L,VL	
		Reaction	pH	5.6-7.3	7.4-7.8, 5.1-5.5	7.8-8.4,4.0-5.0	>8.4,4.0
5	Nutrient Retention (n)	C.E.C	meg/100g	>15	5-15	< 5	
		B.S	%	>50	35-50	<35	
6	Rooting Condition (r)	Effective soil dept	cm	>50	25-50	15-25	<15
		Water table depth	cm				
		Root penetration	class	1,2	3	4	
7	Flood Hazard (f)	Frequency	year/time	10 yrs/1	5-9 yrs/1	3-5 yrs/1	1-2 yrs/1
8	Excess of salts (x)	EC. of saturation	mmho/cm.	<2	2-5	5-8	>8
	Soli toxicities (z)	Depth of jarosite	cm.	>150	100-150	50-100	50
9	Soil workability (k)	Workability Class	Class	1,2	3	4	
10	Potential for Mechanizations (w)	Slope	Class	ABC	D	E	>E
		Rock out crop	Class	1	2	3	4
		Stoniness	class	1	2	3	4
11	Erosion (e)	Slope	Class	A	B	C	> C
		Soil loss	ton/rai/yrs	<2	2-4	4-12	>12

Source: FAO (1976) and Land Development Department (1996).

Table A.2 Factor rating of LQ for longan.

Land-use Requirement				Factor rating			
Land Quality(LQ)		Diagnostic Factor	Unit	S1	S2	S3	N
1	Temperature (t)	Mean temperature in growing period	˚C	20-25	25-30, 19-16	31-35, 15-13	>35, <13
2	Moisture Availability (m)	Ann. Rainfall	mm.	1200-1800	1800-2000, 1100-1200	1000-1100	>2000, <1000
		Water requirement in growing period	mm.				
3	Oxygen Availability (o)	Soil drainage	Class	4, 5, 6		3	1, 2
4	Nutrient Availability (s)	N (total)	%	>0.2	0.1-0.2	<0.1	
		P	ppm	>0.5	6-15	<6	
		K	ppm	>60	30-60	<30	
		Organic matter	%	>2.5	1.0-2.5	<1	
		Nutrient Status	Class	VH, H, M	L	L	
		Reaction	pH	6.1-7.3	7.4-7.8, 5.6-6.0	7.8-8.4, 4.5-5.5	
5	Nutrient Retention (n)	C.E.C	meg/100g	>10	5-10	<5	
		B.S	%	>35	<35		
6	Rooting Condition (r)	Effective soil dept	cm	>150	100-150	50-100	<50
		Water table depth	cm	>150	100-150	50-100	<50
		Root penetration	class	1, 2	3	4	
7	Flood Hazard (f)	Frequency	year/ time	10 yrs/1	6-9 yrs/1		3-5 yrs/1
8	Excess of salts (x)	EC. of saturation	mmho/ cm.	<2	2-4	4-8	>8
9	Soli toxicities (z)	Workability Class	Class	1, 2	3	4	
10	Potential for Mechanizations (w)	Slope	Class	ABC	D	E	>E
		Rock out crop	Class	1	2,3	4	5
		Stoniness	class	1	2	3	4
11	Erosion (e)	Slope	Class	ABC	D	E	>E
		Soil loss	ton/Rai /year	<2	2-4	4-12	>12

Source: FAO (1976) and Land Development Department (1996).

Table A.3 Physical indicator rating for evaluation of land quality factors.

Land-Use Requirement (LUR)	**Rating of Factor**		
1. Radiation regime	Day length		
	Short day and Long day		
2.Temperature regime)	Mean temperature in growing period		
3.Moisture availability			
3.1 Soil texture Classes			
Classes	Soil texture		
(1) VL (very low),	s (coarse sand)		
(2) L (low)	l (fine sandy)		
(3) M (moderate)	scl,sl		
(4) H (high)	scl, l, fsl, cl, c, sc (loamy and clay)		
3.2 Classes standards of capacity moisture availability			
Classes	cm/cm of soil	Classes	cm/cm of soil
(1) VL (very low),	<0.05	(4) H (high)	0.15-0.20
(2) L (low)	0.05-0.10	(5) VH (very high)	>0.20
(3) M (moderate)	0.10-0.15		
Average rainfall/month		Effective Rainfall	
(1) <10 mm.	0%	(6) 201-250 mm.	60%
(2) 11-100 mm.	80%	(7) 251-300 mm.	55%
(3) 101-200 mm.	70%	(8) 251-300 mm.	55%
(4) 201-250 mm.	60%	(9) > 300 mm.	50%
(5) >300 mm.	50%		
4. Classes standards of drained			
(1) Very poorly Drained		(4) Moderately well Drained	
(2) Poorly Drained		(5) Well Drained	
(3) Somewhat poorly Drained		(6) Excessively Drained	
5. Nutrient availability			
5.1 Classes standards of Organic matter			
Classes	% Organic matter		
(1) N (nil)	<0.5	(5) H (high)	2.51-3.5
(2) VL (very low)	0.5-1.0	(6) VH (very high)	3.51-4.5
(3) L (low)	1.01-1.5	(7) E (Extreme)	>4.51
(4) M (moderate)	1.51-2.5		
5.2 Nutrient Status (N)			
Classes	% of Nutrient Status		
(1) N (nil)	<0.1	(4) M (moderate)	0.51-0.75
(2) VL (very low)	0.11-0.2	(5) H (high)	>0.751
(3) L (low)	0.21-0.5	(6) VH (very high)	3.51-4.5
Classes	% of Available P (ppm)		
(1) N (nil)	<3	(5) H (high)	15.1- 25
(2) VL (very low)	3-6	(6) VH (very high)	25.1-45
(3) L (low)	6-10	(7) E (Extreme)	>45
(4) M (moderate)	10.1-15	(8) H (high)	15.1- 25
5.4 Availability K			
Classes	% of Available K(ppm)	(4) H (high)	90.1-120
(1) VL (very low)	<30	(5) VH (very high)	>120.1
(2) L (low)	30-60		
(3) M (moderate)	60.1-90		

Table A.3 Physical indicator rating for evaluation of land quality factors. (Continued)

Land-Use Requirement	Rating of Factor		
5.5 Soil pH			
(1) very extremely acid	(7) Neutral		
(2) Extremely acid	(8) Mindy alkaline		
(3) very acid	(9) Moderately alkaline		
(4) Strongly acid	(10) Strongly alkaline		
(5) Medium acid	(11) Very strongly alkaline		
(6) Slight acid			
6. Nutrient retention capacity			
Classes	meg/100 gm soil		
(1) N (nil)	<3	(5) H (high)	15.1- 20
(2) VL (very low)	3-5	(6) VH (very high)	20.1-30
(3) L (low)	5.1-10	(7) E (Extreme)	>30
(4) M (moderate)	10.1-15		
7. C.E.C			
Classes	B.S (%)		
(1) VL (very low)	<35		
(2) L (low)	35-50		
(3) M (moderate)	50.1-75		
(4) H (high)	>75		
8.Rooting conditions			
Root penetration			
classes	cm.		
(1) Very shallow	<25	(4) depth	100.1-150
(2) Shallow	25-50	(5) Very depth	>150
(3) depth moderate	50.1-100		
9. Flood, storm, wind, frost, hail hazard			
Classes	Frequency		
(1) Class 1	10 year/1	(3) Class 3	3-5 year/1
(2) Class 2	6-9 year/1	(4) Class 4	1-2 year/1
10.Excess of salts			
Classes	mmho/cm		
(1) Class 1	2-4	(3) Class 3	10.1-16
(2) Class 2	4.1-10	(4) Class 4	>16
10. Soil workability			
10.1 Potential for mechanization			
(A) Vary flat	0-2(%)	(D) Moderate	12.1- 20
(B) Flat	2.1-5	(E) Vary Steep	20.1-35
(C) Flat Mix Moderate	5.1-12	(F) Steep high	35.1-50
10.2 Stone with in profile (%)			
Classes	Maximum (%)		
(1) Few to common	<10%	(3) Abundant	<15%
(2) Many	10-15%		
10.3 Stone with in profile (%)			
Classes	Maximum (%)		
(1) Few to common	<10%		
(2)Many	10-15%		
(3) Abundant	< 15%		

Table A.3 Physical indicator rating for evaluation of land quality factors. (Continued)

Land-Use Requirement	Rating of Factor				
10.4 Matrix potential for mechanization					
	Potential (Unit %)				
Classes	1	2	3	4	5
(1) Slope	8	16	35	60	>60
(2) Stone with in profile (%)	1	4	10	25	>25
(3) Rock outcrop (% surface area)	1	5	15	40	>40
11. Soil erosion hazard					
Classes					
(1) Class1 VL (very low)					
(2) Class 2 L (low)					
(3) Class 3 M (moderate)					
(4) Class H1 H (high)					

Source: FAO (1976) and Land Development Department (1996).

Table A.4 Socio-economic factors rating for evaluation land quality in crop production.

Type of land qualities for socioeconomic factors rating (LURs)

A. Agricultural nutrient balance and present farming practices

1.Input-output nutrient

Net profit / yield 1 Kg.

Classes	Percents	Classes	Percents
(1) VL (very low)	<10	(4) H (high)	40.1-50
(2) L (low)	20.1-30	(5) VH (very high)	>50
(3) M (moderate)	30.1-40	(4) H (high)	40.1-50

2.Farm practices

2.1 Crops and varieties planted in the area

Rice		Longan
Classes	Varieties	Classes
(1) Class: A	RD6	(1) Class: A
(2) Class: B	RD15	(2) Class: B
(3) Class: C	KDML 105	(3) Class: C
(4) Class: D	RD 10	(4) Class: D
(5) Class: E	Other varieties	(5) Class: E

2.2 Seed or planting material

Distribution of seeding rate

Classes	Total rate (kg./rai)
(1) Class: 1	<15kg./rai
(2) Class: 2	11-15 Kg./rai
(3) Class: 3	15.1-20 Kg./rai
(4) Class: 4	>20 Kg./rai

2.3 Land rent

2.3.1 Payment of land rent

Classes	(Baht/rai)	Classes	(Bant./rai)
(1) VL (very low)	<300	4) H (high)	501-600
(2) L (low)	301-400	5) VH (very high)	601-700
(3) M (moderate)	401-500	6) E (Extreme)	

2.3.2 Land tenure

Classes	Land holding
(1) Class: A	Owned land
(2) Class: B	Owned land+ Rent more land
(3) Class: C	Only rent the land

2.3.3 Farm sizes

Distribution of farm sizes

Classes	Rai	Classes	Rai
(1) Class: 1	<10	(4) Class: 4	30.1- 40
(2) Class: 2	10.1-20	(5) Class: 5	40.1-50
(3) Class: 3	20.1-30	(6) Class: 6	>50

2.3.4 Land values

Distribution of Land values (Land price (Baht/rai))

Classes

(1) Class: A = <10,000	(4) Class: D = 40,000.1-50,000
(2) Class: B = 20,000.1-30,000	(5) Class: E = >50,000
(3) Class: C = 30,000.1-40,000	

B. Yields

1. Average yield

Rice		longan	
Classes	Average yield	Classes	Average yield
(1) VL (very low)	<300 Kg./rai	VL	<300 Kg./rai
(2) L (low)	301-400 Kg./rai	L	301-600 Kg./rai

Table A.4 Socio-economic factors rating for evaluation land quality in crop production. (Continued)

Type of land qualities for socioeconomic factors rating (LURs)				
(3) M (moderate)	401-500 kg./rai	M	601-900 kg./rai	
(4) H (high)	501-600 kg./rai	H	901-1,200 kg./rai	
(5) VH (very high)	601-700 kg./rai	VH	1,200-1,500 kg./rai	
(6) E (Extreme)	>700 kg./rai	E	>1,500 kg./rai	
2. Price				
Rice		Longan		
Classes	Baht/kg	Classes	Baht/kg	
(1) VL (very low)	<4	(1) 1 VL (very low)	<10	
(2) L (low)	4.1-6	(2) 2 L (low)	10.1-15	
(3) M (moderate)	6.1-8	(3) 3 M (moderate)	15.1-20	
(4) H (high)	8.1-10	(4) H1 H (high)	20.1-25	
C. Fertilizers management				
Input fertilizers				
Rice	Average kg./rai	longan		
Distribution of chemicals fertilizers application				
Classes	Total rate (kg./rai)	Classes		
(1) Class: 1	<10 kg./rai	(1) Class: 1	<10 kg./rai	
(2) Class: 2	11-20 kg./rai	(2) Class: 2	11-20 kg./rai	
(3) Class: 3	21-30 kg./rai	(3) Class: 3	21-30 kg./rai	
(4) Class: 4	31-40 kg./rai	(4) Class: 4	31-40 kg./rai	
(5) Class: 5	>40 kg./rai	(5) Class: 5	>40 kg./rai	
D. Farm pest management				
1.Undesirable characteristic				
Disturbances of pest and insect				
Classes (Frequency)				
(1) Class: A = 10 year/crop	(3) Class: C = 3-5 year/crop			
(2) Class: B = 6-9 year/crop	(4) Class: D = 1-2 year/crop			
2.Vulnerable to past diseases				
Classes (Frequency)				
(1) Class: A = 10 year/crop	(3) Class: C = 3-5 year/crop			
(2) Class: B = 6-9 year/crop	(4) Class: D = 1-2 year/crop			
3. Susceptible to lodging				
(1) Class: A = 10 year/crop	(3) Class: C = 3-5 year/crop			
(2) Class: B = 6-9 year/crop	(4) Class: D = 1-2 year/crop			
4. Fluctuating price				
(1) Class: A = 10 year/crop	(3) C = 3-5 year/crop			
(2) Class: B = 6-9 year/crop	(4) D = 1-2 year/crop			
E. Farm management and marketing				
1. Banks and other credit				
Classes (Source of loan)				
(1) Class: A = Bank of Agriculture and Agricultural				(4) Class: D = Local traders
(2) Class: B = Cooperatives				(5) Class: E = Relatives
(3) Class: C = Agricultural Cooperatives				(6) Class: F = Other

Table A.4 Socio-economic factors rating for evaluation land quality in crop production. (Continued)

Type of land qualities for socioeconomic factors rating (LURs)			
2. Total cost			
Rice		Longan	
Classes	Baht/rai	Classes	Baht/Rai
(1) L (low)	>1000	1) 1 L (low)	>1000
(2) M (moderate)	1,000.1-2,000	2) 2 M (moderate)	1,000.1-2,000
(3) H (high)	2,000.1-3,000	3) H1 H (high)	2,000.1-3,000
(4) VH (very high)	>3,000	4) H2 VH (very high)	>3,000
3. Storage, processing and marketing facilities			
Classes	Member have Storage, processing and marketing facilities		
1) L (low)	>1		
2) M (moderate)	2		
3) H (high)	3		
F. Agricultural soil conservation management			
Soil conservation	Type	Soil conservation	Type
(1) VL (very low)	>1	4) H (high)	4
(2) L (low)	1-2	5) VH (very high)	>4
(3) M (moderate)	3		
G. Irrigation management			
Existing irrigation drainage, domestic water supplies, water tenure rights			
Classes	Type		
(1) Class: A	Annual rainfall		
(2) Class: B	Rainfall with water supplement from natural river system		
(3) Class: C	Rainfall with water resources development project, reservoirs, small irrigation schemes etc.		
(4) Class: D	Rainfall with water from ponds.		
H. Whole household farm management			
1. Household(Full-time on family member)			
Classes	family member have full-time for on farm activities		
(1) Class: 1	1		
(2) Class: 2	2		
(3) Class: 3	3		
(4) Class: 4	>3		
2. Household income of lowland rice farmers			
The ratio of incomes from rice crop per total net income of household			
Classes (Percentage)			
1) VL (very low) = <25	4) H (high) = 45.1-55		
2) L (low) = 25.1-35	5) VH (very high) = >55		
3) M (moderate) = 35.1-45			
3. Household income of longan farmers			
The ratio of incomes from longan crop per total income of household			
Classes (Percentage)			
1) VL (very low) = <25	4) H (high) = 45.1-55		
2) L (low) = 25.1-35	5) VH (very high) = >55		
3) M (moderate) = 35.1- 45			

Source:
1. Classes of factor rating by using PRA method and Interviews at group discussion (level household) method,
2. World Bank (2006) and Community Development Department (2007).

Table A.5 Factors rating of LURs for LQ by crop production of economic crops.

Type of Land-Use Requirement for land qualities of socioeconomic (LURs)	Factor rating			
	S1**	S2**	S3**	N**
A. Agricultural nutrient balance and present farming practices				
1. Input-output nutrients	H, HV	M	L	VL
2. Farm practices				
2.1 Crops and varieties planted in the area				
(1) Lowland rice Area	A, C	B, D	D	E
(2) Longan Area	A, C	B, D	D	E
2.2 Seed or planting material**	1	2	3	4
2.3 Land rent				
(1) Payment of land rent	VL	L, M	H	VH, E
(2) Land tenure	A	B	B	C
(3) Farm sizes	4, 5.6	3	2	1
(4) Land values	A	B	C	D,E
B. Crop Yields				
1. Average yield	VH, E	H	M	L,VL
2. Price	VH, E	H	M	L,VL
C. Fertilizers management	1, 2	3	4	5
D. Farm pest management				
1. Undesirable characteristic	A	B	C	D
2. Vulnerable to past diseases	A	B	C	D
3. Susceptible to lodging	A	B	C	D
4. Fluctuating price	A	B	C	D
E. Farm management and marketing				
1. Banks and other credit	A, B, C	D	E	F
2. Total cost	L	M	H	VH
3. Storage, processing and marketing facilities	VH	H	M	L
F. Agricultural soil conservation management	VH	H	M	L
G. Irrigation management	C	B	D	A
H. Whole household farm management				
1. Household size	4	3	2	1
2. Full-time on family member	VH	H	M	L
3. Household income of farmers	VH	H	M	L

Source: Classes of factor rating by using PRA method and interviews at group discussion (level household) method as show in Table A.6.

Notes: ** Only for lowland rice

Table A.6 Classes of factors rating of LURs.

Classes	Definition	Factor rating score
VL	Very low	0.00-19.99
L	Low	19.00-39.99
M	Moderate	40.00-59.00.
H	High	60.00-79.99.
VH	Very high	80.00-100.

Source: Classes of factor rating by using PRA method and Interviews at group discussion (level household) method

Table A.7 Level of land utilization intensity values for agriculture.

Land-Use Type	Level of intensity		
	Low	**Moderate**	**High**
1. Cropping	1 Crop/year	2-3 Crop/year	>3 Crop/year
2. Market orientation	Subsistence production	Subsistence production plus commercial sale of surplus	Commercial production
3. Capital Intensity	Low	Intermediate with credit on accessible terms	High
4. Labour Intensity	High, including uncosted family labour	Medium, including uncosted family labour	Low, family labour costed if used
5. Power source	Manual labour with hand tools	Manual labour with hand tools and/or animal traction with improved implements; some mechanization	Complete mechanization including harvesting.
6. Technology	Traditional cultivars; no fertilizer or chemical pest, disease and weed control. Fallow periods. Minimum conservation measures	Improved cultivars as available. Appropriate extension packages including some fertilizer application and some chemical pest, disease and weed control. Some fallow periods and some conservation measures	High yielding cultivars including hybrids. Optimum fertilizer application. Chemical pest, disease and weed control. Full conservation measures.
7. Infrastructure	Market accessibility not necessary; inadequate advisory services	Some market accessibility necessary with access to demonstration plots and services	Market accessibility essential. High level of advisory services and application of research findings.

Source: World Bank, (2006).

APPENDIX B

CRITERIA MAP FOR LAND OF PHYSICAL FACTORS CHARACTERISTICS

B.1 Criteria map for land of physical factors characteristics

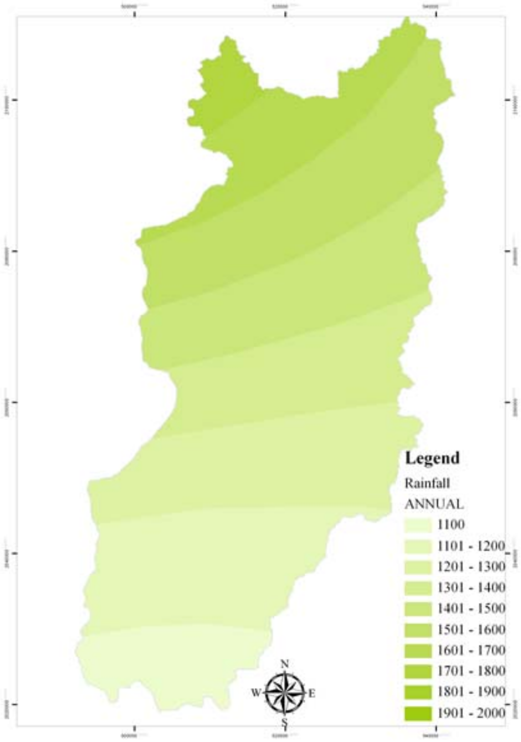


Figure B.1 Climate (Moisture availability: LC2).

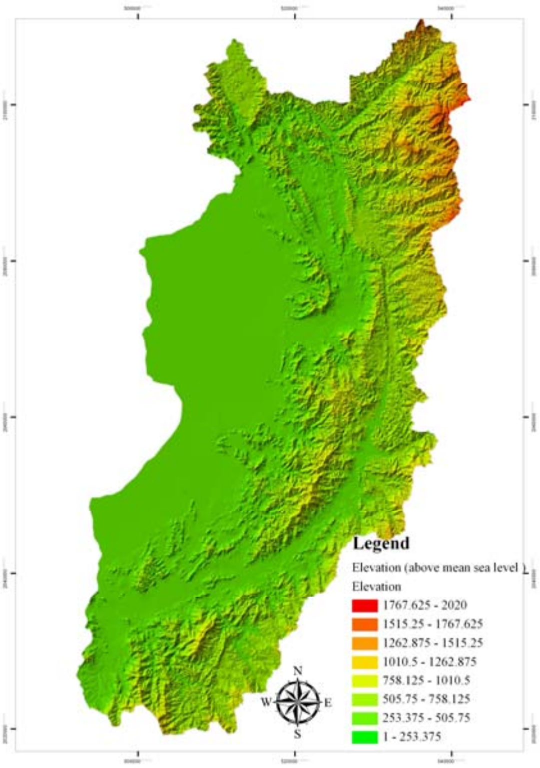


Figure B.2 Topography (Elevation).

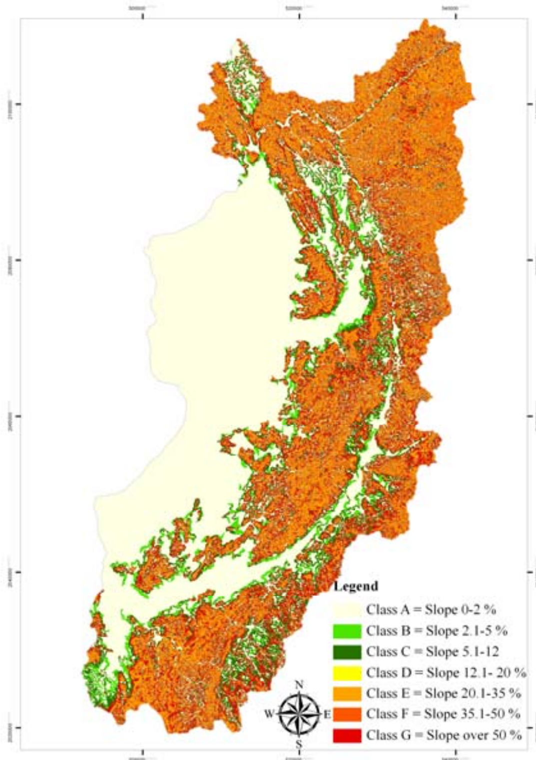


Figure B.3 Topography (Slope: LC3).

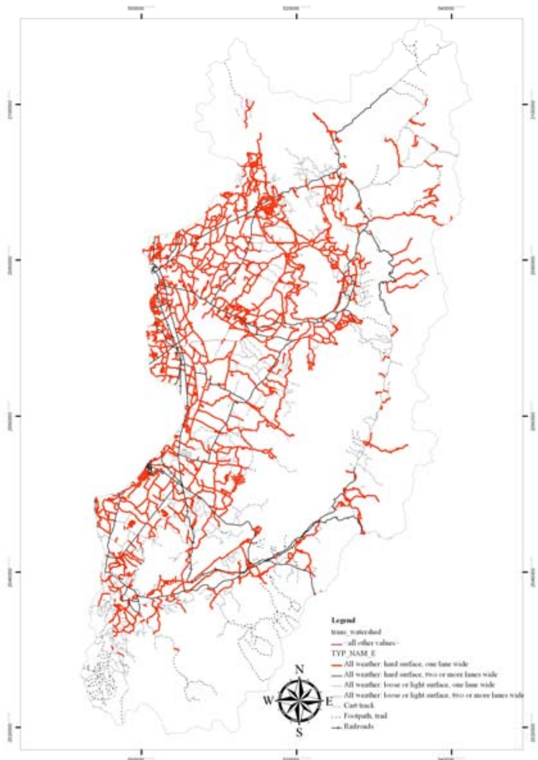


Figure B.4 Infrastructures (Accessibility: LC4).

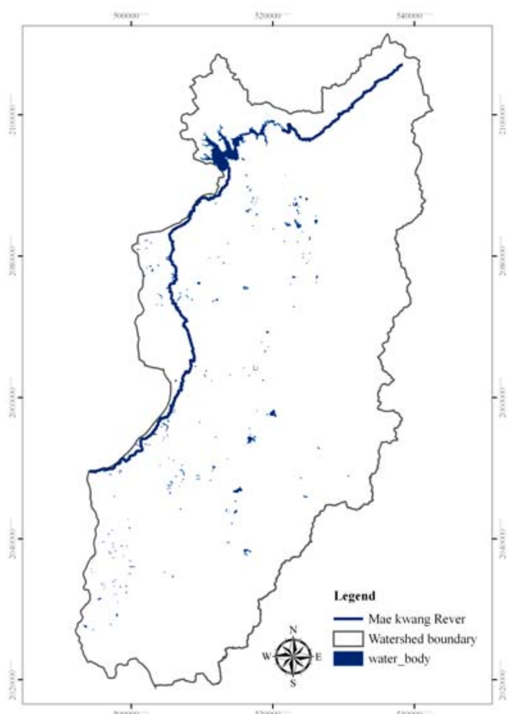


Figure B.5 Water resources (Water body).

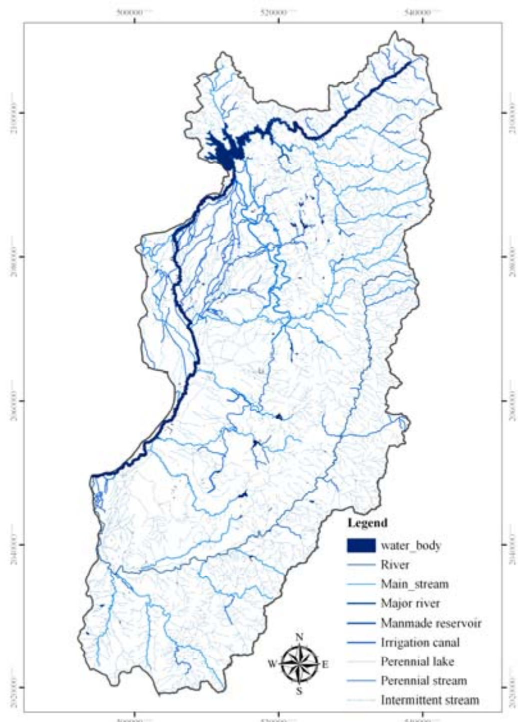
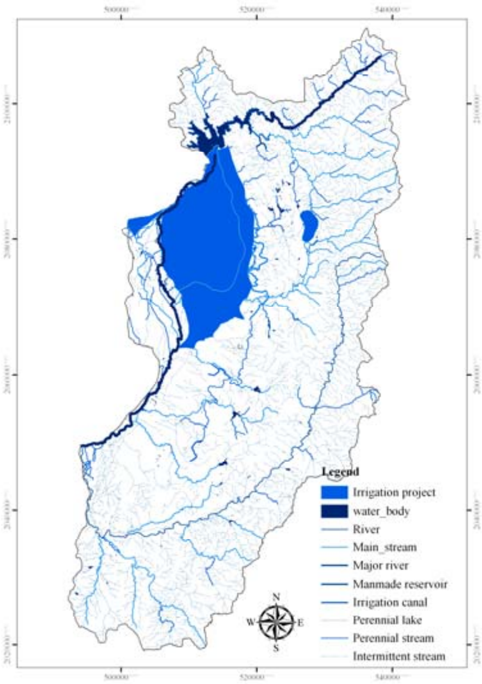


Figure B.6 Water resources (Stream: LC6).



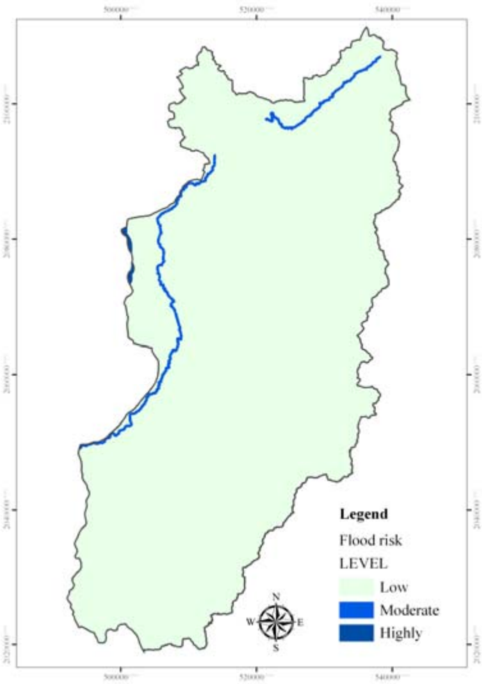
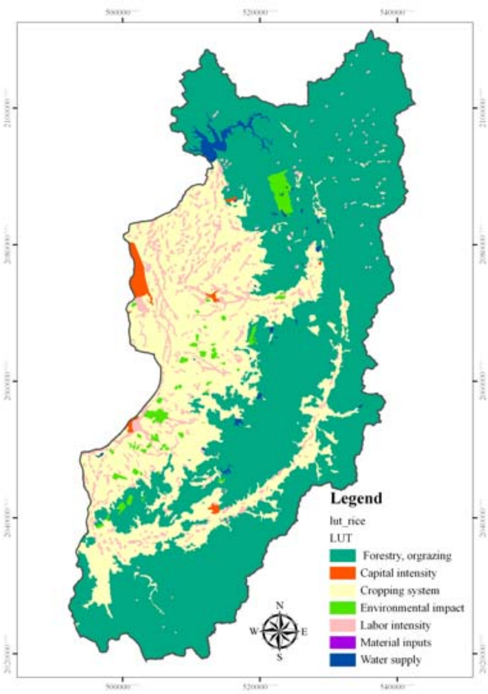


Figure B.7 Water resources (Irrigation project).

Figure B.8 Water resources (Flood hazard: LC8).



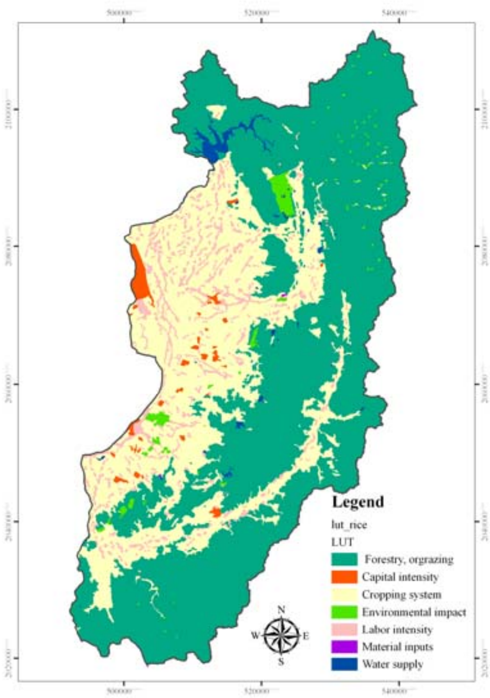


Figure B.9 LU/LC types for lowland rice (Agricultural area: LC9 and Non-agricultural area: LC10).

Figure B.10 LU/LC types for longan (Agricultural area: LC9 and Non-agricultural area: LC10).

APPENDIX C

QUESTIONNAIRES

C.1 Part I: Basic Information of Household

Name of farmer Mr/Mis/Miss ……………………………..…Age…………

Location of abode No..............Village.........................Sub districts............................

Districts…………….. Province...

Occupation: (1) Main Occupation.................... (2) Second Occupation......................

Education:

( ) 1.Under high school ( ) 2. High school ( ) 3. Bachelor ( ) 4. More bachelors

C.1.1 Introduction about household

House hold member

1) Total	(1) Male ……….……	(2) Female ………………..	
2) Labor	(1) Agricultural ……...	(2) Non agricultural ………	
3) Age	(1) 1-18 ……………...	(2) 18-60………	(3) < 60……
4) Main Occupation	(1) Agricultural …...	(2) Non agricultural ………..	

C.1.2 Income and debit

1) Main income	(1) Agricultural ……… Baht /year	(2) Non agricultural …..... Baht /year
2) Second income	(1) Agricultural ……… Baht /year	(2) Non agricultural …..... Baht /year
1) Main debit	(1) Agricultural ……… Baht /year	(2) Non agricultural …..... Baht /year
2) Second debit	(1) Agricultural ……… Baht /year	(2) Non agricultural …..... Baht /year

C.1.3 Source Income

1) Main income	(1) Agricultural ……… Baht /year	(2) Non agricultural …....Baht /year
2) Second income	(1) Agricultural ……… Baht /year	(2) Non agricultural …… Baht /year
1) Main debit	(1) Agricultural ……… Baht /year	(2) Non agricultural …..... Baht /year
2) Second debit	(1) Agricultural ……… Baht /year	(2) Non agricultural ….....Baht /year

C.2 Part II: Crop production

C.2.1 Cropping

1) Major crops

( )1.Rice Varieties………………. ( ) 2. longan Varieties ………………

2) Second crops

( )1.Rice Varieties…………… ( ) 2. longan Varieties ………………

3) Other

( ) ……… Varieties…………… ( ) 2. longan Varieties ……………….

4) Seed or planting material ………………….Kg/Rai or ………………….Bath/Rai

C.2.2 Farm sizes …………… Rai (1600m^2)

C.2.3 Land tenure

( )1. Owned land ( ) 2. Owned land+ rent more land ( ) 3. Only rent the land

C.2.4 Payment of land rent ………Baht /Rai (Only who answer 2and 3 in 2.3)

C.2.5 Land values ……..….. Baht /Rai

C.2.6 Average yield ……..…Kg/Rai Price ……….Bath/Kg (in year 2006/2007)

C.2.7 Input fertilizer ……………Kg/year (Chemicals fertilizer and organic fertilizer)

C.2.8 Product fertilizer …………Kg/year

C.2.9 Input chemicals fertilizers application……… Kg/Rai, Organic fertilizer ……… Kg/Rai

C.2.10 Disturbances of pest and insect Frequency……………. year/ crop

C.2.11 Vulnerable to past diseases Frequency…………. year/ crop

C.2.12 Other Disturbances Frequency…………. year/ crop

C.2.13 Existing irrigation drainage, domestic water supplies, water tenure rights

( ) A. Annual rainfall

( ) B. Rainfall with water supplement from natural river system

( ) C. Rainfall with water resources development project, reservoirs, small irrigation schemes etc.

( ) D. Rainfall with water from ponds

C.2.14 Total cost of production…………...…..... Baht /Crop

C.3 Part III: Farm Management and Marketing

C.3.1 Source of loan and other credit

( ) A = Bank of Agriculture and Agricultural ( ) D = Local traders

( ) B = Cooperatives ( ) E = Relatives

( ) C = Agricultural Cooperatives ( ) F = Other…………….

C.3.2 Member have Storage, processing and marketing facilities ………………………………

C.3.3 The adoption of agricultural soil conservation management in farm management practices

( ) Adoption…………………………………. ( ) Non adoption……………..…………..

C.3.4 Closeness to markets Distance……………Km.

C.4 Part IV: Crop Production (Lowland Rice)

C.4.1 Area ……Rai Average yield ………….Kg/Rai Price ……. Baht /Kg Varieties……….

C.4.2 Location of cropping ( ) Lowland ( ) Highland

C.4.3 Seed or planting material………….Kg/Rai

C.4.4 Yield, Price and Factor of production

Year	Yield (kg/rai)	Price (baht/kg)	Factor of production (bath/rai)				
			Wages	Organic fertilizer	Chemicals fertilizer	Other Chemicals	Other
1							
2							
3							
4							
5							

Note…………………………………………………………………………………………………

……

C.5 Part IV: Crop Production (Longan)

C.5.1 Area ………rai average yield ………….kg/rai price ……. baht /kg

C.5.2 Varieties……………………………………………………………………………

C.5.3 Location of cropping ( ) lowland ( ) highland

C.5.4 Seed or planting material…………baht/rai

C.5.5 Yield, price and factor of production

Year	Yield (Kg/Rai)	Price (baht/kg)	factor of production (bath/rai)				
			Wages	Organic fertilizer	Chemicals fertilizer	Other Chemicals	Other
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

Note……………………………………………………………………………………………………
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APPENDIX D

CRITERIA MAP FOR SOCIO-ECONOMIC OF AGRICULTURAL LAND SUITABILITY

D.1 Criteria map for socio-economic of agricultural land suitability for lowland rice

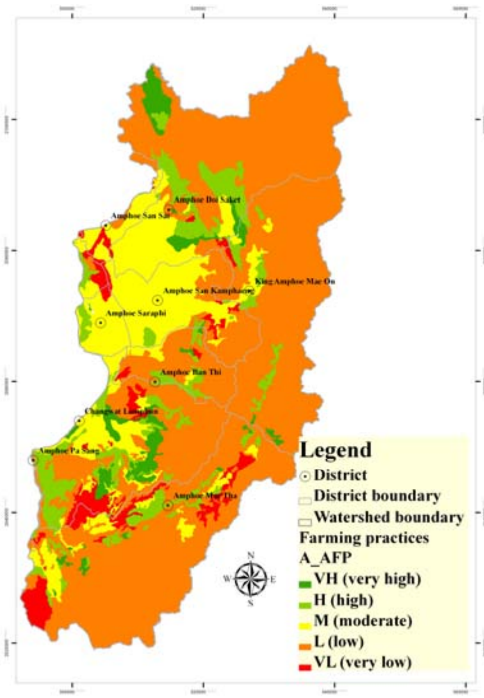

Figure D.1 Agricultural nutrient balance and present farm practices of lowland rice.

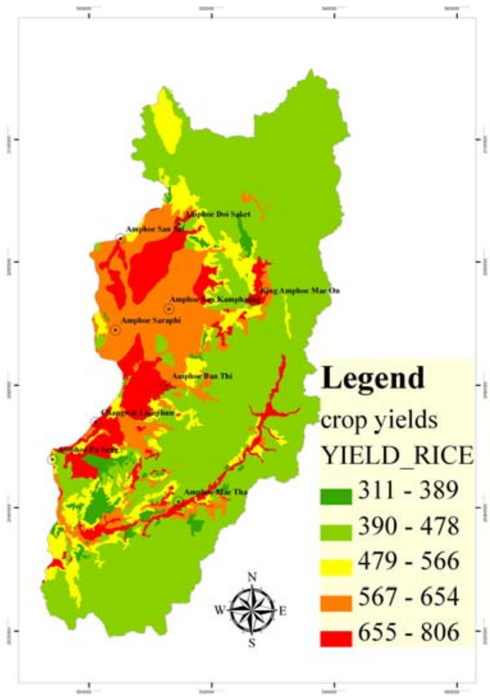

Figure D.2 Yields of lowland rice of lowland rice.

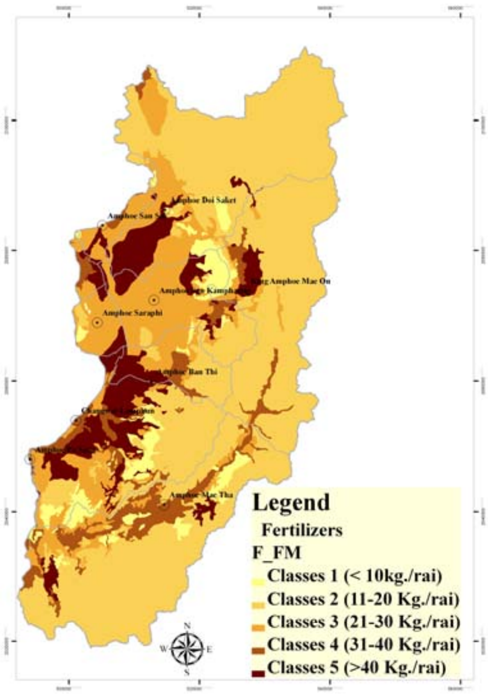

Figure D.3 Fertilizers management of lowland rice.

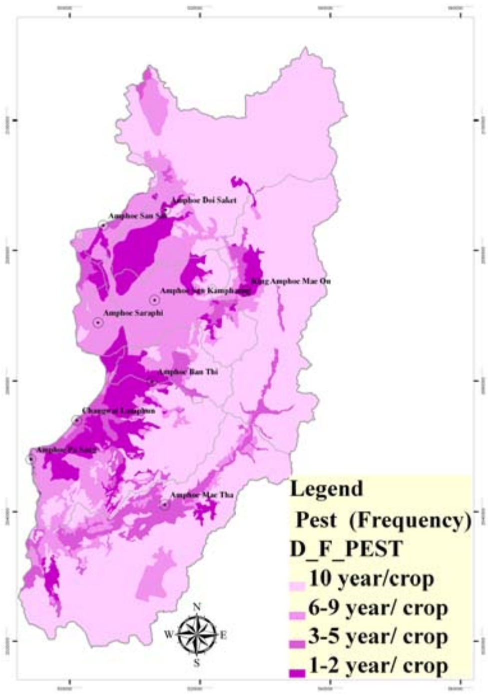

Figure D.4 Farm pest management of lowland rice.

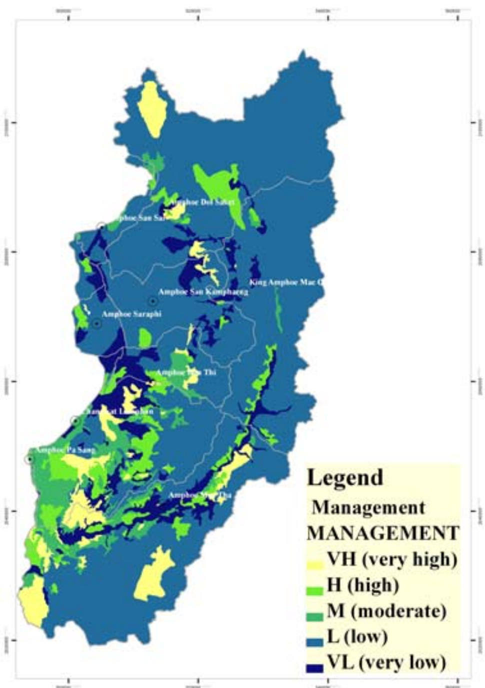

Figure D.5 Farm management and marketing of lowland rice.

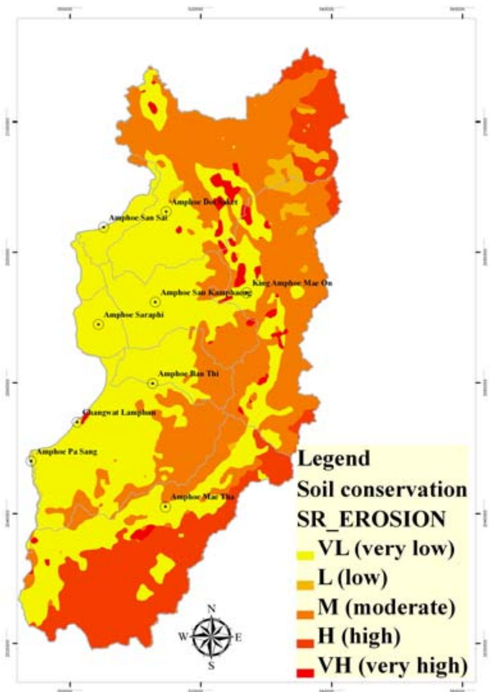

Figure D.6 Agricultural soil conservation management of lowland rice.

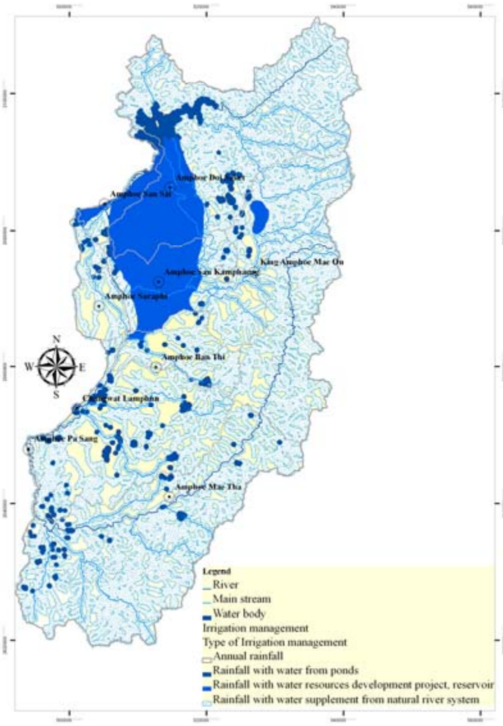

Figure D.7 Irrigation management of lowland rice.

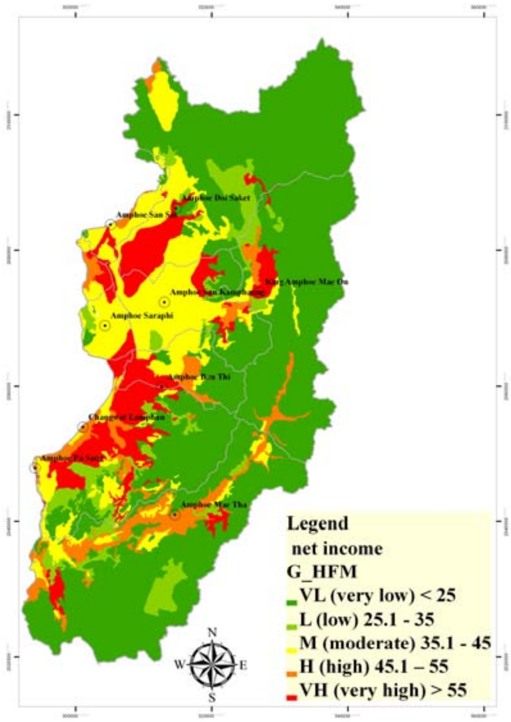

Figure D.8 Whole household farm management of lowland rice.

D.2 Criteria map for socio-economic of agricultural land suitability for longan

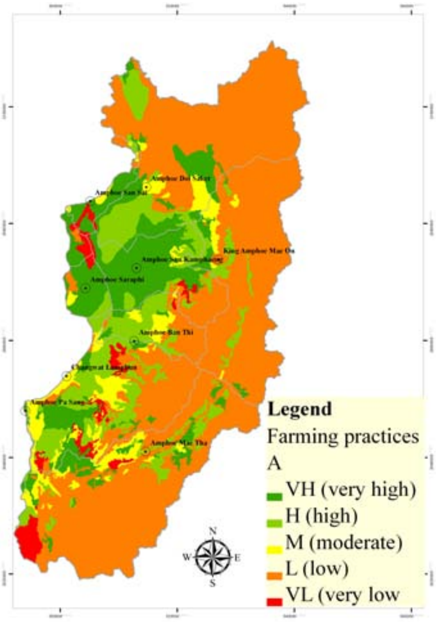

Figure D.9 Agricultural nutrient balance and present farm practices of longan.

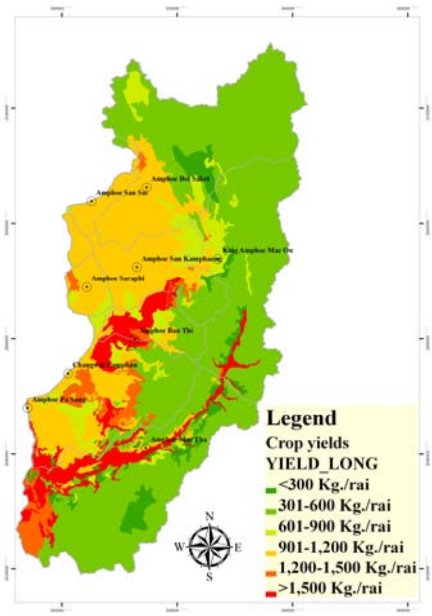

Figure D.10 Yields of lowland rice of longan.

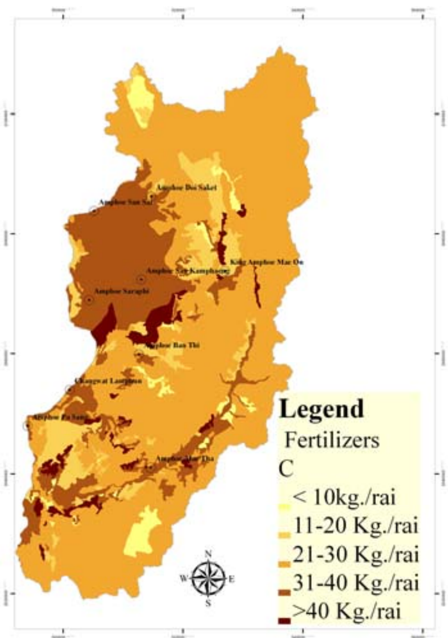

Figure D.11 Fertilizers management of longan.

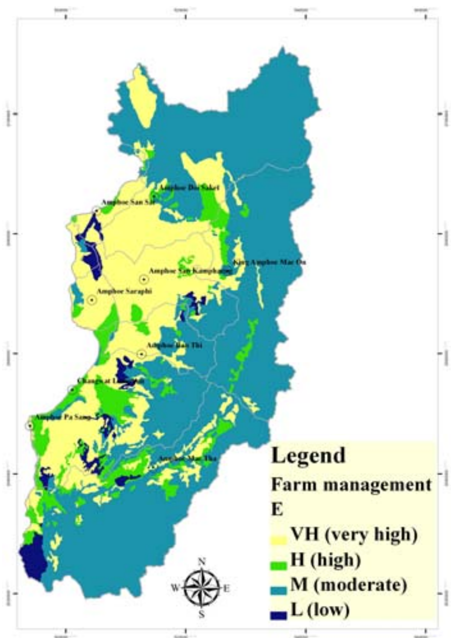

Figure:D.12 Farm management and marketing of longan.

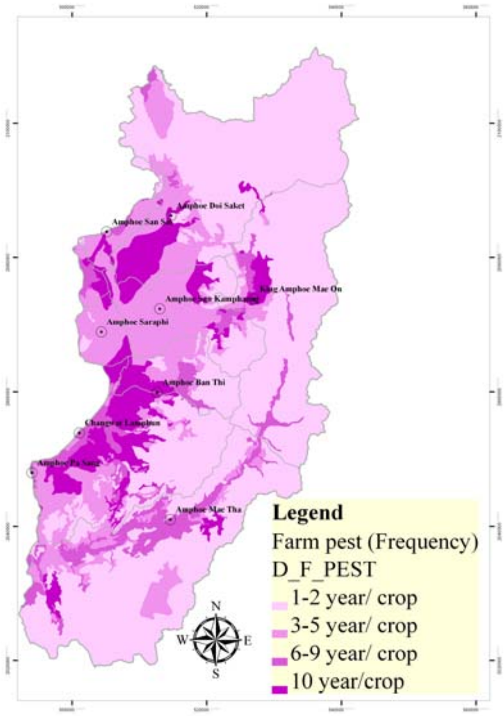

Figure D.13 Farm management and marketing of longan.

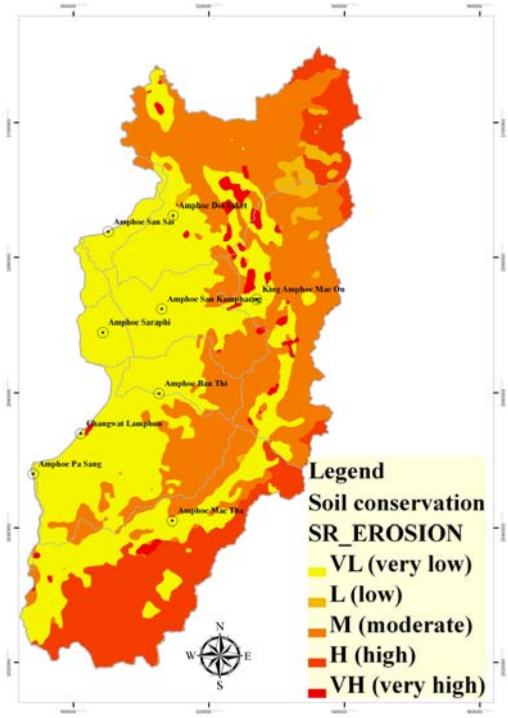

Figure D.14 Agricultural soil onservation c management of longan.

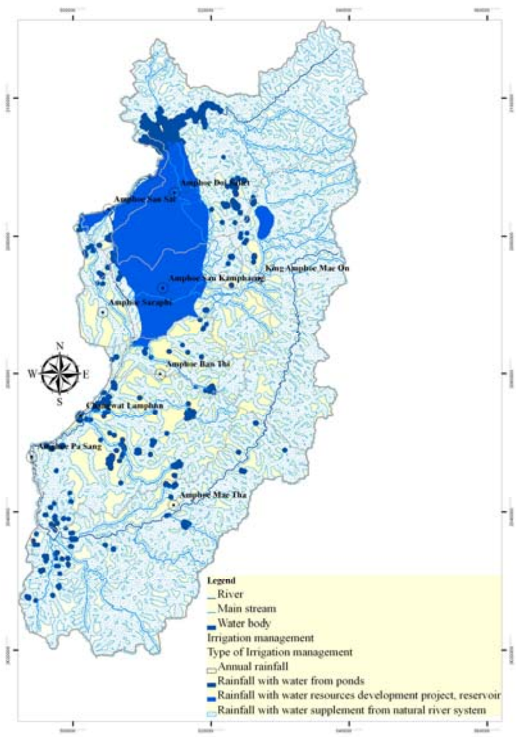

Figure D.15 Irrigation management of longan.

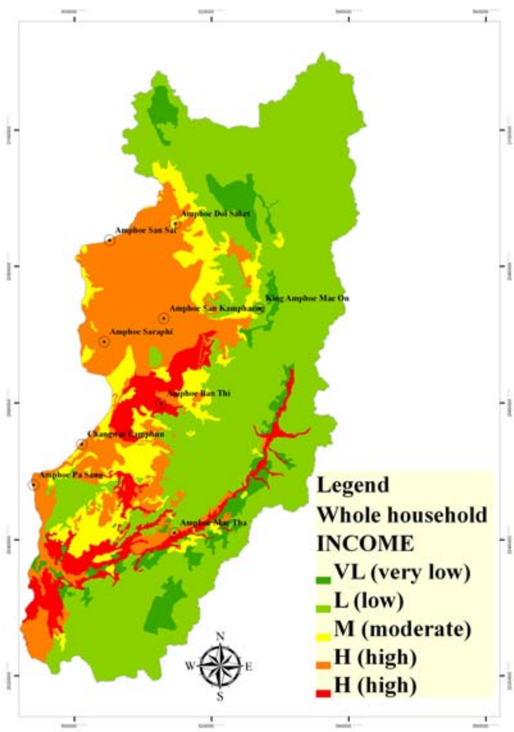

Figure D.16 Whole household farm management of longan.

APPENDIX E

ACCURACY ASSESSMENT OF

LAND USE/LAND COVER

Table: D.1 Accuracy assessment of land use/land cover in 2007.

No	Land use and land cover	Reference data																							
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	
1	Scrub and grass	1	1			23		1				1					1	1							29
2	Bush fallow	1	2			1											1								5
3	Cattle farm house	1		3				1																	5
4	Poultry farm house				2																				2
5	Lowland rice					148	3																		151
6	Longan					2	78					2													82
7	Village						1	47	1			1													50
8	High land village						1	2	2	1															6
9	Allocated land project							1		3	1														5
10	City, town, commercial and service									1	3														4
11	Deciduous dipterocarp forest						11					49	3	1											64
12	Mixed deciduous forest						2					3	67	6		1									79
13	Mixed orchard						1					4	3	16	2	4									30
14	Mixed swidden cultivation						3					3		1	2	1									10
15	Hill evergreen forest															2									2
16	Recreation area							1							2		1								4
17	Factory																	1							1
18	Golf course																	1	1						2
19	Industrial estate																	1		2					3
20	Institutional land																				1				1
21	Mine																					2			2
22	Lake																						1	1	2
23	Reservoir																						2	3	5
	Total	**3**	**3**	**3**	**2**	**174**	**100**	**53**	**3**	**5**	**4**	**63**	**73**	**24**	**6**	**8**	**3**	**4**	**1**	**2**	**1**	**2**	**3**	**4**	**544**

Overall accuracy of all 80.33%
Khat 76.52%

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Boonprasert, R., Boonjung,H., Ongsomwang S., and Sarapirome S. (2008). "GIS-based model to evaluate recent past past-to to-present trend of land use case study of Mae Kwang watershed, Chiang Mai, Thailand". In **International Conference on Mapping and Geo-informatics "Tackling GLOBAL CHANGE with Geo-Informatics"** Bangkok, January 21-23, 2008.

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