STUDY OF ENVIRONMENTAL INDICATORS TO MONITOR SUSTAINABLE HIGHLAND AGRICULTURE: A CASE STUDY OF THE ANGKHANG ROYAL AGRICULTURAL STATION, DOI ANGKHANG, CHIANG MAI PROVINCE, THAILAND

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การศึกษาตัวชี้วัดสิ่งแวดล้อมเพื่อติดตามความยั่งยืนของเกษตรกรรมพื้นที่สูง: กรณีศึกษาสถานีเกษตรหลวงอ่างขาง ดอยอ่างขาง จังหวัดเชียงใหม่ ประเทศไทย

นางสาวสิริรักษ์ เพ็งนาม

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาศิลปศาสตรมหาบัณฑิต
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สิริรักษ์ เพ็งนาม: การศึกษาตัวชี้วัดสิ่งแวดล้อมเพื่อติดตามความยั่งยืนของเกษตรกรรมพื้นที่สูง: กรณีศึกษาสถานีเกษตรหลวงอ่างขาง ดอยอ่างขาง จังหวัดเชียงใหม่ ประเทศไทย.
(STUDY OF ENVIRONMENTAL INDICATORS TO MONITOR SUSTAINABLE HIGHLAND AGRICULTURE: A CASE STUDY OF THE ANGKHANG ROYAL AGRICULTURAL STATION, DOI ANGKHANG, CHIANG MAI PROVINCE, THAILAND)
อ.ที่ปรึกษาวิทยานิพนธ์หลัก: อ. ดร. แสงจันทร์ ลิ้มจิรกาล,
อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: ดร. อัศมน ลิ่มสกุล, 102 หน้า.

มูลนิธิโครงการหลวงได้นำแนวคิดและวิธีปฏิบัติการพัฒนาการอย่างยั่งยืนสำหรับเกษตรกรรมพื้นที่สูง มาใช้ตั้งแต่ปีพ.ศ. 2512 โดยเริ่มดำเนินการนำผลไม้ยืนต้นเมืองหนาวเข้ามาเพาะปลูกในเชิงพาณิชย์ เพื่อการให้เกิดวิถีทางที่ยั่งยืนขึ้น ทั้งนี้การดำเนินการยังขาดตัวชี้วัดสิ่งแวดล้อมอย่างยั่งยืน เพื่อใช้ในการติดตามและวัดผลความก้าวหน้าและความสำเร็จในการดำเนินงานดังกล่าว งานวิจัยนี้มีวัตถุประสงค์เพื่อศึกษาตัวชี้วัดสิ่งแวดล้อมที่เหมาะสมนำไปใช้ติดตามความยั่งยืนของเกษตรกรรมพื้นที่สูง และศักยภาพในการประยุกต์ใช้ในแปลงเกษตรสาธิตของสถานีเกษตรหลวงอ่างขาง

กรอบแนวคิด แรงขับเคลื่อน-ความกดดันต่อสิ่งแวดล้อม-สภาวะของสิ่งแวดล้อม-ผลกระทบ-การตอบสนอง (DPSIR) และตัวชี้วัดสิ่งแวดล้อมที่ถูกพัฒนาขึ้นโดย องค์กรความร่วมมือและพัฒนาทางเศรษฐกิจ (OECD) รวมถึงการเก็บข้อมูลจากการสำรวจพื้นที่ศึกษาได้ถูกนำมาใช้พัฒนาตัวชี้วัดสิ่งแวดล้อม การตรวจวัดและอธิบายสภาพพื้นที่ศึกษา เพื่อนำมาใช้ในการกำหนดและพัฒนาเป็นแบบสอบถามกึ่งโครงสร้าง และนำไปสอบถามความคิดเห็นของผู้เชี่ยวชาญ โดยใช้วิธีการสุ่มตัวอย่างแบบเฉพาะเจาะจงผู้เชี่ยวชาญ 8 คน ที่มีพื้นความรู้เกี่ยวข้องกับสิ่งแวดล้อมและ/หรือเกษตรกรรมพื้นที่สูงและมีประสบการณ์การทำงานที่สถานีเกษตรหลวงอ่างขาง ตัวชี้วัดสิ่งแวดล้อมจากผู้เชี่ยวชาญได้ถูกนำไปใช้ในการสัมภาษณ์เชิงลึกโดยใช้แบบสอบถามกับเจ้าหน้าที่ของสถานีเกษตรหลวงอ่างขาง

จากการศึกษา พบตัวชี้วัดสิ่งแวดล้อม 17 ตัว แบ่งออกเป็น 4 กลุ่ม ได้แก่ การจัดการฟาร์ม การใช้ปัจจัยในการผลิตและทรัพยากรธรรมชาติ ผลกระทบของการเกษตรต่อสิ่งแวดล้อม และโครงสร้างฟาร์มและทรัพยากรทางการเงิน ผู้เชี่ยวชาญและเจ้าหน้าที่มีความเห็นสอดคล้องกันกับตัวชี้วัดสิ่งแวดล้อม 10 ตัว ได้แก่ มาตรฐานการจัดการฟาร์ม แผนการจัดการธาตุอาหาร แผนการจัดการศัตรูพืช การจัดการอนุรักษ์ดิน การใช้ธาตุอาหาร การใช้สารกำจัดศัตรูพืช การใช้ที่ดิน ความหลากหลายของทางชีวภาพ รายได้ และผลผลิตทางการเกษตร ซึ่งมีความเหมาะสมที่จะนำใช้ติดตามความยั่งยืนของเกษตรกรรมพื้นที่สูง ทั้งนี้การศึกษาพบว่ามีข้อจำกัดและความท้าทาย และควรมีการศึกษาตัวชี้วัดดังกล่าวเพิ่มเติม เพื่อนำไปใช้ให้เหมาะสมกับเกษตรกรบนพื้นที่สูง ตลอดจนควรมีการศึกษาตัวชี้วัดในด้านสังคมและเศรษฐกิจ เพื่อที่จะสร้างเสริมความยั่งยืนของเกษตรกรรมพื้นที่สูงแบบองค์รวม

สาขาวิชา	สิ่งแวดล้อม การพัฒนาและความยั่งยืน	ลายมือชื่อนิสิต	.....
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SIRILUCK PENGNAM: STUDY OF ENVIRONMENTAL INDICATORS TO MONITOR SUSTAINABLE HIGHLAND AGRICULTURE: A CASE STUDY OF THE ANGKHANG ROYAL AGRICULTURAL STATION, DOI ANGKHANG, CHIANG MAI PROVINCE, THAILAND. ADVISOR: SANGCHAN LIMJIRAKAN, D.Tech.Sc.,
CO-ADVISOR: ATSAMON LIMSAKUL, Ph.D., 102 pp.

The concept and practices of sustainable development for highland agriculture have been introduced in northern Thailand via the Royal Project Foundation (RPF) since 1969. The sustainability pathway has initiated by introducing of substitute temperate perennial fruits as commercial crops that earn greater benefit than opium to highlanders. However, there is no an appropriate a set of environmental and sustainability-relevant indicators to monitor and measure the progress and success of such practices. The objective of this research is to study appropriate environmental indicators to be introduced and used to monitor sustainable highland agriculture and its potential for application through a case study on the demonstration plots of the Angkhang Royal Agricultural Station.

The conceptual framework of Driving Forces-Pressures-State-Impacts-Responses (DPSIR) and the agri-environmental indicators developed by the Organisation for Economic Co-operation and Development (OECD), as well as relevant data collected by direct observation were used to develop environmental indicators, measure and describe issues of the state of study area, in order to formulate and develop a semi-structured questionnaire and then applied to experts. A purposive sampling method was used to select eight experts who have relevant knowledge and background on environment and/or agriculture as well as their work experiences at the Angkhang Royal Agricultural Station. Selected environmental indicators by expert judgments were introduced to the officials of the study station by using questionnaire for in-depth interview.

The study found that the relevant data of study were 17 environmental indicators which be grouped into 4 categories, namely farm management, use of farm inputs and natural resources, environmental impacts of agriculture and farm structure and farm financial resources. The research findings revealed that experts and officials mutually agreed on ten environmental indicators including farm management standard, nutrient management plan, pest management plan, soil conservation management, nutrient use, pesticide use, land use, biodiversity, farm income and agricultural output that are appropriately used to monitor sustainability highland agriculture. The study has shown some limitations, challenges and also recommends such a set of environmental indicators should be further studied, properly introduced and modified to highland farmers as well as research on the suitable social and economic indicators to enhance sustainability of highland agriculture in a holistic approach.

Field of Study:	Environment Development and Sustainability	Student's Signature	.....
		Advisor's Signature	.....
Academic Year:	2013	Co-Advisor's Signature	.....

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LIST OF ABBREVIATIONS

DPSIR	Driving Forces-Pressures-State-Impacts-Responses
DSR	Driving Force–State–Response
EEA	European Environmental Agency
EM	Micro-Organism
ESI	Environment Sustainability Index
FAO	Food and Agriculture Organization
GAP	Global Good Agricultural Practice
GMP	Good Manufacturing Practice
HACCP	Hazard Analysis and Critical Control Points
HRDI	Highland Research and Development Institute
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management
ISD	Indicators of Sustainable Development
ISTAT	National Institute of Statistics of Italy
MEA	Millennium Ecosystem Assessment
OECD	Organisation for Economic Co-operation and Development
PR	Public Relation
PSR	Pressure–State–Response
RHP	Royal Highland Project
RPF	Royal Project Foundation
SARD	Sustainable Agriculture and Rural Development
UN	United Nations

UNCED	United Nations Conference on Environment and Development
UNCSD	United Nations Commission on Sustainable Development
WCED	World Commission on Environment and Development
WEF	World Economic Forum

CHAPTER I

INTRODUCTION

1.1 Background and importance of the study

It has been realized that over the past decades human activities have exerted substantial pressure on environment and natural resources which can have serious socio-economic consequences (Millennium Ecosystem Assessment, 2005)[1]. As a result of anthropogenic-induced global environmental change, the concept of sustainable development was emerged in 1989 which integrated environmental, economic and social dimensions in the balanced manner. The objective of this concept is to promote the sustainable achievement of development as well as high standard of society and good environment. To quantitatively monitor the progress and the success of this concept, the relevant international organizations such as The United Nations Conference on Environment and Development (UNCED) has developed a set of reliable, readable, measurable and policy-relevant indicators. The development of an analytical framework for constructing indicators was discussed by Organisation for Economic Co-operation and Development (OECD). In addition, the UN Commission on Sustainable Development has requested member countries to use indicators in their annual reports to measure progress in reaching sustainable development. Those include the indicators for Sustainable Agriculture and Rural

[1] The Millennium Ecosystem Assessment (MEA) was initiated by the United Nations to assess the consequences of ecosystem change for human well-being and to develop the scientific basis for actions needed to enhance the conservation and sustainable use of ecosystems by society

Development (SARD), as defined in Agenda 21, adopted at the UNCED Rio Summit in 1992[2].

For years, highland agriculture in northern Thailand was slash-and-burn and well known as traditional opium poppy cultivation. To resolve this problem, temperate perennial fruits have been promoted mainly via the Royal Project by His Majesty King Bhumibol Adulyadej, which increases farmers' revenue to improve their quality of life as well as to conserve soil and water in the upstream catchment where forests have been intensively cleared. The Royal Highland Project (RHP) in northern Thailand has been then established since 1969, aiming to promote sustainable agriculture to local highland people. Temperate perennial fruits were selected, on the basis of their highly commercial potential, as the promising crops that local people can earn great benefit while soil and water as well as highland environment in the mountainous areas can improve their quality (Rojanasoonthon, 2004).

Even though the concept and practice of sustainable highland agriculture have been introduced in northern Thailand via the Royal Project, there is no an appropriate set of environmental and sustainability-relevant indicators to monitor and measure the progress and the success of those activities. As a consequence, it is essential for developing environmental indicators as a simple tool used to monitor highland agricultural activities in the northern Thailand on the basis of some following reasons. First of all, northern Thailand is one of social-ecological

[2] As part of the UN Commission for Sustainable Development Agenda 21 programme to develop information systems on sustainable development (see UN, 1995), the Food and Agriculture Organization (FAO) has begun establishing guidelines for collecting and using indicators related to Sustainable Agriculture and Rural Development (SARD).

vulnerability, and appears to be sensitive to any changes, because of its geographical and topographical settings with diverse and complex mountains as well as upstream catchment areas (Rerkasem, 1995). Secondly, highland agriculture in northern Thailand particularly at farm level is usually lack of sustainable practices, due to the fact that farmers do not well understand the concept of agricultural sustainability. Thirdly, highland agriculture cannot reach the goal of sustainability concept because of its depletion of monitoring state of the environment. Therefore, the research on theenvironmental indicators is undoubtedly useful for providing the fundamental tool to improve measurement of the progress and the level of environmental sustainability on highland agriculture. Such environmental indicators can be studied for agriculture system which integrates environmental concern into agriculture.

This research provides effective methods to study environmental indicators to monitor sustainability on highland agriculture. To enhance agricultural sustainability by introducing the effectiveness environmental indicators is the integrated concept which conserves and improves environment. Moreover, stakeholders need to be reformed their practices moving towards more sustainability (Bélanger and Vanasse, 2012) based on the information derived from the application of environmental indicators at the study area. Furthermore, the recommendations from this research are given for the further study of interest applicable and meaningful for the agricultural sustainability.

1.2 Research objective

- To study appropriate environmental indicators to be introduced and used to monitor sustainable highland agriculture and its potential for application to the demonstration plots of the Angkhang Royal Agricultural Station.

1.3 Research question

- What are the suitable environmental indicators to appropriately monitor sustainable highland agriculture at the study area?

1.4 Scope of the study

- The pilot study area is the demonstration plots of the Angkhang Royal Agricultural Station.
- To achieve above objective, the scope of the study consists of two main parts which are the study of a suitable set of the environmental indicators in order to introduce at the study area in the context of the agricultural sustainability concept.
- The Driving Forces – Pressures – State – Impacts - Responses (DPSIR) framework is used to describe and appropriately integrated the environmental indicators into the concepts of sustainable agriculture.
- The survey of expert judgments is conducted to the respondents selected by whom having knowledge and background on environmental and/or agriculture relevant to their work at the Angkhang Royal Agricultural Station.

- Questionnaire related to the study is developed and used for the survey and in-depth interview.
- A set of environmental indicators is introduced to the pilot study area by using an in-depth interview applying to officials at the study area.

1.5 Expected outcomes

The expected outcomes of the study are:

- a set of environmental indicators which are appropriately applicable for the demonstration plots of the Angkhang Royal Agricultural Station,
- more understandable concept of sustainable agriculture by introducing a set of environmental indicators to the Angkhang Royal Agricultural Station's officials and
- the recommendations which are useful for further related study.

CHAPTER II

LITERATURE REVIEW

2.1 Agricultural sustainability

2.1.1 Background and concept

Since 1987, Brundtland Commission first defined sustainable development as the "ability to make development sustainable—to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). The use of this definition has led to the United Nations Conference on Environment and Development (UNCED) in 1992. This conference was held in Rio de Janeiro and adopted an agenda for environment and development in the 21st Century so-called Agenda 21. It was a programme of action for sustainable development, included agreements on issue of sustainable agriculture. Consequently, the concept has increasingly evolved to achievable sufficiency on agricultural productivity and equitable distribution of resources for long-term maintenance of well-being.

Goodland (1995) reported that environmental sustainability is to maintain of natural resources, thus agriculture is sustained if it conserves their natural resources provided by the ecosystem. The goals of sustainable agriculture generally include the maintenance or enhancement of the natural environment, provision of human food need, economic viability and social welfare (Smith and McDonald, 1998). In general, sustainability of agriculture in the context of development efforts has to

meet: (i) production efficiency, (ii) resilience of ecosystems, (iii) appropriate technology, (iv) maintenance of the environment, (v) cultural diversity, and (vi) satisfaction of the basic needs (Mueller, 1997).

Hansen (1996) stated that sustainability is required for agriculture, and tended to be continued into the future. The Organisation for Economic Co-operation and Development (OECD, 1995) defined sustainable agriculture as "the basic long-term challenge facing agriculture is to produce sufficient food and industrial crops efficiently, profitably and safely, to meet a growing world demand without degrading natural resources and the environment". Simultaneously, the OECD in 1991 established the framework of environmental indicators for agriculture, indicator definitions and measurement methods of the current state (OECD, 1993). However, the future work would be developed as a bottom up approach in particularly farmers practices. This will make agriculture more sustainable (Bélanger and Vanasse, 2012) in order to improve farming practices, nutrient use and water efficiencies while enhance crop production to improve quality of life in the mode of economy efficiency.

2.2 Causal-chain framework and environmental indicators

The causal-chain framework initiated the concept of cause and effect relationship between diagnostic variables. It has been used in environmental assessment reports applying environmental indicators, proposed by the OECD in the late 1990s. These frameworks had generated the importance of causality as a means of structuring and organizing indicators in the context of decision makers such as Pressure – State – Response (PSR) framework (OECD, 1993), Driving Force – State –

Response (DSR) framework (UN, 1996) and Driving Forces – Pressures – State – Impacts – Responses (DPSIR) framework (EEA, 1995).

2.2.1 Pressure – State – Response (PSR) framework

The Pressure – State – Response (PSR) framework was developed by the OECD since 1993. It is based on the concept that human activities exert pressures on the environment and affect its quality and quantity of natural resources (state) and society responds to these changes through environmental (OECD, 1993). The PSR framework has the advantage to highlighting the cause-effect relationships and to helps decision makers and public understanding all elements interconnected as shown in Figure 2.1.

This framework also offers an evaluation by distinguishing three types of indicators to help quantifying and simplifying complex phenomena. Pressure indicators describe the pressures creating on the environment by human activities. State indicators provide a condition on the present state of matters, while response indicators represent societal action aimed at searching on sustainable approach.

The PSR approach has been comprehensively applied to both national and international levels, for example; it is used in Environment Sustainability Index (ESI), developed by the World Economic Forum (WEF). However, some recent works have shown that pressure and response indicators are not adapted because of the approach is not clear enough and problematic to understand, and manage relationships between economical and social dimension (Biodiversity and Conservation, 2009). For example; the Indicators of Sustainable Development (ISD) program adopted by the United Nations Commission on Sustainable Development

(UNCSD) was found to be inappropriate indicators for economic and social pillars because of the lack of focus on policies (UNCSD, 2001).

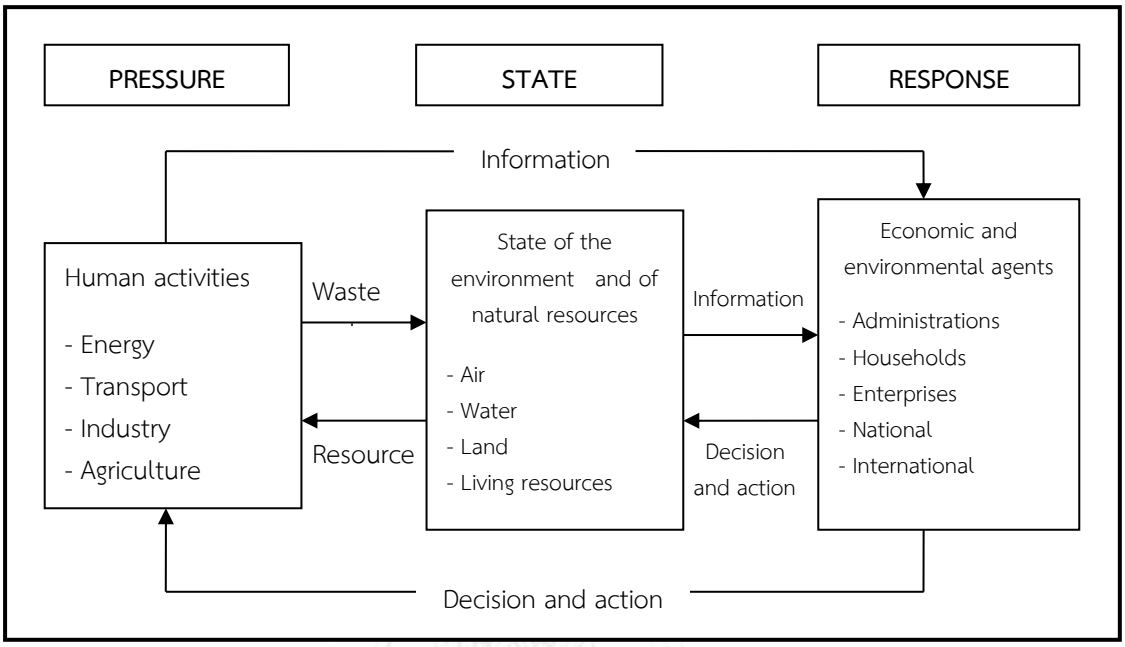

Figure 2.1. The Pressure – State – Response (PSR) framework.

Source: OECD, 2003.

2.2.2 Driving Force – State – Response (DSR) framework

The Driving Force – State – Response (DSR) framework was a modified form of the PSR framework and was adopted by the General Assembly of the United Nation held in 1996 under the title of "Indicators of Sustainable Development: Framework and Methodologies" (UN, 1996). In this framework, the "Pressure" element was replaced by the concept of "Driving Forces" in order to aid more precisely the supplement of social, economic and institutional indicators. More specific

characteristics of agriculture and its relation to the environment are in the broader context of sustainable development.

The OECD defined that, agricultural activities can both produce beneficial impacts to enhance environmental quality and also have negative impacts on the environment" (OECD, 1999). This framework outlines the analysis of sustainable development as illustrated the linkages in Figure 2.2. Such linkages include farmer behaviour, governmental policy and economic, social and also cultural factor which effect on the environment. The DSR framework can be summarized as follows,

- Driving Force indicators include all elements that cause changes by social and economic and natural processes and biophysical patterns in the state of the environment,
- State or condition indicators that indicate the state of environment in agriculture, referring to any changes in environmental conditions. Those impacts from agriculture activities can occur in both on-farm and off-farm, and
- Response indicators referring to the reaction in both society and policy that would make a response to changes in the state of the environment in agriculture. These included farmer behavior, consumer reaction, responses by institution, organization and government.

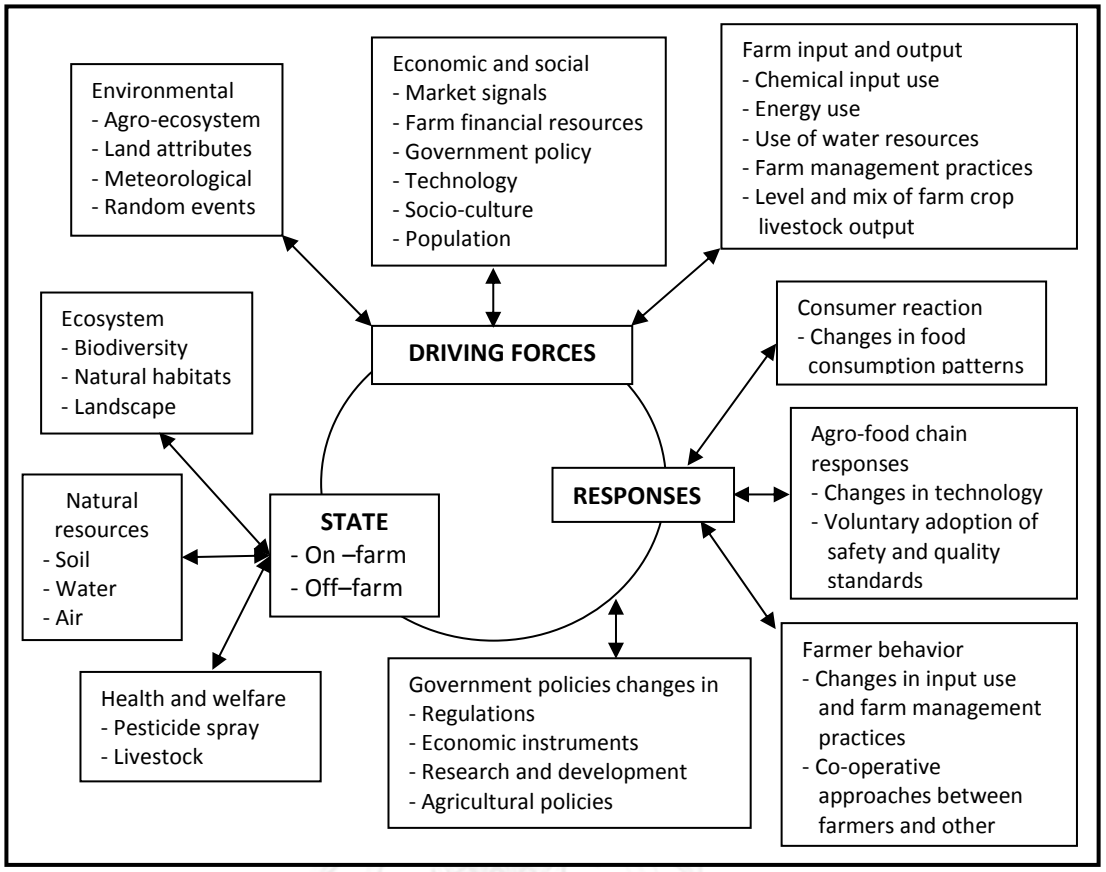

Figure 2.2. The Driving Force – State – Response (DSR) framework to address agri-environmental linkages and sustainable agriculture

Source: OECD, 1999.

2.2.3 Driving Forces – Pressures – State – Impacts - Responses (DPSIR) framework

The DPSIR stands for Driving Forces, Pressures, State, Impact and Responses. The DPSIR framework is an extension version of the PSR framework developed by the OECD. This framework was adapted by the European Environmental Agency (EEA) in 1995 and the European Statistical Office in 1997 (Eurostat, 1997). The approach is focused on driving force indicators that underline causes of pressure whereas impacts are the effect of the observed changes in the state of the environment as shown in Figure 2.3.

The DPSIR framework is used as a structuring mechanism to select indicators measuring and describing issues on the impact of the environment. The interactions between human activities and the environment (cause-effect) can also reflect the driving force indicators that are commonly practical. According to Louwagie and Northey (2012), the indicators should reflect the specific and predictable response of environmental systems to farming activities. Moreover, the indicator can present results of impacts to encourage and support decision-makers on environmental quality giving feedbacks to policy maker. The DPSIR framework can be concluded as follows,

- Driving Force indicators are useful for calculating a variety of pressure indicators. They also help decision makers to plan actions (responses) needed to avoid future problems (pressures) and serve as a basis for scenario development and long-term planning.
- Pressure indicators point directly to the causes of problems, so that a decision maker has an opportunity to reduce numbers of indicator (and thus the problem) by initiating appropriate actions.
- State indicators are a result of pressures which can help in making the first assessment of a situation. They are composed of physical, chemical and biological indicators.
- Impact indicators demonstrate the DPSIR patterns, particular cause-effect chains, and facilitate informed discussions on actions needed in order to avoid future negative impacts.
- Response indicators monitor measures that are intended to make the gentle socio-economic system move forward.

Therefore, indicators are very useful to indicate progressed work toward sustainability fulfilment which reduces pressures on the environment. In particular, indicators on driving forces can clearly explain whether a sustainable production system aimed at reducing pressures on the environment stresses. Those can be applied in the field (UNDSD, 2001; WCED, 1987; OECD, 2000).

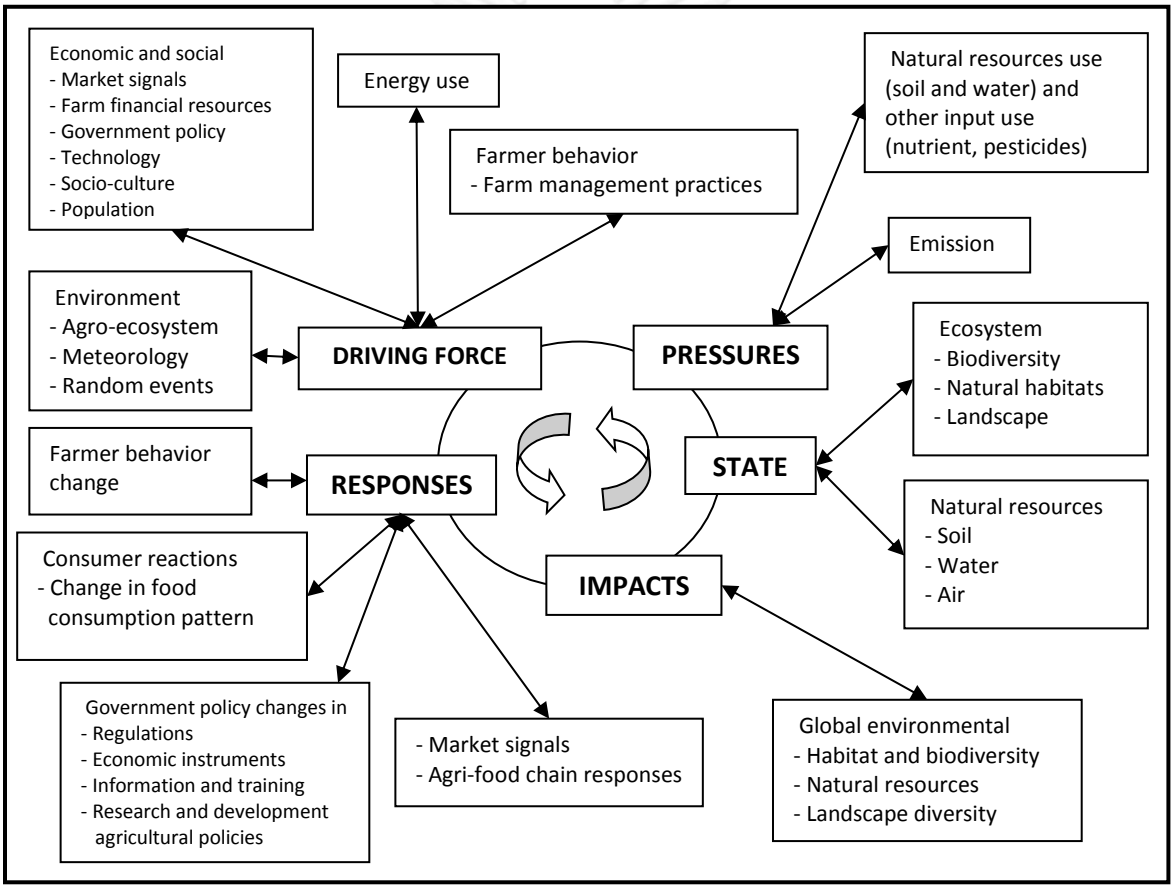

Figure 2.3. The Driving forces – Pressures – State – Impact – Responses (DPSIR) framework for agricultural activity

Source: National Institute of Statistics of Italy (ISTAT) modified from OECD, 1997.

2.3 Environmental impacts and environmental indicators for agriculture

2.3.1 Farming practice and its environmental impact

As commonly known, agriculture is significantly reflected in socio-economic prosperity. However the recent intensification of agriculture along with farming practices such as an increase in chemical utilization and machineries for achieving higher productivity has changed ecosystem. This leads to several environmental impacts such as accelerated soil erosion, declined water quality and quantity, biodiversity loss and agriculture's contribution to greenhouse gases (IPCC, 2000). In addition, deforestation for agricultural proposes is one of the most serious environmental problems which cause a decline in ecosystem and biodiversity which eventually lead to environmental disaster risks such as floods and droughts.

The consequences of environmental impact of agriculture mostly depend on farm management practices (emission to the environment) and also environmental and climate-related factors such as rainfall and temperature. Therefore, it is necessary to better understand positive and negative impacts from agriculture activities, based on indicator-derived calculation.

2.3.2 Characteristic of environmental indicators for agriculture

Environmental indicators can be used to analyze the linkages between agricultural system and its ecosystems in particular. The indicators also characterize the environmental impacts of farming practices (OECD, 2000). The environmental indicators provide information primarily on risks for the environment linked to farming activities. In general, the environmental indicators can minimize the pressure

from economic and social activities. The European Environment Agency (EEA) and the OECD described specific environmental issues which provide framework to develop a set of environmental indicators. Such environmental indicators provide on the way into state and dynamics of the environment and generally indicators of environmental pressures that consist of physical, biological and chemical indicators (Smeets and Weterings, 1999), conditions or change in state and (societal) responses (OECD, 1993). Nevertheless, Hammond et al., (1995) argued that such indicators are not immediately detectable as they need to be measured or make perceptible a trend or phenomenon. However, it was very a useful tool to highlight environmental conditions and trends for policy purposes which help policymakers to examine and determine appropriate actions (Niemeijer, 2002). Schomaker (1997) stated that indicators are required to be SMART (Specific, Measurable, Achievable, Relevant and Time-Bound). SMART indicators can be used to provide information and describe the current state of the phenomena. These are useful to monitor any changes, predict trends and track progresses over time. Such indicators can be used for both quantitative and qualitative statistics. In fact, they can be used for logical assumptions in terms of available resources whilst they can also be found useful for issues at hand that are sensitive to changes within policy time-frames (Primdahl et al., 2010).

2.4 Definition and selection of environmental indicators for agricultural sustainability

Since causal-chain framework was developed by several international organizations such as the OECD, UN and EEA, their works were largely increased in term of performances on their progress towards sustainable agriculture development

through environmental indicators application. The OECD developed agri-environmental indicators of sustainable agriculture as shown in Table 2.1. These indicators aim to monitor and measure resources productivity that are linked to economic and environmental (e.g. nutrient and water use efficiency) and social aspects (e.g. impact of agrochemical on human health). In general, environmental indicators cover factors such as soil, water, and human resources which are commonly used to assess agricultural sustainability. A core set of agri-environmental indicators as well as its definitions are provided by the OECD Member countries. These indicators are relevant to overall issues on environment and agriculture which are useful for policy-making (OECD, 2001).

Table 2.1. Complete list of OECD Agri-environmental Indicators.

<table>
<tr><th colspan="3">I. AGRICULTURE IN THE BROADER ECONOMIC, SOCIAL AND ENVIRONMENTAL CONTEXT</th></tr>
<tr><th colspan="2">1. Contextual Information and Indicators</th><th>2. Farm Financial Resources</th></tr>
<tr><td colspan="2">● Agricultural GDP
● Agricultural output
● Farm employment
● Farmer age/gender distribution
● Farmer education
● Number of farms
● Agricultural support</td><td>● Farm income
● Agri-environmental expenditure
—Public and private agri-environmental expenditure
—Expenditure on agri-environmental research</td></tr>
<tr><th colspan="3">II. FARM MANAGEMENT AND THE ENVIRONMENT</th></tr>
<tr><th colspan="3">1. Farm Management</th></tr>
<tr><td>● Whole farm management
– Environmental whole farm management plans
– Organic farming</td><td>● Nutrient management
– Nutrient management plans
– Soil tests
● Pest management
– Use of non-chemical pest control methods
– Use of integrated pest management</td><td>● Soil and land management
– Soil cover
– Land management practices
● Irrigation and water management
– Irrigation technology</td></tr>
</table>

Table 2.1. Complete List of OECD Agri-environmental Indicators (continued).

<table>
<tr><th colspan="3">III. USE OF FARM INPUTS AND NATURAL RESOURCES</th></tr>
<tr><th>1. Nutrient Use</th><th>2. Pesticide Use and Risks</th><th>3. Water Use</th></tr>
<tr><td>● Nitrogen balance
● Nitrogen efficiency</td><td rowspan="2">● Pesticide use indicator
● Pesticide risk indicators</td><td rowspan="2">● Water use intensity
● Water use efficiency
– Water use technical efficiency
– Water use economic efficiency
● Water stress</td></tr>
<tr><th>4. Land Use</th></tr>
<tr><td>● Land use
— Stock of agricultural land
— Change in agricultural land
— Agricultural land use</td><td></td><td></td></tr>
<tr><th colspan="3">IV. ENVIRONMENTAL IMPACTS OF AGRICULTURE</th></tr>
<tr><th>1. Soil Quality</th><th>3.Land Conservation</th><th>4. Greenhouse Gases</th></tr>
<tr><td>● Risk of soil erosion by water
● Risk of soil erosion by wind</td><td rowspan="2">● Water retaining capacity
● Off-farm sediment flow</td><td rowspan="2">● Gross agricultural greenhouse gas emissions</td></tr>
<tr><th>2. Water Quality</th></tr>
<tr><td>● Water quality risk indicator
● Water quality state indicator</td><td></td><td></td></tr>
<tr><th>5. Biodiversity</th><th>6. Wildlife Habitats</th><th>7. Landscape</th></tr>
<tr><td>● Genetic diversity
● Species diversity
– Wild species
– Non-native species
● Ecosystem diversity</td><td>● Intensively farmed agricultural habitats
● Semi-natural agricultural habitats
● Uncultivated natural habitats
● Habitat matrix</td><td>● The structure of landscape
– Environmental features and land use patterns
– Man-made objects
● Landscape management
● Landscape costs and benefits</td></tr>
</table>

Source: Environmental Indicators for Agriculture: Methods and Results, Volume 3 by OECD, 2001.

In addition, Bélanger and Vanasse (2012) suggested that the functions of environmental indicators should be simply quantified and easily communicated since that is the best approach for assessing sustainability. They also described and selected 13 environmental indicators by using experts' consultation and farmers' participation. Consequently, this selection of environmental indicators dose not only serves as a framework but also as an instrument in which stakeholders can use to

identify environmental issues on their farms (Shaxson, 1997). In addition, Tzilivakis and Lewis (2004) showed that some important information is procured by farmers, to select environmental indicators to assess their production systems. Because all stakeholders are key elements for building and developing environmental indicators to agricultural systems assessment (Rossing, et al., 1997; King, et al., 2000; Rigby, et al., 2001). Therefore, indicators' selection should involve and include opinions and discussions since stakeholders' participation is probably the best way in developing and/or selecting more pragmatic indicators.

CHAPTER III

RESEARCH METHODOLOGY

3.1 Conceptual framework

The conceptual framework of this research is designed to relate to sustainable agriculture approach. Such indicators are applicable to monitor levels of sustainable highland agriculture. The DPSIR framework for agricultural activity and the agri-environmental indicators developed by the OECD were as duse a main conceptual framework to study environmental indicators, measure and describe issues of the state of highland agriculture at the study area.

This research used both qualitative and quantitative data together with detailed information. The process of this study also included desk study, direct observation, expert judgments and in-depth interviews. Moreover, the Angkhang Royal Agricultural Station officials were engaged in the process of introducing a set of environmental indicators to strengthen participation and interaction between users and technicians/researchers. The methodology and research design are shown in Figure 3.1, while details regarding data processing and analysis are illustrated in Figure 3.3.

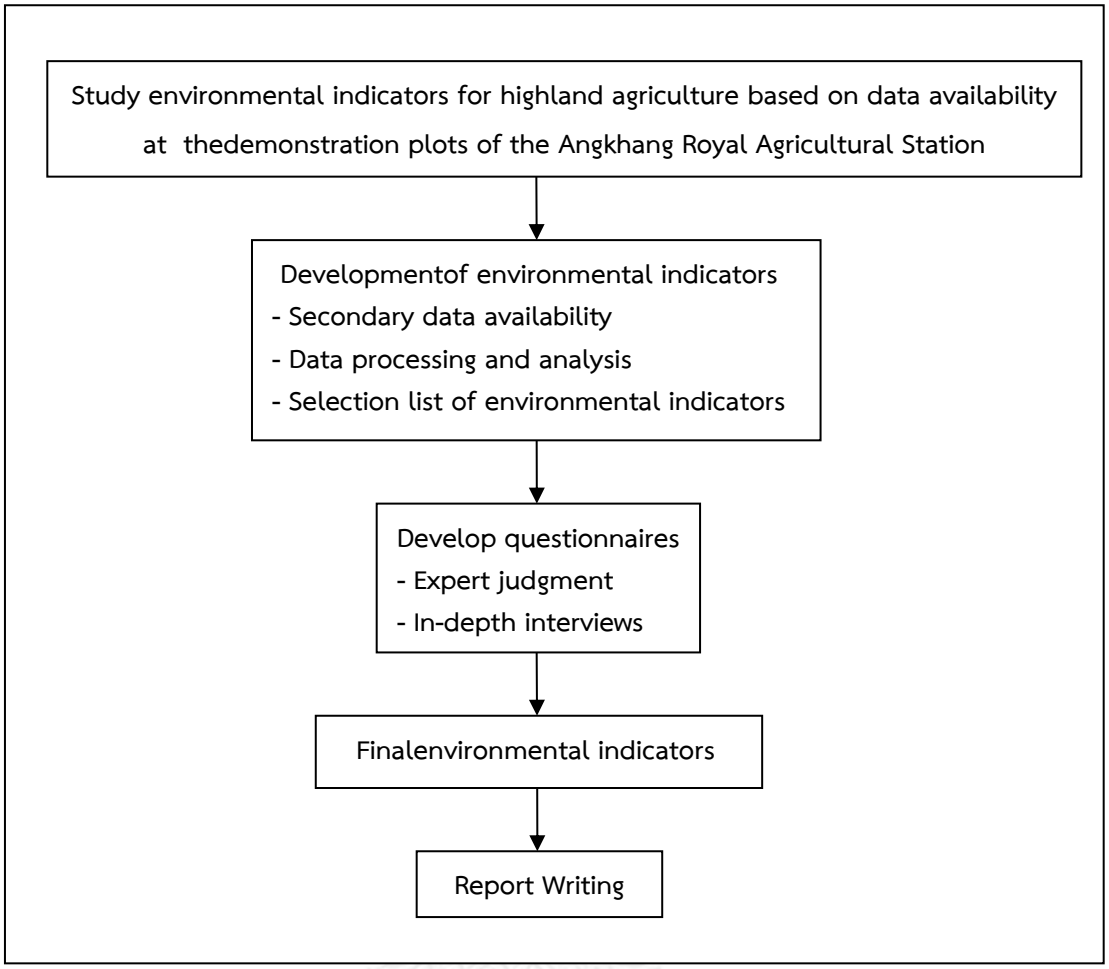

Figure 3.1. Methodology and research design.

3.2 Study area

The selected study area was the demonstration plots of the Angkhang Royal Agricultural Station. It is the first research station of the Royal Project Foundation (RPF). The project was founded in 1969, undertaken through the initiative of His Majesty King Bhumibol Adulyadej. The first RPF's objective was to dissuade highlanders (hill-tribes) from opium poppy cultivations, to shift the practice of cultivation and to help poor livelihood of highlanders in northern Thailand. Meanwhile, the project aims to cope and solve problems of the destruction of

natural resources, loss in upstream catchment, deforestation and counter erosion effects with economically viable alternative crops to diversify farming system. The sustainability pathways are also initiated through an introduction of a substitution of temperate perennial fruits as commercial crops that earn greater benefit than opium plantations to highlanders. Therefore, the Angkhang Royal Agricultural Station is suitable for planting and researching on highland agriculture that can deliver outcomes to highlanders for their sustainable livelihood.

The Angkhang Royal Agricultural Station is located in the valley Angkhang, Baan-Khum Moo 5, Mae Ngon Sub-district, Fang District, Chiang Mai province in northern Thailand as shown in Figure 3.2. It is located near 5 villages consisting Ban Luang, Ban Khum, Ban Pang Ma, Ban Khop Dong, and Ban Nor Lae. There are a number of highland minority groups (hill-tribe groups) such as the Haw Chinese, Tai Yai, Lahu Na, and Palong.

The geography and topography of the Angkhang valley is steep, diverse and complex mountains. The geological structure of the Angkhang valley is dominated by sedimentary rocks of numerous ages which are mainly shales and limestones. The mountains run into parallel line from north to south and concur south to north with ridges stretching about 8 kilometers in length and 3 kilometers in width forming a sink in the center. The sinkholes that cause groundwater loss are generally round with 5.3 meters in width and 4.2 meters in depth. In addition, Topography of Angkhang valley is Karst landform. It has slopes ranging from 15 % to 45 % and with rough and bumpy ground surface. The highest peak of the area is about 1,820 meters above the mean sea level. The Angkhang Royal Agricultural Station's office is located at a plain area at the attitude of about 1,400 meters above the mean sea level.

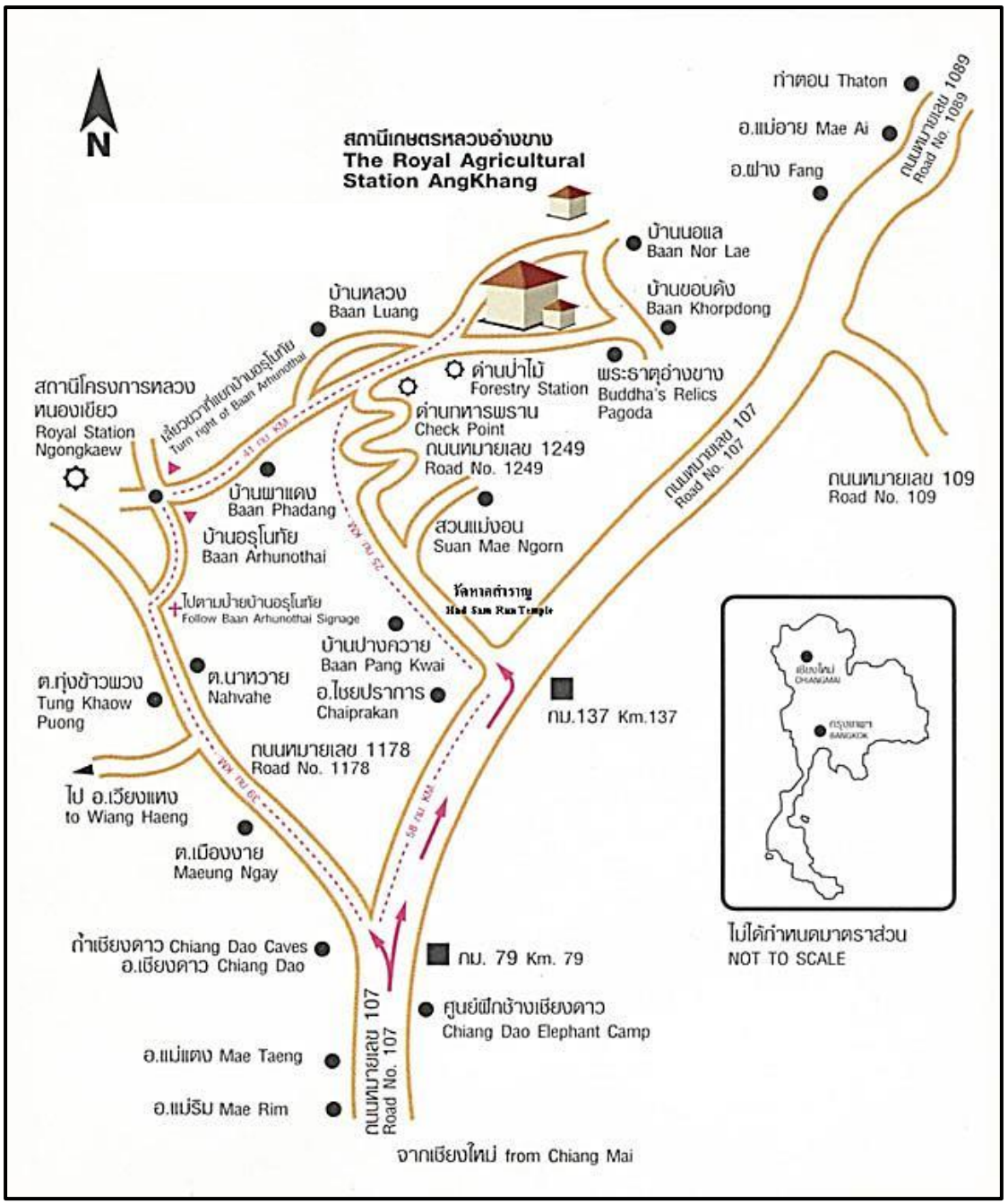

Figure 3.2. Location map of the Angkhang Royal Agricultural Station.

Source: http://www.angkhangstation.com/public/img/Map.jpg

The area of the Angkhang Royal Agricultural Station comprises of hills and mountain with 2 major soil series. The first series is Reddish Brown Lateritic (Ban Luang series) which is mostly found in the eastern part of the Angkhang valley. The second series is Red Brown Earths (Angkhang series) which is mostly found in the western part of the Angkhang valley of the Thai-Burmese border. Both series have relatively high clay content and high percentage of organic matters content with the pH of 4.5-6.0. In addition, the subgroups of Angkhang soil include Fluverntic Eutrudepts, Lithic Eutrudepts, Oxyaquic Eutrudepts, Rhodic Paleudalfs, Typic (Mollic) Paleudalfs, Typic Hapludalfs, Typic Paleudalfs, Ultic (Mollic) Hapludalfs, Ultic Eutrudepts, and Ultic Hapludalfs (Udomsri, 2006).

The study area is classified as the Humid Subtropical climate which is under the influence of the southwest from the Indian Ocean, the rainy season which is a long period, starts from an early April to late October. For the cool-dry season, the Northeast monsoons bring cool and dry air from the south of China which starts from November and ends in March. The hot-dry season starts from the end of March to April which is a short period. The climate is cool throughout the year, the average temperature is about 17.9 ^{0}C and the average minimum - maximum temperature are in the range of 12.5-24.1 ^{0}C. The lowest temperature is -3 ^{0}C which is usually in January and the highest temperature is 31.5 ^{0}C which is typical in April. On average the relative humidity is about 69 % in the cool-dry season, the average humidity range is 65-30 % while in the rainy season; the average humidity range is 90-85 %. The total annual rainfall accumulation is averagely about 2,055 mm. with the highest usually peaks in August and lowest in January (Udomsri, 2006).

3.3 Data collection

Instruments and approaches used for data collections are as follows;

1) Desk study

Various literature reviews, publishing papers, reports of academic research, book sections, project reports, etc. were used as background information, as well as the DPSIR framework and the agri-environmental indicators developed by the OECD were used as key information in this study.

2) Direct observation

Direct observation was significant to identify an overall basis of limitation and performance information of the demonstration plots at the study area for better understanding of the area system. The relevant data recorded in 2012 which used to list the environmental indicators were collected.

3) Expert judgments

The process of selecting the indicators through stakeholder participation is found to be important (King et al., 2000; Rigby et al., 2001). Expert judgments were used to refine the lists of appropriately environmental indicators used to monitor sustainable highland agriculture of the study area. A semi-structured questionnaire was developed and applied to experts. A purposive sampling method was used to select eight experts who have knowledge and background on environment and/or agriculture as well as their work experiences at the Angkhang Royal Agricultural Station.

A set of the questionnaire for experts was developed which consists of four parts, as follows; i.) general information, ii.) highland agriculture and identify its barriers/problems, iii.) the environmental indicators selection by expert judgments, and iv.) recommendations and suggestions. Closed-ended and open-ended questions were also included in the questionnaires. Multiple choices, categorical and numerical were used in the part of general information. Likert-scale was used in the part of the environmental indicators selection. The open-ended questions were used in the part of highland agriculture and identify its barriers/problems as well as recommendations and suggestions.

4) In-depth interview

A semi-structured questionnaire was developed for introducing the selected environmental indicators of expert judgments to in-depth interviews 10 respondents as representatives of the Angkhang Royal Agricultural Station's officials who work out at the demonstration plots. The in-depth interview questionnaire contained questions interrelating to questionnaire for experts and its result which included i.) basic information of respondents, ii.) barriers/problems on demonstration plots of the Angkhang Royal Agricultural Station, iii.) environmental indicators, and iv.) recommendations and suggestions. Furthermore, the respondents were interviewed and discussed whether those selected environmental indicators and its potential for application in order to enhance sustainable highland agriculture by introducing those indicators to their work fields.

3.4 Data analysis

Based on overall framework shown in Figure 3.1, the details of the data processing and analysis can be determined as shown in Figure 3.3 and as follows,

- The DPSIR framework and the agri-environmental indicators developed by the OECD were used to study the environmental indicators.
- The primary and secondary data obtained direct observations at the study area were used to list the environmental indicators. Descriptive statistics were used to analyze the data.
- The listed of environmental indicators was refined by using expert judgments to select the appropriately such environmental indicators used to monitor sustainable agriculture at the pilot study area. It was analyzed using the content analysis.
- The selected environmental indicators from expert judgments were introduced to the Angkhang Royal Agricultural Station's officials by using questionnaire for in-depth interview. It also was analyzed using the content analysis.
- The importance findings from both experts and official questionnaire analysis were summarized into a set of environmental indicators.

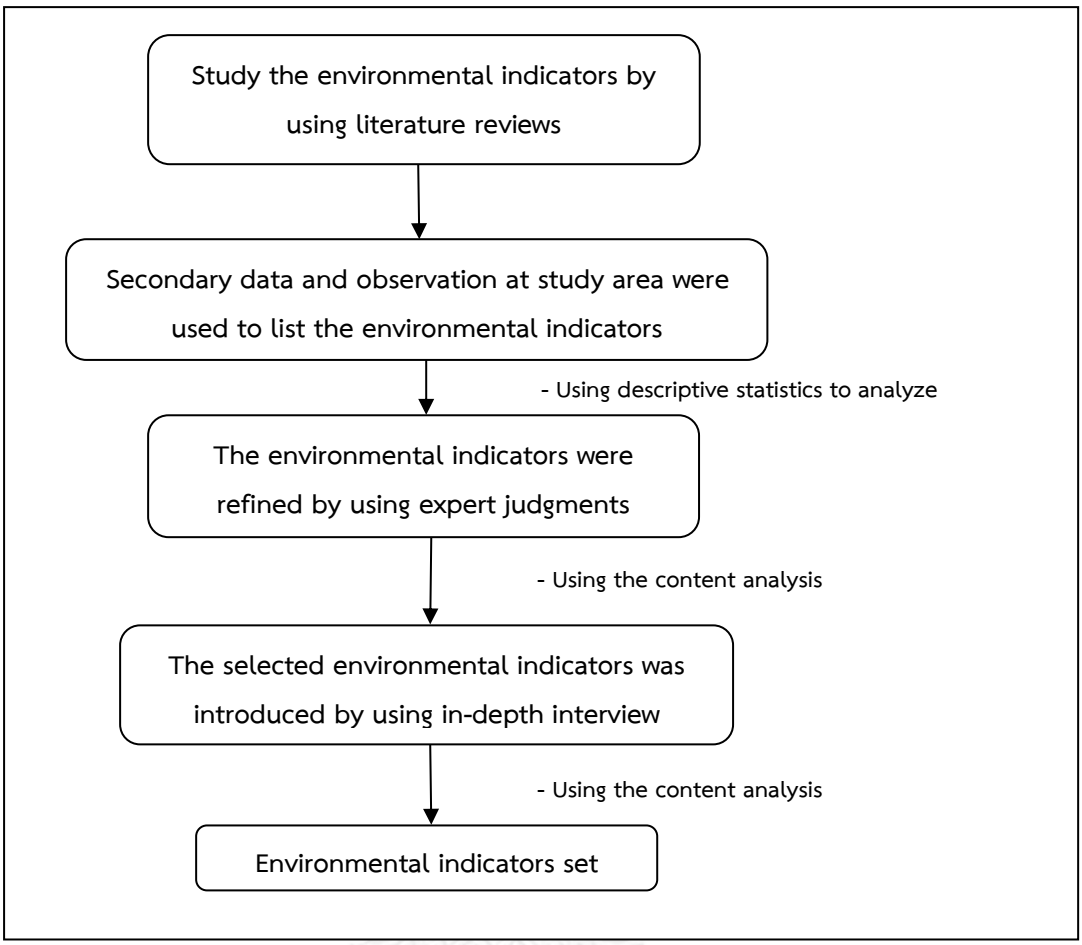

Figure 3.3. Data processing and analysis.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 The study area

4.1.1 Study area

The Angkhang Royal Agricultural Station is located in upper northern Thailand, at the latitude between 19° 56' 00" N and 19° 56' 02" N and the longitude between 99° 01' 27" E and 99° 04' 25 E. The elevation of the land is approximately 1,400 meters above the mean sea level as shown in Figure 4.1. The Station area is designed to be 2.89 square kilometers (1,811 rais), for planting demonstration and other relevant area. It comprises of station buildings, demonstration plots, reforest plantation plots, career promotion and development plots, roads and natural areas as shown in Figure 4.2. The study focused on the demonstration plots of the study station area which is 0.47 square kilometers (291.10 rais) as the details shown in Table 4.1.

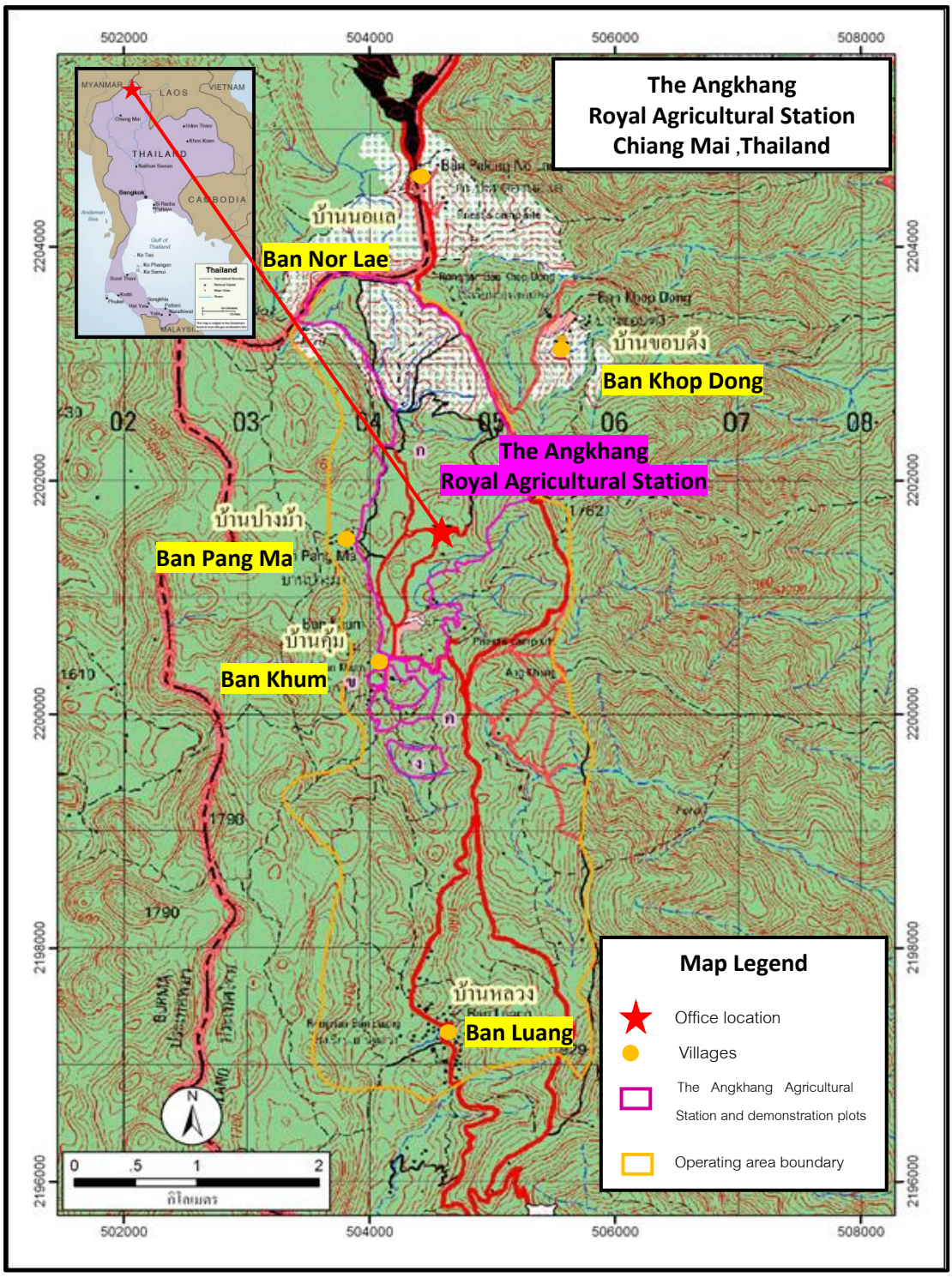

Figure 4.1. The Angkhang Royal Agricultural Station and its vicinity surrounding.

Source: The Angkhang Royal Agricultural Station, 2007.

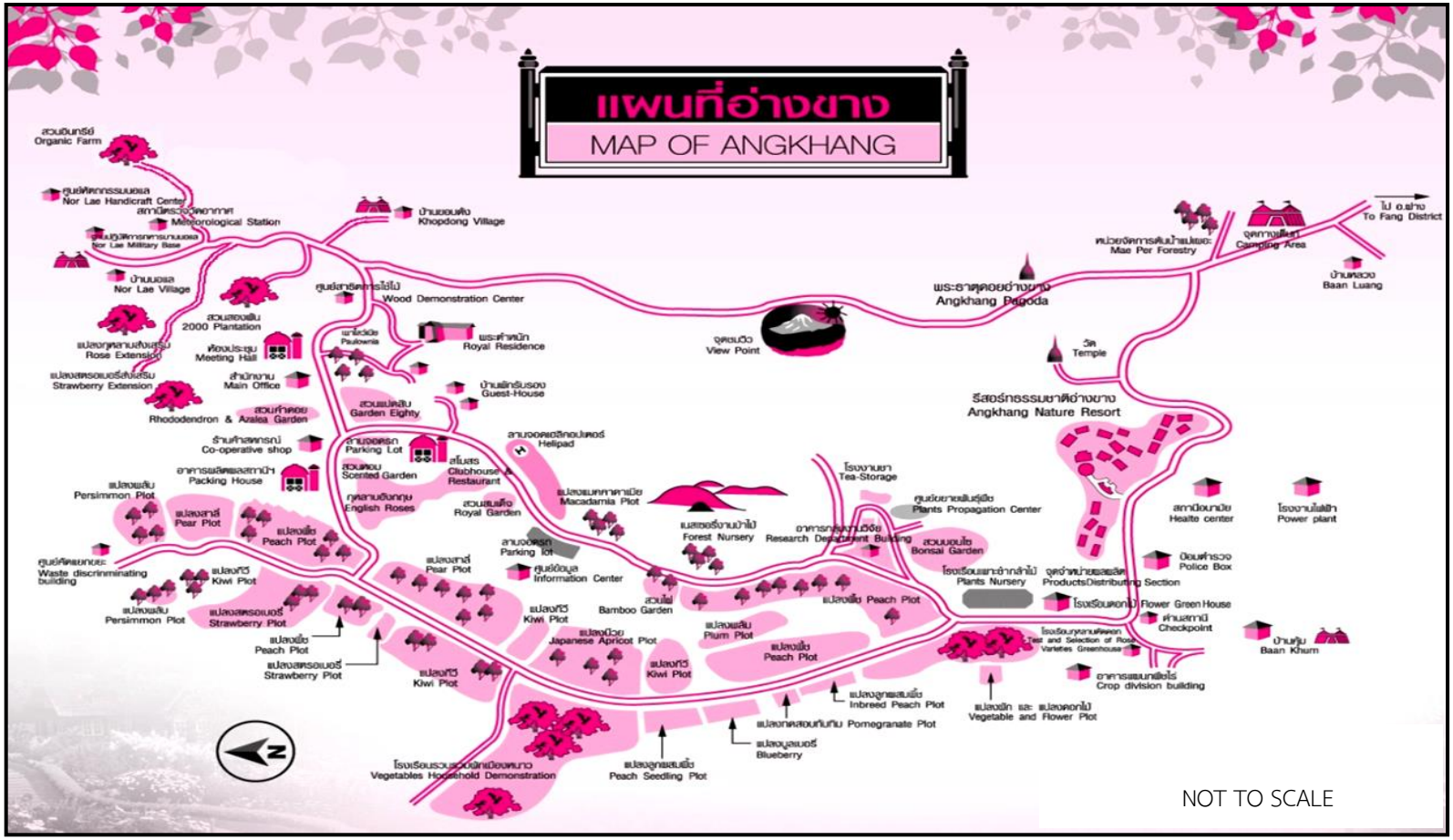

Figure 4.2. Map of the Angkhang Royal Agricultural Station and its demonstration plots.

Source: http://www.angkhangstation.com/travel/touristspots.

Table 4.1. Demonstration plots categorized by land use.

Land use categories	Demonstration plots areas (rais)
1. Temperate perennial crops	141.30
2. Evergreen or small trees	4.86
3. Vegetables	34.50
4. Herbal plants	5.57
5. Flowers and ornamental plants	2.50
6. Pine and bonsai	11.26
7. Field crop	8.00
8. Coffee trees	18.80
9. Nut trees	16.0
10. Portobello mushroom	0.18
11. Bamboo	5.0
12. Gardens	35.60
13. Livestock	7.50
Total areas	**291.10**

Source: Research Project Division of the Angkhang Royal Agricultural Station, 2012.

In addition, for vicinity villages career promotion and development, the operational area under the jurisdictions of the Angkhang Royal Agricultural Station include five main vicinity villages namely Ban Luang, Ban Khum, Ban Pang Ma, Ban Khop Dong, and Ban Nor Lae and four minor vicinity villages namely Ban Pha Daeng, Baan Tam Ngab, Ban Sin Chai and Ban Pa Kha. The area is about 26.52 square kilometers (16,577 rais).

The meteorological data were collected by the meteorological station of the Angkhang Royal Agricultural Station with the elevation level of 1,410 meters above the mean sea level. The annual meteorological data recorded in 2012 were

conducted during the field visit at study area. They include temperature, humidity, rainfall, evaporation, wind velocity, and dew point temperature. In 2012, the average mean temperature was 18.3 ^{0}C with the lowest average minimum and the highest average maximum temperature of 6.2 ^{0}C in January and 25.9 ^{0}C in April, respectively. The average relative humidity was 66.9 % with the lowest average minimum and the highest average maximum relative humidity of 18.3 % in February and 89.2 % in December, respectively. The annual rainfall accumulation was 2,096.20 mm. with the lowest and highest amount of monthly rainfall accumulation recorded of 0.00 mm. in February and 517.50 mm. in September, respectively.

The long period of the rainy season in 2012, started from April to October with the average temperature in the range of 14.7-24.3 ^{0}C. The average relative humidity was between 32.7 % and 87 % and the rainfall accumulation was between 76.10 mm. and 517.5 mm. For the cool-dry season which started from November to March, the average temperature was in the range of 6.2-25.6 ^{0}C. The average relative humidity was between 18.3 % and 89.2 % and the rainfall accumulation was between 0.00 mm. and 88.90 mm. The short period of hot-dry season was during March-April with the average temperature in the range of 10.6-25.9 ^{0}C, the average relative humidity was between 23.2 % and 87.9 % and the rainfall accumulation was between 61.00 mm and 134.40 mm. More details are as shown in Table 4.2 - 4.3 and Figure 4.3 - 4.5.

Table 4.2. Monthly average temperature (^{0}C) and monthly average relative humidity (%) measured at the Angkhang Royal Agricultural Station in 2012.

Month	Average temperature (°C)			Average relative humidity (%)		
	Maximum	Minimum	Mean	Maximum	Minimum	Mean
January	20.9	6.2	13.6	87.4	34.8	61.1
February	23.9	7.1	15.5	87.1	18.3	52.7
March	25.6	10.6	18.1	87.9	23.2	55.6
April	25.9	14.0	19.9	86.3	32.7	59.5
May	24.3	17.5	20.9	81.6	50.3	66.0
June	22.3	18.7	20.5	76.5	54.6	65.6
July	21.6	18.3	19.9	85.6	68.7	77.2
August	22.3	18.4	20.4	84.2	63.0	73.6
September	22.5	17.1	19.8	86.2	63.6	74.9
October	22.5	14.7	18.6	87.7	58.7	73.2
November	22.5	14.3	18.4	88.3	60.2	74.3
December	20.7	7.8	14.2	89.2	49.2	69.2
Mean	**22.9**	**13.7**	**18.3**	**85.7**	**48.1**	**66.9**
Max.	**25.9**	**18.7**	**20.9**	**89.2**	**68.7**	**77.2**
Min.	**20.7**	**6.2**	**13.6**	**76.5**	**18.3**	**52.7**

Source: The meteorological station at the Angkhang Royal Agricultural Station, 2012.

Table 4.3. Average rainfall (mm.), evaporation (mm./day), daylight (hour/ day), wind velocity (m./s), dew point temperature (^{0}C) and precipitation frequency (day) at the Angkhang Royal Agricultural Station in 2012.

Month	Parameters					
	Rainfall accumulation (mm.)	Average evaporation (mm./day)	Average daylight (hour/ day)	Average wind velocity (m/s)	Average dew point temperature ($^{\circ}$C)	Rainfall frequency (day)
January	6.70	2.18	7.30	1.87	3.60	3
February	0.00	3.34	8.40	2.37	4.10	-
March	61.00	3.50	7.10	2.11	7.50	4
April	134.40	4.06	7.40	2.39	11.60	10
May	236.60	3.01	4.50	1.87	15.40	19
June	76.10	2.50	3.10	2.97	17.00	21
July	429.60	1.85	1.90	2.77	17.80	28
August	305.50	2.28	2.80	1.95	17.70	26
September	517.50	2.46	1.10	1.54	15.80	23
October	230.80	2.33	4.80	1.26	13.30	20
November	88.90	2.04	5.80	1.33	12.60	16
December	9.10	1.92	7.30	1.51	4.50	3
Total	**2,096.20**		**61.50**			**173**
Mean	**174.70**	**2.62**	**5.10**	**2.00**	**11.70**	
Max.	**517.50**	**4.06**	**8.40**	**2.97**	**17.80**	
Min.	**0.00**	**1.85**	**1.10**	**1.26**	**3.60**	

Source: The meteorological station at the Angkhang Royal Agricultural Station, 2012.

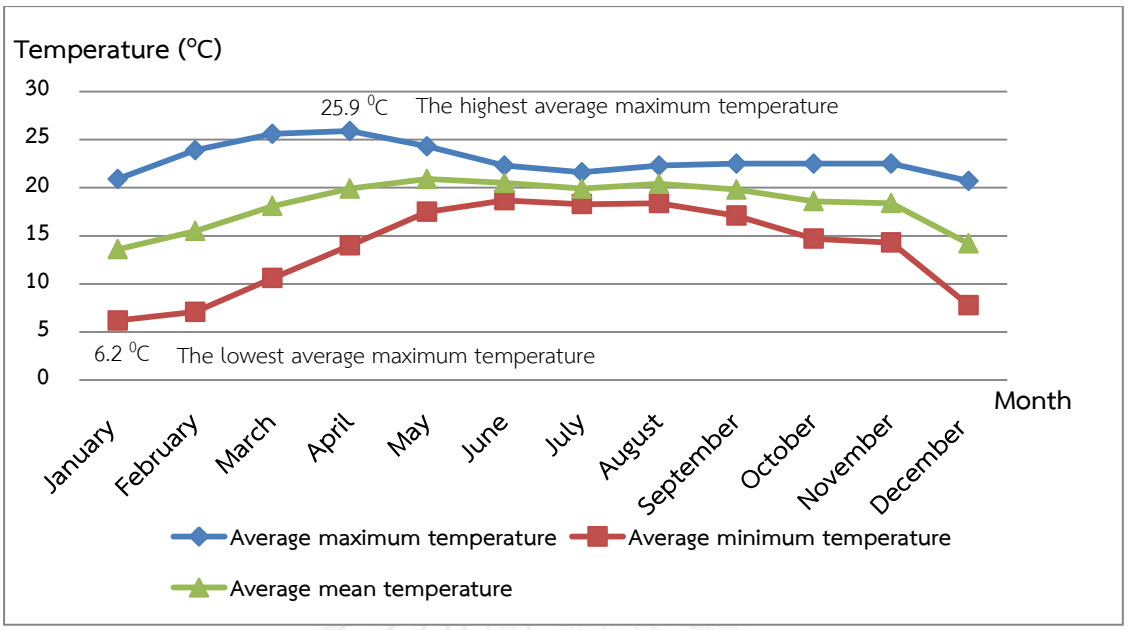

Figure 4.3. Average maximum, minimum and mean temperature (^{0}C) at the Angkhang Royal Agricultural Station in 2012.

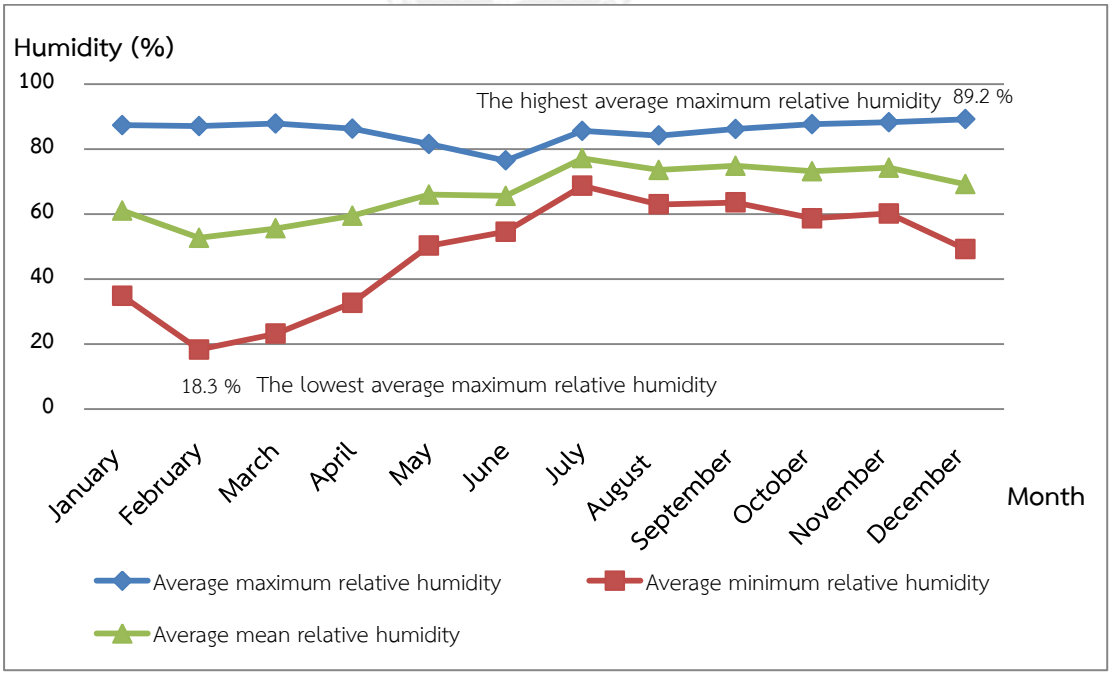

Figure 4.4 Average maximum, minimum and mean relative humidity (%) at the Angkhang Royal Agricultural Station in 2012.

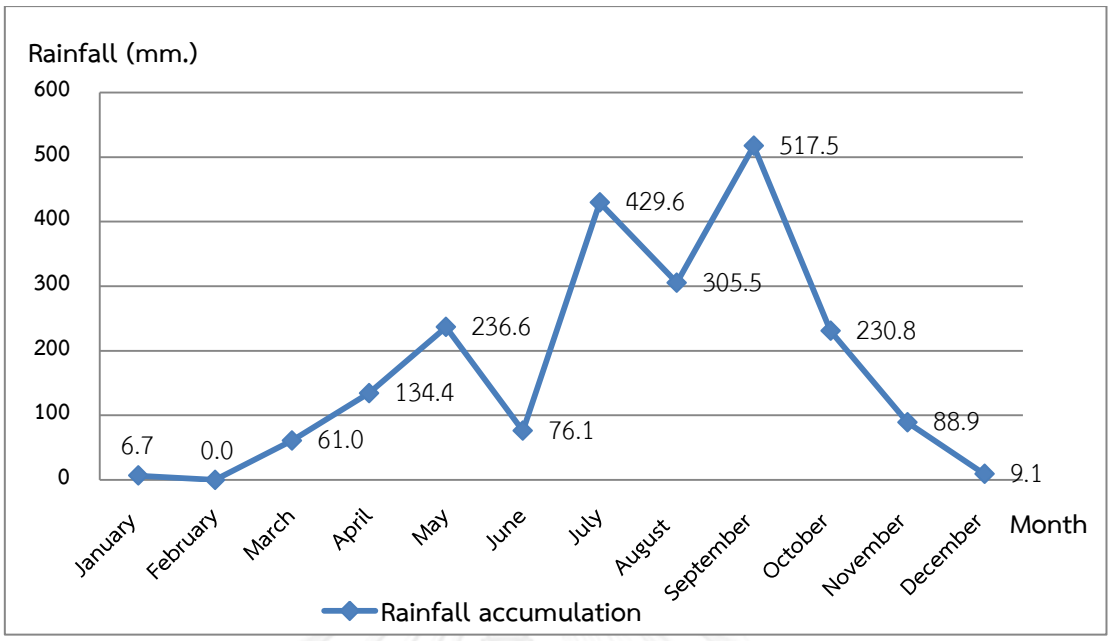

Figure 4.5. Monthly rainfall accumulation (mm.) measured at the Angkhang Royal Agricultural Station in 2012.

4.1.2 The operational organization structure of the Angkhang Royal Agricultural Station

The operational organization structure of the Angkhang Royal Agricultural Station is divided into five divisions as shown in Figure 4.6 namely (i) administrative division, (ii) research project division, (iii) services and publishing knowledge division, (iv) project and special activities division and (v) career development and promotion division. In 2012, there are 60 people who worked as officials in the station, in which 36 are male and 24 are female. The details are shown in Table 4.4. There are 335 farm workers as shown in details below in Table 4.5. They comprised of 46 Thai, 210 Tai Yai (Shan), 50 Burmese, 4 Chinese and 39 unknown nationalities (The Angkhang Royal Agricultural annual report, 2012).

Table 4.4. A number of officials at the Angkhang Royal Agricultural Station in 2012.

Officials positions	Male (persons)	Female (persons)	Total (persons)
Administrations	8	8	16
Academic (Technical researchers)	17	2	19
Assistant technical researchers	1	3	4
Career Development and Promotion	4	3	7
Full-time employees	0	2	2
Temporary employees	6	5	11
Research and development institution	0	1	1
Total (persons)	**36**	**24**	**60**

Source: Administrations division of the Angkhang Royal Agricultural Station, 2012.

Table 4.5. A number of farm workers at the Angkhang Royal Agricultural Station in 2012.

Farm workers	Male (persons)	Female (persons)	Total (persons)
Production sector	13	7	20
Researching sector	97	78	175
Special employment sector	27	33	60
Service sector	11	0	11
Services and publishing knowledge sector	6	8	14
Project sector	23	31	54
Administration sector	19	2	21
Total (persons)	**196**	**159**	**355**

Source: Administrations division of the Angkhang Royal Agricultural Station, 2012.

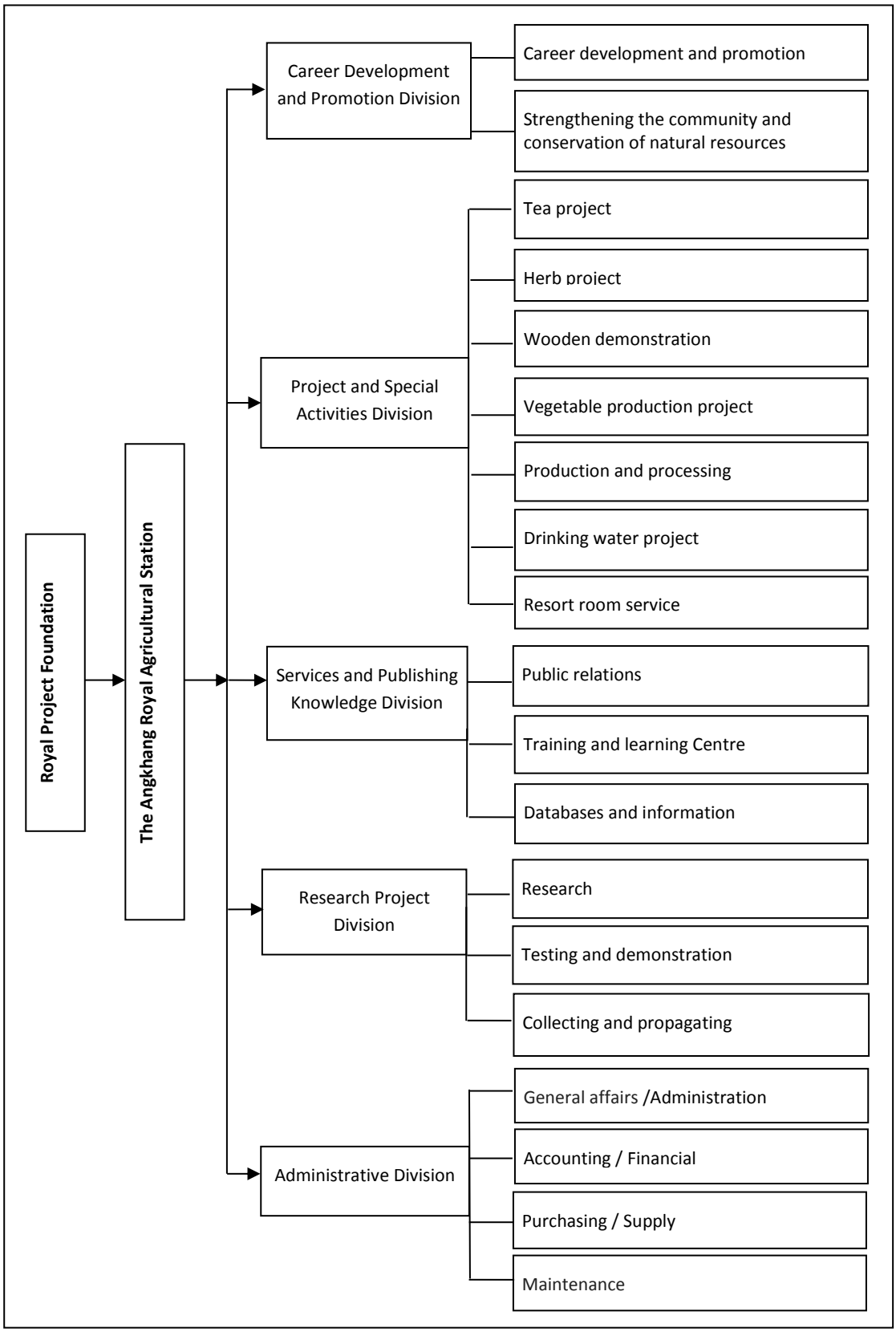

Figure 4.6. Organization structure chart of the Angkhang Royal Agricultural Station.
Source: Administrative Division of the Angkhang Royal Agricultural Station, 2012.

According to an organization structure chart, the objective of the station is to research and develop highland agriculture. Therefore, the activities are mainly categorized in three major divisions as follows.

1) Research Project Division

- Researching on temperate fruit crops such as Peach, Nectarine, Japanese plum, Japanese apricot, Kiwifruit, Asian pear, Persimmon and Strawberry.
- Studying and trialing on some of temperate flowers and ornamental plants such as Rose, Chrysanthemum, Freesia, Dahlia, Pansy, Begonia, Cherry blossom, Lavender and others.
- Studying on other crops such as Avocado, Loquat, Red Bayberry, Feiloa, Pomegranate, Pecan nut, Chestnut, Macadamia nut and Coffee, Wheat, Linseed, Pine and Bonsai.
- Collecting and propagating on temperate fruit crops.
- Collecting and propagating on various exotic forest trees and bamboos such as Taiwan acacia, Cinnamon, Camphor, Paulownia, Fragrant maple, Formosana sweet, Makino bamboo Taiwan Stone bamboos and others.
- Collecting and propagating herbal plants, Chinese tea, temperate vegetables and new crops.

2) Services and Publishing Knowledge Division

The Angkhang Royal Agricultural Station is the main source of highland agricultural research station. Therefore, services and publishing knowledge division has various roles such as being a public relation, learning and training center, and database and information. The details are as follows:

- Learning and training center is assigned to transfer technologies and knowledge. For example, the station provides short-term training session courses and cooperative education program which trains 43 trainees from 10 academic institutions each year.
- Public Relation (PR) role is to provide services and disseminate of information from experts/specialists to officials and farm workers as well as general public for both Thai and foreigners. In 2012, the station hosted nearly two hundred thousand visitors which currently becomes a major tourist attraction.
- Public media such as journals and books are produced based on database and information.

3) Career Development and Promotion Division

The operation of career development and promotion division covered the area of vicinity villages. It comprises of 4 ethnic minority groups with 1,059 households, 1,126 families and with the population of 5,534 people (The Angkhang Royal Agricultural Station, 2012). Furthermore, the collaboration between

government sectors and the station aid highlander by providing advices and career promotions. Their missions are as shown below.

- Career development and promotion such as temperate fruit crops flowers, Chinese tea, strawberry, vegetables and other crops. Moreover, it also develops craft products by using natural material such as bamboo and grass.
- Strengthening the community and conservation of natural resources such as waste disposal, environmental protection and forest conservation.

4.1.3 Current agricultural practices

As commonly known, the primary objective of the operation of the Angkhang Royal Agricultural Station is currently emphasis on research management. The Research Project Division of the station has received its financial support from the Royal Project Foundation (RPF), Highland Research and Development Institute (HRDI) and its own annual budget to support research projects. According to the annual report of the station in 2012, 19 and 6 research projects were supported by the RPF and HRDI, respectively. In addition, 11 research projects were conducted on fruit crops, flowers, vegetables and forest trees in which it was operated by the Research Project Division of the Angkhang Royal Agricultural Station.

The station operated those researches on the demonstration plots comprising of temperate fruit crops, flowers, ornamental plants, pine, bonsai, wheat, coffee, mushrooms, bamboo and livestock. Those areas produce crop yields which earn great income return to the station. In 2012, the total production area was about

255.47 rais. Table 4.6 shows that temperate perennial fruit crop occupied most of production area about 141.30 rais with 47,073.74 kilograms of production yields. The evergreen or small tree is about 4.85 rais with 1811.15 kilograms of production yields. The vegetable is about 34.50 rais with 52,889.30 kilograms of production yields. The herbal plant is about 5.57 rais with 401.50 kilograms of production yields. The flowers and ornamental plant is about 2.50 rais with 25,900 flowers/panicles and 323,834 pots of production yields. The pine and bonsai is about 11.26 rais with 2,211 pots of production yields. The wheat is about 8.00 rais with 100 kilograms of production yields. The coffee tree is about 18.80 rais with no production yields. The nut tree is about 16.00 rais with 234.4 kilograms of production yields. Portobello mushroom about 0.18 rais (4 greenhouses) with 851.29 kilograms of production yields. The bamboo is about 5.00 rais with 152 bundles, 1,954.00 kg. and 240 bamboos. Lastly, the livestock is about 255.47 rais with 2,590.80 kilograms of production yields.

Furthermore, the station has constantly developed the quality of agricultural production through the application of the standard of Good Agricultural Practice (GAP), Global Good Agricultural Practice (Global GAP), Hazard Analysis and Critical Control Points (HACCP) and the standard of Good Manufacturing Practice (GMP) for packaging system.

Table 4.6. Production area and yields in 2012.

Plant categories	Production areas (rais)	Production (kg.)
1. Temperate perennial crops		
- Peach	23.75	18,318.50
- Nectarine	3.00	No production yield
- Japanese Plum	10.00	2,343.00
- Japanese apricot	50.00	13,265.00
- Kiwifruit	11.80	7,467.00
- Asian Pear	13.75	728.44
- Persimmon	28.00	4,951.80
- Avocado	1.00	No production yield
Total	**141.3**	**47,073.74**
2. Evergreen or small trees		
- Strawberry	3.50	1,503.80
- Blueberry	1.20	5.85
- Raspberry	0.11	9.00
- Cape gooseberry	0.05	292.50
Total	**4.85**	**1,811.15**
3. Vegetables	**34.5**	**52,889.30**
4. Herbal plants	**5.57**	**401.50**
5. Flowers and ornamental plants	**2.50**	**25,900 flowers/panicles** **323,834 pots**
6. Pine and bonsai	**11.26**	**2,211 pots**
7. Wheat	**8.00**	**100.00**
8. Coffee trees	**18.80**	**No production yield**
9. Nut trees		
- Pecan nut	9.00	18.40
- Chestnut tree	2.00	216.0
- Macadamia nut	5.00	No production yield
Total	**16.00**	**234.40**
10. Portobello mushroom	**0.18** **(4 greenhouses)**	**851.29**
11. Bamboo	**5.00**	**1,954.00** **152 bundles** **240 shoots**
12. Livestock		
- Poultry		382.50
- Pasteurized Goat milk		2,034.80
- Raw goat milk		3.00
- Duck		170.50
Total	**7.50**	**2,590.80**
Total	**255.47**	

Source: Research Project Division of the Angkhang Royal Agricultural Station, 2012.

The Services and Publishing Knowledge and Research Project Division worked together to collect plants database for academic service and further research. In 2012 plant varieties collection was divided into 5 categories. There were 234 varieties of temperate perennial fruit trees, 51 varieties of evergreen/small trees, 150 varieties of vegetables, 769 varieties of flowers, 59 varieties of forest trees and 257 varieties of other crops such as wheat, herbal plants, pine and bonsai as shown in Table 4.7. Moreover, the station also imports flower and fruit crops for the purpose of researching, testing and collecting. In 2012, the crops imported from Netherlands, Taiwan, Australia and Japan were 478 varieties comprising of 823,575 seeds and 5,255 trees/branches as shown in Table 4.8.

In addition, all divisions of the Angkhang Royal Agricultural Station are achieving substantial progress on natural resources conservation. In 2012, the activities could be conducted as follows;

- reforest plantation zone area was about 800 rais (1.28 sq.km.) which consist of growing-fast forest trees and bamboos,
- vegetation protection plants and cover crop are planted while crop residue were applied into the demonstration plots,
- the station produced manure/ compost from agriculture wastes, animal dung, worms and micro-organisms, and
- the station applied the Integrated Pest Management (IPM) technique to control plant diseases, insects and pests for examples, using antagonistic fungi, effective Micro-Organism (EM.) and natural enemies of insect pests such as Wolff (*Eocanthecona furcellata*.).

Table 4.7. Plant varieties collection database.

Plant categories	Plant names	Plant varieties*
1. Fruit tree	1.1 Temperate perennial crops	
	- Peach	46
	- Nectarine	19
	- Japanese Plum	44
	- Persimmon	17
	- Kiwifruit	78
	- Asian Pear	26
	- Loquat	2
	- Red Bayberry	1
	- Feijoa	1
	1.2 Evergreen or small trees	
	- Strawberry	37
	- Blueberry	10
	- Raspberry	1
	- Cape gooseberry	3
2. Vegetables		150
3. Flowers and ornamental plants	3.1 English roses	237
	3.2 Ornamental plants	
	- Annuals	210
	- Biennials	73
	- Perennials	235
	- Orchids	14
4. Forest trees		59
5. Other plants	5.1 Wheat and linseed	58
	5.2 Herbal plants	158
	5.3 Pine and bonsai	41
Total		**1520**

Source: Research project division of the Angkhang Royal Agricultural Station, 2012.

Note: Plant varieties* is included experimental varieties.

Table 4.8. Imported plant varieties.

Plant categories	Varieties	Amount		Countries
		seeds	trees/branches	
Flowers	460	823,575	86	Netherlands, Taiwan, Australia
Roses	9	-	4,500	Netherlands
Fruit trees	9	-	699	Taiwan and Japan
Total	**478**	**823,575**	**5,255**	

Source: Research project division of the Angkhang Royal Agricultural Station, 2012.

4.2 Development of the environmental indicators to monitor sustainable highland agriculture

4.2.1 Identifying environmental indicators

The DPSIR framework for agricultural activity and the agri-environmental indicators developed by the OECD as well as data and information derived from direct observation were used to list the environmental indicators for its usage on monitoring sustainable highland agriculture at the study area. The study found that the relevant data of the study area can be used to develop and apply 17 environmental indicators from the list of OECD agri-environmental indicators as mentioned in Table 2.1.

These environmental indicators are set into 4 categories;

(i.) farm management,

(ii.) use of farm inputs and natural resources,

(iii.) environmental impacts of agriculture and

(iv.) farm structure and farm financial resources.

The farm management has 5 indicators comprising of farm management standard, nutrient management plan, pest management, soil management and water efficiency management. The use of farm inputs and natural resources has 4 indicators consisting of nutrient use, pesticide use, water use, and land use. The environmental impact of agriculture has 4 indicators including soil quality, water quality, biodiversity and landscape. Finally, the farm financial resources have 4 indicators which are farm income, agricultural output, farm employment and age/gender distribution. Relevant information on such indicators is shown in Table 4.9.

Table 4.9. The list of environmental indicators for the Angkhang Royal Agricultural Station.

Code	Environmental indicators for agriculture	Definition	Data types and sources	Indicator type*
		1. Farm Management		
1.1	Farm management standard	Portion of the demonstration land area that follows Good Agricultural Practice (GAP) management standards relative to the total demonstration land area	Department of Agriculture, Ministry of Agriculture and Cooperatives Thailand/ Bureau Veritas (Thailand) Ltd.	D/R
1.2	Nutrient management plan	Portion of the demonstration land area that follows nutrient management plan	Research Project Division of the Angkhang Royal Agricultural Station	D/R
1.3	Pest management plan	Portion of the demonstration land area that follows the Integrated Pest Management (IPM) regulations	Research Project Division of the Angkhang Royal Agricultural Station	R
1.4	Soil conservation management	Portion of the demonstration land area that follows soil conservation management practices for examples: vegetation cover, crops rotation, strip cropping, reducing tillage, etc.	Research Project Division of the Angkhang Royal Agricultural Station	R
1.5	Water efficiency management	Portion of the demonstration land area that applies irrigation technology for examples: drip irrigation, mini sprinklers, etc.	Research Project Division of the Angkhang Royal Agricultural Station/ Department of Groundwater Resources, Ministry of Natural Resources and Environment Thailand	R

Table 4.9. The list of environmental indicators selected for the Angkhang Royal Agricultural Station (continued).

Code	Environmental indicators for agriculture	Definition	Data types and sources	Indicator type*
2. Use of farm inputs and natural resources				
2.1	Nutrient use	Portion of chemical fertilizer usage of total fertilizer application (manure/compost and chemical fertilizer)	Research Project Division of the Angkhang Royal Agricultural Station/ Soil Analysis, Land Development Regional Office 6, Ministry of Agriculture and Cooperatives Thailand	D/R
2.2	Pesticide use	Portion of chemical pest control use of total integrated pest control scheme adoption (physical, biological and chemical pest control)	Research Project Division of the Angkhang Royal Agricultural Station	D/R
2.3	Water use	Portion of demonstration water use in total water utilization	Research Project Division of the Angkhang Royal Agricultural Station	S
2.4	Land use	Portion of the demonstration land area of total land area of the Angkhang Royal Agricultural Station	Research Project Division of the Angkhang Royal Agricultural Station	I

Table 4.9. The list of environmental indicators selected for the Angkhang Royal Agricultural Station (continued).

Code	Environmental indicators for agriculture	Definition	Data types and sources	Indicator type*
3. Environmental impacts of agriculture				
3.1	Soil quality	Portion of the analytical results of heavy metals in demonstration soil that exceed the standard value	The Royal Project Land Development Center/ Soil Analysis, Land Development Regional Office 6, Ministry of Agriculture and Cooperatives Thailand	S/I
3.2	Water quality	Portion of the analytical results of heavy metals in demonstration water that exceed the standard value	The Royal Project Land Development Center/ Water analysis, Land Development Regional Office 6, Ministry of Agriculture and Cooperatives Thailand	S/I
3.3	Biodiversity	Portion of main crop varieties (temperate perennial crops) of total varieties (crops and livestock) which registered and certified for marketing at the Angkhang Royal Agricultural Station	Research Project Division of the Angkhang Royal Agricultural Station	S/I
3.4	Landscape	Portion of land use pattern, including changes in demonstration land use patterns at the Angkhang Royal Agricultural Station	Research Project Division of the Angkhang Royal Agricultural Station	S

Table 4.9. The list of environmental indicators selected for the Angkhang Royal Agricultural Station (continued).

Code	Environmental indicators for agriculture	Definition	Data types and sources	Indicator type*
4. Farm structure and farm financial resources				
4.1	Farm income	Portion of gross output value relative to all expenses from agricultural activities at the Angkhang Royal Agricultural Station	Administrative division of the Angkhang Royal Agricultural Station	D
4.2	Agricultural output	Portion of final agricultural output value produced at the Angkhang Royal Agricultural Station	Administrative division of the Angkhang Royal Agricultural Station	I
4.3	Farm employment	Portion of agriculture related employment in total civilian employment (officials and farm workers) at the Angkhang Royal Agricultural Station	Administrative division of the Angkhang Royal Agricultural Station	D
4.4	Age/gender distribution	Portion of farm workers categorized by age and gender at the Angkhang Royal Agricultural Station	Administrative division of the Angkhang Royal Agricultural Station	D

Note: Indicator type*; D – Driving forces, P – Pressures, S – State, I – Impact, R – Responses.

Source: OECD, 2001 and the Angkhang Royal Agricultural Station, 2012.

4.2.2 Expert judgments on environmental indicators to monitor sustainable highland agriculture

The mutual agreement among experts was used to refine the 17 environmental indicators through semi-structured questionnaire. Eight experts were asked of their viewpoints on barriers/problems of the study area. They are inquired to discuss and select the environmental indicators that will be introduced and used to monitor sustainable highland agriculture at the study area.

The expert judgments questionnaire shown in Appendix A consists of 4 parts as follows:

i.) General information of experts

ii.) Highland agriculture and identify its barriers / problems

iii.) The environmental indicators selection by expert judgments

iv.) Expert recommendations and suggestions

The results of expert judgments were analyzed and concluded as the following details.

i.) General information of experts

The experts comprised of six males and two females. Their ages are widely distributed although most of them (5 experts) are between 51 and 55 years old while the remaining experts are in the range of 35-40, 46-50 and over 61 years, respectively. They all have education background on agricultural disciplines comprising of Horticulture, Plant Protection, Agricultural Science, Plant Breeding, Agronomy, and Soil Ecotoxicology and Soil Microbiology. The study found that all

experts are specialists in their work fields. Five experts have experience working in their discipline for more than 21 years while the remaining ones are in the range of 16-20, 11-15 and 5-10 years' experience work.

All the experts are involved and have responsibilities at the Angkhang Royal Agricultural Station. Four experts have been doing researches on temperate fruit crops. One of them was formerly a chief of the Angkhang Royal Agricultural Station. Three experts are involved in promotion and development of avocado production, advisory persimmon fruit crop, and advisory vermiculture and hydroponics respectively. The remaining expert used to be exclusive board member of the Angkhang Royal Agricultural Station.

ii.) Highland agriculture and identify its barriers/problems

The research on expert opinions on barriers/problems of highland agriculture reveal that 62.5% of experts viewed that highland agriculture can resolve and reduce deforestation problem in the northern part of Thailand as well as can conserve the environment in the mountainous areas. Also 37.5% of them pointed out that highland agriculture is encouraged as a career for highlanders, which can reduce social problems, benefit national security and enhance sustainability. On the other hand, two experts also discussed on unsustainable practices that are still remain in highland agriculture areas such as chemical inputs use that would adversely affect the ecological system at upstream and downstream catchment areas.

To identify present and future barriers/problems of highland agriculture in the study area, the experts indicated those perceived barriers/problems, which are concluded in Table 4.10.

Table 4.10. Expert judgments on present and future of highland agriculture barriers and problems.

Highland agriculture barriers/problems	
At present	**In the future**
Society and culture	Society and culture
Economic force	Economic force
Commercial crop intensification	Commercial crop intensification
Climate change	Climate change
Drought/water shortage	Drought/water shortage
Agriculture production quality	Agriculture production quality
Wildfire	Agricultural tourism
Agriculture input cost	Lack of conservation awareness
Soil erosion/land degradation	Selfishness of highlanders
Ecological degradation	
Undefined boundaries land use	

From Table 4.10, the study of expert judgments found that six barriers/problems existed both in the current status and future trends in the study area. They include society and culture, economic force, commercial crop intensification, climate change, drought/water shortage and agriculture production quality. The experts noted that current problems also included wildfire, agriculture input cost, soil erosion/land degradation, ecological degradation and undefined boundaries land use. These problems were not identified in the future probably because of the success in the Royal Project. One example is the development of

temperate perennial fruit crops in the area based on the promotion of the environmental conservation principles. This principle and its success can be explained by continuous reduction in highland agriculture barriers/problems such as soil erosion/land degradation, ecological degradation and earning indirect benefit to reduce wildfire.

The experts anticipated that three new problems would occur in the near future. These problems are agricultural tourism, lack of conservation awareness and selfishness of highlanders. The rise of agricultural tourisms will bring greater income to local highlanders nevertheless it would intensify those barriers/problems such as water shortage in dry season and ecological degradation. One expert also indicated that lack of conservation awareness and selfishness of highlanders would occur due to differences in society, culture of ethnic minority groups and the economic crisis.

Experts were also asked on their opinions about the study of environmental indicators that will be used to monitor sustainable highland agriculture hence, reduce those barriers and problems. Two of them viewed that environmental indicators can help reduce the problems. However six experts claimed that environmental indicators may reduce only some of the problems. One of them also pointed out that highland agriculture problems can be reduced if the environmental indicators are used and analyzed correctly. In addition, another expert emphasized that governmental officials who are in charge of highland agricultural management, must take actions by setting up relevant regulations in order to reduce those barriers/problems to further enhance sustainability in highland agriculture.

iii.) The environmental indicators selection by expert judgments

One of environmental indicator set entitled farm management category was selected through expert judgments. Such indicators composed of farm management standard, nutrient management plan, pest management plan, soil conservation management and water efficiency management. The study found that all experts selected the farm management standard as one of the key indicators. One of them suggested that the farm management standard is a significant indicator to measure environmental impact reduction and optimal for monitoring sustainable highland agriculture. In addition, three experts also pinpointed that the farm management standard indicator would not be difficult to apply at the Angkhang Royal Agricultural Station. Seven of eight experts agreed that the nutrient management plan, pest management plan and soil conservation management indicators are also suitable to be utilized at the study area. They disclosed that agriculture practices of the study area have followed the regulations of Good Agricultural Practice (GAP) which included nutrient, pest and soil management practices. The water efficiency management indicator was selected by six experts, while the other two experts noted that the indicator may not be applicable at the present time due to the limitation of irrigation technology at the Angkhang Royal Agricultural Station.

Under the use of farm inputs and natural resources category, the experts selected nutrient use, pesticide use, water use and land use as indicators. The study found that three of these indicators were selected by seven experts including nutrient use, pesticide use and land use. Those experts described that the chemical inputs would be vital to agricultural productivity but would be significantly impact on natural environments such as surface and ground water sources. Nutrient and

pesticide use indicators are suitable for monitoring the study area in order to reduce such impacts. Additionally, water use indicator was agreed upon by five experts. However the remaining three experts stated that this indicator would be found ineffective when applied due to the lack of accurate water usage data as well as the water supply management in the study area.

The environmental impacts of agriculture category including soil quality, water quality, biodiversity and landscape indicators were recognized by all experts. The study discovered that the biodiversity indicator was individually admitted by seven out of eight experts whilst soil quality, water quality and landscape indicators were selected by six experts. Two experts stated that soil quality and water quality indicators are beneficial to the area, but its application is difficult. The landscape indicator is also not adoptable since landscape components within the station would not change greatly as shown in Figure 4.2. They noted that the cultivation zone within the demonstration area of the Angkhang Royal Agricultural Station is limited. Hence, it would not be extended as reforestation areas.

A set of farm structure and farm financial resources including farm income, agricultural output, farm employment and age/gender distribution indicators were selected by experts. The study revealed that farm income and agricultural output indicators were accepted by seven experts. They explained that these indicators present the quality and quantities of agricultural are reflecting production successful from operational practices of the station. Additionally, farm employment and age/gender distribution indicators were agreed upon by five experts. Three remaining experts viewed that these indicators may not be practical to monitor in relation to sustainable highland agriculture.

It can be concluded from expert judgments that there are ten environmental indicators selected to monitor sustainable highland agriculture which comprising of farm management standard, nutrient management plan, pest management plan, soil conservation management, nutrient use, pesticide use, land use, biodiversity, farm income and agricultural output.

iv.) Expert recommendations and suggestions

Experts were asked whether the selected environmental indicators are beneficial for users or not. Most of them (7 of 8) agreed that they are very useful for officials who work at the Angkhang Royal Agricultural Station while one did not ensure. To apply those ten selected environmental indicators to the study area, six of eight experts viewed that the officials could apply such indicators to their field works while, the other two are not certain. One expert stated that the officials could still apply those indicators even though the analytical data and its thorough validation of each indicator might be difficult.

Three experts also suggested other environmental indicators to monitor sustainable highland agriculture for further study such as farmer education, change in number of farm workers, agriculture waste quantity, solid waste management, income from tourism at the Angkhang Royal Agricultural Station and tourists' number at the Angkhang Royal Agricultural Station. Importantly, one expert recommended that social and economic aspects should be further studied as indicators to ensure sustainability of highland agriculture.

4.2.3 In-depth interviewing to the Angkhang Royal Agricultural Station's officials

In-depth questionnaire was developed to introduce the environmental indicators from expert judgments to the Angkhang Royal Agricultural Station's officials. The purposive technique was used to select ten respondents as representatives of the Angkhang Royal Agricultural Station's officials to interview and discuss whether those selected environmental indicators have potential to apply to the demonstration plots of the Angkhang Royal Agricultural Station.

The questionnaire composes of:

i.) basic information of respondents

ii.) barriers/problems on demonstration plots of the Angkhang Royal Agricultural Station

iii.) environmental indicators

iv.) recommendations and suggestion from respondents

The results of the interviews which its detail is in Appendix B were analyzed and concluded as the following.

i.) Basic information of respondents

The respondents comprised of six males and four females. Their ages are between 26 and 40 years old. Two respondents age are in the range of 26-30 years, five respondents are of age 31-35 years and three respondents are of age 36-40 years, respectively. All respondents have educational background on agricultural disciplines comprising Plant Sciences, Horticulture, Agronomy, Entomology, and Agricultural Extension and Community Development. All respondents were also

asked on work experience at the Angkhang Royal Agricultural Station. The study found that two respondents are in the range of 1-5 years of work experience, four respondents are of 6-10 years of work experience and the others are in the range of 11-15 years of work experience.

Respondents are responsible in various divisions at the study station, namely Research Project Division, Career Development and Promotion Division, Project and Special Activities Division, Services, Publishing Knowledge Division, and Administrative Division. In addition, two respondents have responsibilities in other division as well.

ii.) Barriers/problems on demonstration plots of the Angkhang Royal Agricultural Station

Respondents were inquired about the demonstration plots and its barriers/problems. The study found their opinions aligned with the experts. Both of experts and officials viewed highland agriculture as a way to promote agriculture careers, income generation, reduce social problems, reduce deforestation, conserve the environment, enhance sustainability and benefit to national security. In addition, one of them pointed that highland agriculture can reduce highlanders migration to urban area.

However, ten respondents mentioned several problems at the station that concur with experts' opinions. Such current problems were indicated by respondents as followings. Climate change and ecological degradation were indicated by eight respondents. Drought/water shortage was viewed by seven respondents. Economic force and agriculture input cost were noted by five respondents. Society and culture, agriculture production quality and soil erosion/land degradation were indicated by

three respondents. Commercial crop intensification, wildfire and undefined boundaries land use were mentioned by two respondents. In addition, two respondents claimed that the current problems at the study area also include non-native insect and disease outbreaks.

All respondents also mentioned that some of current barriers/problems will occur in the near future as followings. Climate change was highlighted by eight respondents, drought/water shortage was indicated by seven respondents, commercial crop intensification was noted by five respondents, and economic force was indicated by two respondents. In addition, three of eight respondents emphasized the issue of climate change as one of current serious problems. They reasoned that the issue of climate change cannot be solved in the short term and is subsequently, interlinked with other problems such as drought/water shortage as well as the quality of agricultural production.

Other barriers/problems that are expected to occur in the future include selfishness of highlanders, lack of conservation awareness and agricultural tourism problems. Seven respondents viewed that selfishness of highlanders will be increased due to the economic force. Three of them noted that selfishness of highlanders leads to an expansion to other problem such as lack of conservation awareness. Moreover, five respondents revealed that rising tourisms would cause water shortage and solid waste. One of them stated that this problem has affected to the station environmental area.

iii.) Environmental indicators

Respondents were asked their opinions on selected environmental indicators of expert judgments. There are 10 environmental indicators which comprises of farm management standard, nutrient management plan, pest management plan, soil conservation management, nutrient use, pesticide use, land use, biodiversity, farm income and agricultural output.

Half of the respondents agreed that those indicators can significantly reduce both direct and indirect agriculture problems mentioned. One of them noted that good environmental indicators are valuable to sustain highland agriculture for producers, consumers and environment by using those environmental indicators to monitor agricultural practices on their demonstration plots. The second half of respondents did not sure that such indicators would reduce those problems at the study area. One of them mentioned that the environmental indicators would help to reduce some of the problems such as drought/water shortage, wildfire, agriculture input cost, soil erosion land degradation, ecological degradation and agriculture production quality. In addition, three respondents pointed that the selected environmental indicators might not reduce problem on changing in climate such as temperature, relative humidity, light intensity and rainfall which are significant to plant growth as well as agriculture production quality and quantity.

The study found that all respondents were confident that they could apply the selected environmental indicators into their field works. Five respondents stated that the data used to develop those indicators are routinely collected from their actual practices and activities. Importantly, the agricultural practices on the

demonstration plots of the station are conducted under the GAP regulations. Environmental indicators on farm management standard, nutrient management plan, pest management plan and soil conservation management can help them design the annual management plan on their plots. This leads to an improvement of quality and quantity of products. Two respondents mentioned that indicators on nutrient and pesticide use are very useful to minimize amount of chemical used which would lead to a good environment consequently. One respondent felt that land use and biodiversity indicators would help them to recover and obtain good physical environment such as land, water, forest, etc. Additionally, the two remaining respondents illustrated that farm income and agricultural output indicators were not difficult to apply into their work fields because the production yields data has been recorded into the annual report by the station as the detail shown in Figure 4.6. Furthermore, most of them (9 respondents) concluded that those selected environmental indicators of expert judgments would help other officials who are responsible in other divisions such as Research Project, Career Development and Promotion, Project and Special Activities, Services, and Publishing Knowledge, to understand more about the practice in order to achieve the sustainable highland agriculture.

For question on disseminating information of the selected environmental indicators to highland farmers, the majority of respondents (9 of 10) clearly expressed that it seems very difficult and would take a long time to carry out, but they can introduce those indicators to highland farmers to their agricultural practices. However, the remaining expert is not certain if he can propose these indicators to be used by highland farmers. He described challenges to apply the environmental

indicators including farmers' lack of basic environmental sustainability knowledge, difficulty in communicating with different cultural, linguistic and ethnic minority groups of highlanders.

iv.) Recommendations and suggestion from respondents

Six respondents suggested other environmental indicators to monitor sustainable highland agriculture for further study such as water quality and quantity, air quality, agriculture awareness, solid waste management, agriculture conservation and agriculture income effect on environment.

Most of respondents also made recommendations and suggestions on the selected environmental indicators to appropriately monitor sustainable highland agriculture at the Angkhang Royal Agricultural Station. Two of them stated that the selected environmental indicators need to be monitored continuously and be further studied in order to evaluate the success of those indicators. Three respondents noted that all stakeholders including government agencies, non-governmental organizations (NGOs), specialists, academics, institutions, officials and farmers should take action on their behalf when applying those selected environmental indicators to highland agriculture. Four respondents viewed that those indicators should appropriately be introduced and modified to highland farmers for their capability to take actions in order to improve sustainable highland agriculture.

4.3 Mutual agreement by experts and officials

The results of the study found that experts and officials mutually agreed on a set of 10 environmental indicators for their potential to monitor sustainable highland agriculture at the demonstration plots of the Angkhang Royal Agricultural Station.

Such a set of environmental indicators, as shown detail in Table 4.11, comprise of farm management standard, nutrient management plan, pest management plan, soil conservation management, nutrient use, pesticide use, land use, biodiversity, farm income and agricultural output.

Farm management standard indicator is the agriculture area under the standard of GAP, defined as the portion of the demonstration land area that follows GAP management standards relative to the total demonstration land area.

Nutrient management plan indicator is the cultivated area with nutrient management plan, defined as the portion of the demonstration land area that follows nutrient management plan.

Pest management plan indicator is the cultivated area under the IPM, clarified as the portion of the demonstration land area that follows the IPM regulations.

Soil conversation management indicator is the agriculture land area covered with vegetation, explained as the portion of the demonstration land area that follows soil conservation management practices, for examples: vegetation cover, crops rotation, strip cropping, reducing tillage, etc.

Nutrient use indicator is the quantity of nutrient consumed by agriculture, defined as the portion of chemical fertilizer use of total fertilizer use.

Pesticide use indicator shows trends of pesticide use, clarified as the portion of chemical pest control use of total integrated pest control use (physical, biological and chemical pest control).

Land use indicator represents changes in total agriculture land use with other use, which is defined as the portion of the demonstration land area of total land area of the Angkhang Royal Agricultural Station.

Biodiversity indicator is related to agriculture which can be considered in term of number and population of plant and livestock varieties, defined as the portion of main crop varieties (temperate perennial crops) of total varieties (crops and livestock) registered and certified for marketing at the Angkhang Royal Agricultural Station.

Farm income indicator is trends in net farm income defined as the portion of the value of gross output relative to all expenses from agricultural activities at the Angkhang Royal Agricultural Station.

Agricultural output indicator is amount of farm production which correlates to an efficiency of resources and inputs used in production, defined as the portion of the value of final agricultural output produced at the Angkhang Royal Agricultural Station.

Table 4.11. Environmental indicators set for the Angkhang Royal Agricultural Station.

No.	Environmental indicators for agriculture	Definition	Data types and sources	Indicator type*
1.	Farm management standard	Portion of the demonstration land area that follows Good agricultural Practice (GAP) management standards relative to the total demonstration land area	Department of Agriculture, Ministry of Agriculture and Cooperatives Thailand/ Bureau Veritas (Thailand) Ltd.	D/R
2.	Nutrient management plan	Portion of the demonstration land area that follows nutrient management plan	Research Project Division of the Angkhang Royal Agricultural Station	D/R
3.	Pest management plan	Portion of the demonstration land area that follows the Integrated pest management (IPM) regulations	Research Project Division of the Angkhang Royal Agricultural Station	R
4.	Soil conservation management	Portion of the demonstration land area that follows soil conservation management practices for examples: vegetation cover, crops rotation, strip cropping, reducing tillage, etc.	Research project Division of the Angkhang Royal Agricultural Station	R
5.	Nutrient use	Portion of chemical fertilizer use of total fertilizer use (manure/compost and chemical fertilizer)	Research Project Division of the Angkhang Royal Agricultural Station/ Soil Analysis, Land Development Regional Office 6, Ministry of Agriculture and Cooperatives Thailand	D/R

Table 4.11. Environmental indicators set for the Angkhang Royal Agricultural Station (continued).

No.	Environmental indicators for agriculture	Definition	Data types and sources	Indicator type*
6.	Pesticide use	Portion of chemical pest control use of total integrated pest control use (physical, biological and chemical pest control)	Research Project Division of the Angkhang Royal Agricultural Station	D/R
7.	Land use	Portion of the demonstration land area of total land area of the Angkhang Royal Agricultural Station	Research Project Division of the Angkhang Royal Agricultural Station	I
8.	Biodiversity	Portion of main crop varieties (temperate perennial crops) of total varieties (crops and livestock) which registered and certified for marketing at the Angkhang Royal Agricultural Station	Research Project Division of the Angkhang Royal Agricultural Station	S/I
9.	Farm income	Portion of the value of gross output relative to all expenses from agricultural activities at the Angkhang Royal Agricultural Station	Administrative Division of the Angkhang Royal Agricultural Station	D
10.	Agricultural output	Portion of the value of final agricultural output produced at the Angkhang Royal Agricultural Station	Administrative Division of the Angkhang Royal Agricultural Station	I

Note: Indicator type*; D – Driving forces, P – Pressures, S – State, I – Impact, R – Responses.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The objective of this research was to study appropriate environmental indicators to be introduced and used to monitor sustainable highland agriculture and its potential for application to the demonstration plots of the Angkhang Royal Agricultural Station. The study applied the Driving forces-Pressures-State-Impact-Responses (DPSIR) framework for agricultural activity and agri-environmental indicators developed by the Organisation for Economic Co-operation and Development (OECD), as the main conceptual frameworks to study and develop the environmental indicators for the study area. For data collection, instrument and procedures including desk study, direct observation, expert judgments and in-depth interviews were being utilized.

The research findings and results can be concluded and recommended as follows.

5.1 Conclusion of research finding

5.1.1 Identifying environmental indicators

DPSIR framework for agricultural activity and the agri-environmental indicators developed by the OECD as well as the current agricultural practices data collected by direct observation at the study station, were used to list appropriate environmental indicators to monitor sustainable highland agriculture at the Angkhang Royal Agricultural Station.

There are 17 environmental indicators and it can be grouped into 4 categories as follows.

(i.) Five indicators of farm management comprise of farm management standard, nutrient management plan, pest management plan, soil conservation management and water efficiency management.

(ii.) Four indicators of use of farm inputs and natural resources consist of nutrient use, pesticide use, water use, and land use.

(iii.) Four indicators of environmental impacts of agriculture include soil quality, water quality, biodiversity and landscape.

(iv.) Four indicators of farm structure and farm financial resources cover farm income, agricultural output, farm employment and age/gender distribution.

5.1.2 Expert judgments on environmental indicators to monitor sustainable highland agriculture

The experts expressed their opinions on barriers/problems of the study area that six problems existed both in the current status and future trends on the study area. Those problems include society and culture, economic force, commercial crop intensification, climate change, drought/water shortage and agriculture production quality. In addition, the experts highlighted on three new problems that would occur in the near future, namely agricultural tourism, lack of conservation awareness and selfishness of highlanders.

To monitor those problems, through mutual agreements among experts 10 selected environmental indicators are introduced and used to monitor sustainable

highland agriculture of the study area comprising of farm management standard, nutrient management plan, pest management plan, soil conservation management, nutrient use, pesticide use, land use, biodiversity, farm income and agricultural output indicators. One of the key environmental indicators is farm management standard which is significant to environmental impact reduction on overall agriculture system. The nutrient management plan, pest management plan and soil conservation management indicators as well as nutrient use, pesticide use and land use are also suitable to be utilized at the study area which has linkages to an enhancement of a better agricultural practice. Biodiversity is also an important indicator that can be applied into an agriculture system of the study area. The farm income and agricultural output indicators can be presented the quality and quantities of agricultural reflecting the production success from operational practices of the station.

Expert also suggested other environmental indicators that can be used to monitor sustainable highland agriculture should be further studied such as farmer education, change in number of farm workers, agriculture waste quantity, solid waste management, income from tourism at the Angkhang Royal Agricultural Station and tourists' number at the Angkhang Royal Agricultural Station.

5.1.3 In-depth interviewing to the Angkhang Royal Agricultural Station's officials

Officials' opinions that aligned with problems mentioned by experts include society and culture, economic force, commercial crop intensification, climate change, drought/water shortage, agriculture production quality, wildfire, agriculture input cost, soil erosion/land degradation, ecological degradation and undefined boundaries land

use. Additionally, they mentioned that non-native insect and disease outbreaks are also one of the current problems at the study area.

Officials agreed with experts' selected environmental indicators that they have potential for application in their work fields. They pointed out that some of those indicators are beneficial to minimize negative impacts and would lead to good environmental circumstances. For example, nutrient and pesticide use indicators substantially display trends of the amount of chemical use in their plantation area. In general, they indicated that the data use to develop those indicators are usually collected from their work and practices.

The officials expected that the selected environmental indicators can be applied and be active in all level. Governmental agencies, particular policy makers, should take actions on their behalf when applying those indicators to highland agriculture. Furthermore, those indicators need to be continuously monitored and be further studied to evaluate the success of their application.

5.1.4 Mutual agreement of experts and officials on environmental indicators

The experts and the Angkhang Royal Agricultural Station's officials mutually agreed that a set of environmental indicators to monitor sustainability highland agriculture compose of farm management standard, nutrient management plan, pest management plan, soil conservation management, nutrient use, pesticide use, land use, biodiversity, farm income and agricultural output.

5.2 Limitations of the study

1) All selected experts for their judgment were limited based on their knowledge background in agricultural disciplines and their work experiences at the Angkhang Royal Agricultural Station.

2) The study found that the conceptual framework of DPSIR and the list of OECD agri-environmental indicators applied to the study area would be inappropriate in some theoretical aspects for application at the local scale. For example, environmental indicators on soil quality, water quality, land conservation, greenhouse gases, wildlife habitats and landscape.

5.3 Challenges of the study

1) The selected experts should include experts who have knowledge and background on environmental disciplines to reflect their experiences to select the suitable environmental indicators for the study area.

2) This study found that a set of environmental indicators for the study area which mostly from expert judgments who have single disciplines on agricultural knowledge base, would be lacking of environmental aspects. Some physical indicators do not exist on a set of environmental indicators of the study such as water use, water quality and soil quality which are significantly to reduce the environmental impacts from agriculture practices. Physical environmental indicators need to be further studied in order to improve and sustain agriculture practices of the study area.

3) To enhance sustainability, economic and social indicators for agricultural activity should be further studied to collaborate with the list of the OECD agri-environmental indicators.

5.4 Recommendation

Regarding the research findings, there are some recommendations to consider on the following issues.

1) A set of environmental indicator should be further studied via the experimental plots at the study area and other highland agricultural sites.
2) Those indicators should be properly introduced and modified to highland farmers for their capability taking action in order to improve sustainable highland agriculture.
3) Suitable social and economic indicators should be further studied to monitor sustainable highland agriculture in order to enhance sustainability of highland agriculture in a holistic approach.

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APPENDICES

APPENDIX A

EXPERT JUDGMENTS QUESTIONNAIRE

Expert Code: .....

Subject: Questionnaire of Study of Environmental Indicators to Monitor Sustainable Highland Agriculture: a Case Study of the Angkhang Royal Agricultural Station, Doi Angkhang, Chiang Mai Province, Thailand.

Instruction:

1. The questionnaire is provided by Miss Siriluck Pengnam, Master degree Candidate in Environment Development and Sustainability Program of Chulalongkorn University.
2. The objective of this questionnaire is to survey experts opinions under the thesis entitled "Study of Environmental Indicators to Monitor Sustainable Highland Agriculture: a Case Study of the Angkhang Royal Agricultural Station, Doi Angkhang, Chiang Mai Province, Thailand".
3. A set of the questionnaire consists of four parts and please fill in the following the questionnaire.

All information that you provide in this questionnaire which includes personal information and your comments will be used exclusively for research objectives under this thesis.

Thank you very much for your cooperation in this research.

Yours truly,

Siriluck Pengnam

Instruction: The questionnaire is divided into 4 parts composes of:

Part 1: General information.

Part 2: Highland agriculture and identify its barriers / problems.

Part 3: The environmental indicators selection.

Part 4: Recommendations and suggestion.

Part 1: General information

Instruction: Please mark ✓ into ☐ fill in the following the questionnaire.

Question 1: Gender

☐ Male ☐ female

Question 2: Age

☐ Less than 35 years ☐ 35-40 years old

☐ 41-45 years old ☐ 46-50 years old

☐ 51-55 years old ☐ 56-60 years old

☐ Over 61 years old

Question 3: Educational level

☐ Bachelor's Degree ☐ Master's Degree

☐ Doctor of Philosophy

☐ Others (please specify) .....

Question 4: Educational Background

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Question 5: Organization / Company

- ☐ Government / State-Owned
- ☐ Public Organization
- ☐ Public Enterprise
- ☐ Private Sector / Business
- ☐ Academic Institution
- ☐ Research institution
- ☐ Private Sector
- ☐ Others (please specify) .....

Question 6: Type of Organization / Company

- ☐ Academic / technical
- ☐ Consultants
- ☐ Research and development
- ☐ Training
- ☐ Teaching / lecturer
- ☐ Management
- ☐ Others (please specify).....

Question 7: Work Experience

- ☐ 5-10 years
- ☐ 11-15 years
- ☐ 16-20 years
- ☐ more than 21 years

Question 8: Do you have responsible / involved with the Angkhang Royal Agricultural Station? If yes please describe.

- ☐ No
- ☐ Yes (Please describe) .....

Part 2: Highland agriculture and identify its barriers / problems

Instruction: Please fill in the following the questionnaire.

Question 9: What is your opinion on highland agriculture?

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Question 10: What is / are the current highland agriculture barriers / problems at the Angkhang Royal Agricultural Station?

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Question 11: What is / are the future highland agriculture barriers / problems at the Angkhang Royal Agricultural Station?

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Question 12: Do you think that study of environmental indicators to monitor sustainable highland agriculture can reduce those barriers / problems from Question 10-11?

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Part 3: The environmental indicators selection

Instruction:

1. Please mark ✓ into ☐ fill in the following the questionnaire.
2. Please rank how much you agree on environmental indicators to be introduced and used to monitor sustainable highland agriculture at the demonstration plots of the Angkhang Royal Agricultural Station.

Very Strongly Agree	5
Strongly Agree	4
Agree	3
Disagree	2
Strongly Disagree	1

3. Please leave your comment / suggestion on the space provided.

Example

1. Farm Management							
Environmental Indicators		Level of Agreement					Comment and Suggestion
		5	4	3	2	1	
13.	Farm management standard	☑	☐	☐	☐	☐	

Table1: The list of environmental indicators for the Angkhang Royal Agricultural Station.

Environmental indicators for agriculture	Definition	Data types and sources
1. Farm Management		
Farm management standard	Portion of the demonstration land area that follows Good Agricultural Practice (GAP) management standards relative to the total demonstration land area	Department of Agriculture, Ministry of Agriculture and Cooperatives Thailand/ Bureau Veritas (Thailand) Ltd.
Nutrient management plan	Portion of the demonstration land area that follows nutrient management plan	Research Project Division of the Angkhang Royal Agricultural Station
Pest management plan	Portion of the demonstration land area that follows the Integrated Pest Management (IPM) regulations	Research Project Division of the Angkhang Royal Agricultural Station
Soil conservation management	Portion of the demonstration land area that follows soil conservation management practices for examples: vegetation cover, crops rotation, strip cropping, reducing tillage, etc.	Research Project Division of the Angkhang Royal Agricultural Station
Water efficiency management	Portion of the demonstration land area that applies irrigation technology for examples: drip irrigation, mini sprinklers, etc.	Research Project Division of the Angkhang Royal Agricultural Station/ Department of Groundwater Resources, Ministry of Natural Resources and Environment Thailand

Table1: The list of environmental indicators for the Angkhang Royal Agricultural Station (continued).

Environmental indicators for agriculture	Definition	Data types and sources
2. Use of farm inputs and natural resources		
Nutrient use	Portion of chemical fertilizer usage of total fertilizer application (manure/compost and chemical fertilizer)	Research Project Division of the Angkhang Royal Agricultural Station/ Soil analysis, Land Development Regional Office 6, Ministry of agriculture and cooperatives Thailand
Pesticide use	Portion of chemical pest control use of total integrated pest control scheme adoption (physical, biological and chemical pest control)	Research Project Division of the Angkhang Royal Agricultural Station
Water use	Portion of demonstration water use in total water utilization	Research Project Division of the Angkhang Royal Agricultural Station
Land use	Portion of the demonstration land area of total land area of the Angkhang Royal Agricultural Station	Research Project Division of the Angkhang Royal Agricultural Station

Table1: The list of environmental indicators for the Angkhang Royal Agricultural Station (continued).

Environmental indicators for agriculture	Definition	Data types and sources
3. Environmental impacts of agriculture		
Soil quality	Portion of the analytical results of heavy metals in demonstration soil that exceed the standard value	The Royal Project Land Development Center/ Soil Analysis, Land Development Regional Office 6, Ministry of Agriculture and Cooperatives Thailand
Water quality	Portion of the analytical results of heavy metals in demonstration water that exceed the standard value	The Royal Project Land Development Center/ Water Analysis, Land Development Regional Office 6, Ministry of Agriculture and Cooperatives Thailand
Biodiversity	Portion of main crop varieties (temperate perennial crops) of total varieties (crops and livestock) which registered and certified for marketing at the Angkhang Royal Agricultural Station	Research Project Division of the Angkhang Royal Agricultural Station
Landscape	Portion of land use pattern, including changes in demonstration land use patterns at the Angkhang Royal Agricultural Station	Research Project Division of the Angkhang Royal Agricultural Station

Table1: The list of environmental indicators for the Angkhang Royal Agricultural Station (continued).

Environmental indicators for agriculture	Definition	Data types and sources
4. Farm structure and farm financial resources		
Farm income	Portion of gross output value relative to all expenses from agricultural activities at the Angkhang Royal Agricultural Station	Administrative Division of the Angkhang Royal Agricultural Station
Agricultural output	Portion of final agricultural output value produced at the Angkhang Royal Agricultural Station	Administrative Division of the Angkhang Royal Agricultural Station
Farm employment	Portion of agriculture related employment in total civilian employment (officials and farm workers) at the Angkhang Royal Agricultural Station	Administrative Division of the Angkhang Royal Agricultural Station
Age/gender distribution	Portion of farm workers categorized by age and gender at the Angkhang Royal Agricultural Station	Administrative Division of the Angkhang Royal Agricultural Station

Source: OECD, 2001 and the Angkhang Royal Agricultural Station, 2012.

Question13-29: Please rank how much you agree on environmental indicators to be introduced and used to monitor sustainable highland agriculture at the demonstration plots of the Angkhang Royal Agricultural Station.

Q.	Environmental Indicators	Level of Agreement					Comment and Suggestion
		5	4	3	2	1	
1. Farm Management							
13.	Farm management standard	☐	☐	☐	☐	☐	
14.	Nutrient management plan	☐	☐	☐	☐	☐	
15.	Pest management plan	☐	☐	☐	☐	☐	
16.	Soil conservation management	☐	☐	☐	☐	☐	
17.	Water efficiency management	☐	☐	☐	☐	☐	
2. Use of farm inputs and natural resources							
18.	Nutrient use	☐	☐	☐	☐	☐	
19.	Pesticide use	☐	☐	☐	☐	☐	
20.	Water use	☐	☐	☐	☐	☐	
21	Land use	☐	☐	☐	☐	☐	

Q.	Environmental Indicators	Level of Agreement					Comment and Suggestion
		5	4	3	2	1	
3. Environmental impacts of agriculture							
22.	Soil quality	☐	☐	☐	☐	☐	
23.	Water quality	☐	☐	☐	☐	☐	
24.	Biodiversity	☐	☐	☐	☐	☐	
25.	Landscape	☐	☐	☐	☐	☐	
4. Farm structure and farm financial resources							
26.	Farm income	☐	☐	☐	☐	☐	
27.	Agricultural output	☐	☐	☐	☐	☐	
28.	Farm employment	☐	☐	☐	☐	☐	
29	Age/gender distribution	☐	☐	☐	☐	☐	

Part 4: Recommendations and suggestion

Instruction: Please fill in the following the questionnaire.

Question 30: Apart from indicators listed in Part 3, do you have any additional indicator? Please describe.

☐ No

☐ Yes (Please describe) .....

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Question 31: According to your answer in Part 3 for the indicators that you selected as very strongly agree and strongly agree what are their benefits to the Angkhang Royal Agricultural Station's officials? Please describe.

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Question 32: According to your answer in Part 3 for the indicators that you selected as very strongly agree and strongly agree, how the Angkhang Royal Agricultural Station's officials could apply these indicators to the station to monitor the sustainability at the plot.

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Question 33: According to your answer in Part 3 for the indicators that you selected as very strongly agree and strongly agree which indicators are easy to understand for highland farmers? Please describe.

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Question 34: Any comment or suggestion about the environmental indicators to be introduced and used to monitor sustainable highland agriculture at the Angkhang Royal Agricultural Station

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APPENDIX B

IN-DEPTH INTERVIEW QUESTIONNAIRE

Respondent Code: .....

Subject: Questionnaire of Study of Environmental Indicators to Monitor Sustainable Highland Agriculture: a Case Study of the Angkhang Royal Agricultural Station, Doi Angkhang, Chiang Mai Province, Thailand.

Instruction:

1. The questionnaire is provided by Miss Siriluck Pengnam, Master degree Candidate in Environment Development and Sustainability Program of Chulalongkorn University.

2. The objective of this questionnaire is to survey the Angkhang Royal Agricultural Station's officials opinions under the thesis entitled "Study of Environmental Indicators to Monitor Sustainable Highland Agriculture: a Case Study of the Angkhang Royal Agricultural Station, Doi Angkhang, Chiang Mai Province, Thailand".

3. A set of the questionnaire consists of four parts and please fill in the following the questionnaire.

All information that you provide in this questionnaire which includes personal information and your comments will be used exclusively for research objectives under this thesis.

Thank you very much for your cooperation in this research.

Yours truly,

Siriluck Pengnam

Instruction: The questionnaire is divided into 4 parts composes of:

Part 1: Basic information.

Part 2: Barriers/problems on demonstration plots of the Angkhang Royal Agricultural Station.

Part 3: Environmental indicators.

Part 4: Recommendations and suggestion.

Part 1: Basic information

Instruction: Please mark ✓ into ☐ fill in the following the questionnaire.

Question 1: Gender

☐ Male ☐ female

Question 2: Age

☐ 20-25 years old ☐ 26-30 years old

☐ 31-35 years old ☐ 36-40 years old

☐ 41-45 years old ☐ 46-50 years old

☐ 51-55 years old ☐ 56-60 years old

☐ Over 61 years old

Question 3: Educational level

☐ Bachelor's Degree ☐ Master's Degree

☐ Doctor of Philosophy

☐ Others (please specify) .....

Question 4: Educational Background

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Question 5: Division

- ☐ Administrative Division
- ☐ Research Project Division
- ☐ Career Development and Promotion Division
- ☐ Project and Special Activities Division
- ☐ Services and Publishing Knowledge Division

Question 6: Positions

- ☐ Administrations
- ☐ Academic (Technical researchers)
- ☐ Career Development and Promotion official
- ☐ Assistant technical researchers
- ☐ Research and development institution
- ☐ Others (please specify) .....

Question 7: Work Experience

- ☐ Less than 1 year
- ☐ 1-5 years
- ☐ 6-10 year
- ☐ 11-15 years
- ☐ 16-20 year
- ☐ more than 21 years

Part 2: Barriers/problems on demonstration plots of the Angkhang Royal

Instruction: Please fill in the following the questionnaire

Question 8: What is your opinion on highland agriculture? (Can answer more than 1)

- ☐ Environmental conservation
- ☐ Deforestation
- ☐ Career promotion for highlanders
- ☐ Social problems reduction
- ☐ Beneficial to national security
- ☐ Increasing highland farmer revenue
- ☐ Enhancement sustainable highland agriculture
- ☐ Cause-affect the ecological system at upstream and downstream catchment areas if agricultural practices are not properly
- ☐ Others (please specify) .....

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Question 9: What is / are the current highland agriculture barriers / problems at the Angkhang Royal Agricultural Station? (Can answer more than 1)

- ☐ Society and culture
- ☐ Economic force
- ☐ Commercial crop intensification
- ☐ Climate change
- ☐ Drought/water shortage
- ☐ Agriculture production quality
- ☐ Wildfire

- ☐ Agriculture input cost
- ☐ Soil erosion/land degradation
- ☐ Ecological degradation
- ☐ Undefined boundaries land use
- ☐ Others (please specify) .....

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Question 10: What is / are the future highland agriculture barriers / problems at the Angkhang Royal Agricultural Station? (Can answer more than 1)

- ☐ Society and culture
- ☐ Economic force
- ☐ Commercial crop intensification
- ☐ Climate change
- ☐ Drought/water shortage
- ☐ Agriculture production quality
- ☐ Wildfire
- ☐ Agriculture input cost
- ☐ Soil erosion/land degradation
- ☐ Ecological degradation
- ☐ Undefined boundaries land use
- ☐ Agricultural tourism
- ☐ Lack of conservation awareness
- ☐ Selfishness of highlanders
- ☐ Others (please specify) .....

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Part 3: Environmental indicators

Table of the selected environmental indicators of expert judgments.

No.	Environmental indicators for agriculture	Definition
1.	Farm management standard	Portion of the demonstration land area that follows Good agricultural Practice (GAP) management standards relative to the total demonstration land area
2.	Nutrient management plan	Portion of the demonstration land area that follows nutrient management plan
3.	Pest management plan	Portion of the demonstration land area that follows the Integrated pest management (IPM) regulations
4.	Soil conservation management	Portion of the demonstration land area that follows soil conservation management practices for examples: vegetation cover, crops rotation, strip cropping, reducing tillage, etc.
5.	Nutrient use	Portion of chemical fertilizer usage of total fertilizer application (manure/compost and chemical fertilizer)
6.	Pesticide use	Portion of chemical pest control use of total integrated pest control scheme adoption (physical, biological and chemical pest control)
7.	Land use	Portion of the demonstration land area of total land area of the Angkhang Royal Agricultural Station
8.	Biodiversity	Portion of main crop varieties (temperate perennial crops) of total varieties (crops and livestock) which registered and certified for marketing at the Angkhang Royal Agricultural Station
9.	Farm income	Portion of gross output value relative to all expenses from agricultural activities at the Angkhang Royal Agricultural Station
10.	Agricultural output	Portion of final agricultural output value produced at the Angkhang Royal Agricultural Station

Instruction: Please fill in the following the questionnaire.

Question 11: Do you think that the selected environmental indicators of expert judgments can reduce those barriers / problems from Question 9-10?

☐ Reduce, because .....

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☐ May reduce, because.....

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☐ Not reduce, because .....

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Question 12: What is your opinion, if you could apply those indicators into your work fields? Please describe.

☐ Can apply.....

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☐ Not sure.....

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☐ Cannot apply.....

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Question 13: What is your opinion, if you can disseminate information of the selected environmental indicators to highland farmers?

☐ Can disseminate.....

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☐ Not sure.....

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☐ Cannot disseminate .....

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Part 4: Recommendations and suggestion

Instruction: Please fill in the following the questionnaire

Question 14: Apart from the selected environmental indicators of expert judgments in Part 3, do you have any additional indicator? Please describe.

☐ No

☐ Yes .....

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Question 15: Any comment or suggestion about the environmental indicators to be introduced and used to monitor sustainable highland agriculture at the Angkhang Royal Agricultural Station.

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VITA

Siriluck Pangnam was born in Bangkok, Thailand on 9 August 1986. In 2008, she received her Bachelor's Degree in Tropical Agriculture (International Program) from Kasetsart University, Thailand and International Trade from Victoria University, Australia. In 2012, she enrolled in the Environment, Development and Sustainability (EDS) Program at Graduate School of Chulalongkorn University in Bangkok, Thailand.