DEVELOPMENT OF ENVIRONMENTAL INDICATORS WITH RELEVANT STAKEHOLDERS' INVOLVEMENT FOR SUSTAINABLE WATERSHED MANAGEMENT: A CASE STUDY OF THE LAM NAM YANG PART 1 WATERSHED IN NORTHEASTERN THAILAND

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การพัฒนาตัวชี้วัดสิ่งแวดล้อมของผู้มีส่วนได้ส่วนเสียสำหรับการจัดการลุ่มน้ำอย่างยั่งยืน : กรณีศึกษาลุ่มน้ำลำนำยังส่วนที่ 1 ในภาคตะวันออกเฉียงเหนือของประเทศไทย

นางวรินธร คุณเอนก

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาศิลปศาสตรดุษฎีบัณฑิต
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วรินธร คุณเอนก : การพัฒนาตัวชี้วัดสิ่งแวดล้อมของผู้มีส่วนได้ส่วนเสียสำหรับการจัดการลุ่มน้ำอย่างยั่งยืน : กรณีศึกษาลุ่มน้ำลำนำยังส่วนที่ 1 ในภาคตะวันออกเฉียงเหนือของประเทศไทย (DEVELOPMENT OF ENVIRONMENTAL INDICATORS WITH RELEVANT STAKEHOLDERS' INVOLVEMENT FOR SUSTAINABLE WATERSHED MANAGEMENT: A CASE STUDY OF THE LAM NAM YANG PART 1 WATERSHED IN NORTHEASTERN THAILAND) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ผศ. ดร.อาจอง ประทัตสุนทรสาร, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: รศ. ดร.สุระ พัฒนเกียรติ, 161 หน้า.

การมีส่วนร่วมของผู้มีส่วนได้ส่วนเสียถือว่าเป็นปัจจัยสำคัญที่มีผลต่อความสำเร็จหรือความล้มเหลวของการจัดการลุ่มน้ำ ดังนั้นเพื่อให้มีการจัดการลุ่มน้ำการอย่างยั่งยืนจึงมีความจำเป็นต้องมีกระบวนการที่จะให้ผู้มีส่วนได้ส่วนเสียเข้ามามีส่วนร่วมมากที่สุด ซึ่งวิธีการหนึ่งคือกระบวนการในการพัฒนาตัวชี้วัดความยั่งยืนและตัวชี้วัดสถานภาพของลุ่มน้ำเพื่อใช้ในการติดตามสถานการณ์ในลุ่มน้ำ งานวิจัยในครั้งนี้ มีวัตถุประสงค์เพื่อวิเคราะห์การจัดการลุ่มน้ำลำน้ำลำน้ำยังส่วนที่ 1 และพัฒนาชุดของตัวชี้วัดด้านสิ่งแวดล้อมสำหรับการจัดการลุ่มน้ำอย่างยั่งยืนบนพื้นฐานของกระบวนการการมีส่วนร่วม โดยใช้วิธีการสำรวจความเห็นของชุมชนในพื้นที่ลุ่มน้ำ การสัมภาษณ์ผู้ที่มีส่วนเกี่ยวข้อง และการคัดเลือกตัวชี้วัดโดยผู้เชี่ยวชาญและผู้มีส่วนได้เสียหลักที่เกี่ยวข้อง

กรอบแนวคิดแรงขับเคลื่อน-ความกดดันต่อสิ่งแวดล้อม-สภาวะของสิ่งแวดล้อม-ผลกระทบ-การตอบสนอง (DPSIR) ถูกนำมาใช้เพื่อระบุปัญหาสิ่งแวดล้อมที่สำคัญและใช้เป็นแนวทางในการพัฒนาชี้วัดด้านสิ่งแวดล้อมของลุ่มน้ำลำน้ำยังส่วนที่ 1 จากการศึกษาพบว่าปัญหาสิ่งแวดล้อมที่สำคัญในพื้นที่ลุ่มน้ำ ได้แก่ปัญหาการขาดแคลนน้ำเพื่อการเกษตร การขาดแคลนน้ำเพื่อการอุปโภคบริโภค การสูญเสียความอุดมสมบูรณ์ของดิน การทำป่าและการลดลงของพันธุ์พืชและพันธุ์สัตว์ และการชะล้างพังทลายของดินและการสูญเสียหน้าดินทำให้ดินเสื่อมสภาพลง ซึ่งชุดของตัวชี้วัดด้านสิ่งแวดล้อมที่ได้รับการคัดเลือกเพื่อที่จะใช้ในการวัดความอย่างยั่งยืนของลุ่มน้ำมีจำนวนรวมทั้งสิ้น 101 ตัวชี้วัด ประกอบด้วยตัวชี้วัดที่เป็นแรงผักดัน จำนวน 13 ตัวชี้วัด ตัวชี้วัดที่เป็นแรงกดดัน 24 ตัวชี้วัด และตัวชี้วัดสถานภาพจำนวน 24 ตัวชี้วัด และตัวชี้วัดผลกระทบจำนวน 21ตัวชี้วัด และตัวชี้วัดการตอบสนองจำนวน 19 ตัวชี้วัด ซึ่งจากการศึกษาพบว่ามีข้อจำกัดและมีความยากลำบากบางประการในกระบวนการพัฒนาตัวชี้วัดด้านสิ่งแวดล้อม และควรมีการศึกษาเพิ่มเติมเพื่อพัฒนาขยายและปรับตัวชี้วัดด้านสิ่งแวดล้อมให้เหมาะสมต่อบริบทของพื้นเพื่อให้บรรลุการจัดการลุ่มน้ำอย่างยั่งยืนต่อไป อย่างไรก็ตามในกระบวนการพัฒนาตัวชี้วัดในครั้งนี้ ผู้มีส่วนได้ส่วนเสียและผู้เชี่ยวชาญได้เข้ามามีส่วนร่วมในการแสดงความเห็นที่เป็นประโยชน์และได้แลกเปลี่ยนความรู้ระหว่างกัน

สาขาวิชา สิ่งแวดล้อม การพัฒนา และความยั่งยืน ลายมือชื่อนิสิต .....

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5387809520 : MAJOR ENVIRONMENT DEVELOPMENT AND SUSTAINABILITY
KEYWORDS: WATERSHED SUSTAINABILITY / STAKEHOLDER INVOLVEMENT / DPSIR / ENVIRONMENTAL INDICATORS

WARINTORN KHUNANAKE: DEVELOPMENT OF ENVIRONMENTAL INDICATORS WITH RELEVANT STAKEHOLDERS' INVOLVEMENT FOR SUSTAINABLE WATERSHED MANAGEMENT: A CASE STUDY OF THE LAM NAM YANG PART 1 WATERSHED IN NORTHEASTERN THAILAND. ADVISOR: ASST. PROF. ART-ONG PRADATSUNDARASAR, Ph.D., CO-ADVISOR: ASSOC. PROF. SURA PATTANAKIAT, Ph.D., 161 pp.

Stakeholders' involvement have been said to be critical factor to success or failure of the watershed management, as a result sustainable and integrated watershed management to engage all stakeholders is therefore needed. One approach is through the application of the indicator-based to develop a watershed sustainability and watershed health indicators to provide conditions of watershed. This study aims to identify the state of the Lam Nam Yang Part1 watershed management, and to develop a set of environmental indicators for sustainable watershed management based on stakeholders' involvement process through community survey, key informant interview, experts and relevant stakeholders' judgments.

The Driver-Pressure-State-Impact-Response (DPSIR) framework was applied to identify key environmental issues and used to frame the environmental indicators of the Lam Nam Yang Part1 watershed. It was found that key environmental issues included water shortage for agriculture, water shortage for consumption, loss of soil fertility, forest destruction, decline of plant and animal species, soil erosion and loss of topsoil causing soil degradation, respectively. A set of environmental indicators selected to monitor the sustainable of the watershed totaled 101 indicators including 13 Drivers indicators, 24 Pressure indicators, 24 State indicators, 21 Impact, and 19 Response indicators. The study has experienced that there are some limitations and difficulties in the construction of environmental indicators in development process, and there should be further studied in order to develop, extend, and adapt the environmental indicators to specific contextual area for achieving sustainable watershed management. However, it is also clear that this is a worthwhile exercise and that the benefit of developing a set of environmental indicators creates the knowledge sharing among stakeholders and local experts in the watershed level.

Field of Study:	Environment Development and Sustainability	Student's Signature	.....
		Advisor's Signature	.....
Academic Year:	2016	Co-Advisor's Signature	.....

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LIST OF ABBRIVIATIONS

ADB	Asian Development Bank
CSD	Commission on Sustainable Development
DNP	Department of National Parks, Wildlife and Plant Conservation
DPCSD	UN Department for Policy Coordination and Sustainable Development
DPSIR	Driving forces-Pressure-State-Impacts-Responses
DSR	Driving Force-State-Responses
EEA	European Environmental Agency
EUROSTAT	Statistical Office of the European Communities
GISDA	Geo-Informatics and Space Technology Development Agency
GMS	The Greater Mekong Sub region
LDD	Land Development Department
MCA	Multi-Criteria Analysis
NESDB	National Economic and Social Development Board
OECD	Organization for Economic Co-operation and Development
ONEP	Office of Natural Resources and Environmental Policy and Planning
PSR	Pressure-State-Responses
REO12	Regional Environmental Office 12
RID	Royal Irrigation Department
SDGs	Sustainable Development Goals
UN	United Nations
UNEP	United Nations Environment Program
US-EPA	United States Environmental Protection Agency
WB	The World Bank
WRI	World Resources Institute

CHAPTER I
INTRODUCTION

1.1 Statement of the Problem

Stakeholders' involvement have been said to be critical factor to success or failure of the watershed management programs or projects for decades. The role of stakeholders' involvement in environmental management process has shifted continuously from top-down approach to bottom-up in recent years (Johnson, *et.al*, 2001). The success in watershed management requires all stakeholders in watershed management including users, policymakers, researchers, and others recognizing that participation is not simply as technological solutions. Participation in watershed management means that all stakeholders have to work together to set criteria for sustainable management, identify priority constraints, evaluate possible solutions, recommend technologies and policies, and monitor and evaluate impacts (Johnson, *et. al*., 2001). A sustainable and integrated watershed management to engage all stakeholders is therefore needed; such watershed management has demonstrated to be capable of integrating all issues of watershed resources management.

One approach to achieve sustainable and integrated watershed management is through the application of the indicator-based approach. In recent years, this approach has been used to develop many watershed sustainability and watershed health indicators to provide information on current conditions of watershed resources, provide inputs to decision makers and prioritize watershed-related issues (Juwana *et al.*, 2009). This indicator-based approach tool helps to identify factors contributing the sustainability of the watershed and to communicate with all related stakeholders in a holistic picture. The indicators can be used as baseline data which is useful for providing the public with a short evaluation of the state of the watershed, and also helps to establish programs or remedial action to ensure the long-term health of the area and assist decision makers and all relevant agencies to improve more effective programs.

In Thailand, participation of stakeholders in watershed management is now gained recognition for the conservation and sustainable use watershed resources. Since the late 1990s, the issue of participation such as the right of local communities and authorities to participate in the management of natural resources has been included in the 1997 Constitution of the country. Major ministries, line departments, local government agencies responsible for resources management have applied many approaches to participatory resource management into practice together with implementing programs and projects to improve the quality of the watershed and wellbeing of the people (Hedy and Neef, 2004). Unfortunately, several watersheds in the country are still in poor condition; for example; the quality of surface water is still decreasing, groundwater is depleting, and other resources are deteriorating including the natural resources of the Chi River Basin (Coordination and Management of Lower Chi River Basin Division, 2010). Like other watersheds around the world, the question remains such as; Are these implemented programs acknowledged by or met the satisfactory of stakeholders? Are there any appropriate monitoring and evaluation indicators that involve relevant stakeholders to measure success or improvement of the watershed quality? To answer these questions, there should be a process to involve stakeholders in developing appropriate indicators to help in tracking the state of the watershed health and to measure the improvements in the watershed. Stakeholders can assist in the indicators development process by using their knowledge in local social, economic, political and ecological conditions to provide desirable outcome, watershed goals, problems, remediation strategies, resources protection strategies, legal and institution requirements, and others. In addition, to understand perceptions and roles of stakeholders in watershed management will help in the collaboration among various stakeholder groups and policy makers in the adoption of indicators and development of effective environmental policy in the future and providing opportunities for benefit sharing to both bottom-up and top-down management.

This study aims to identify state of the watershed and develop a set of watershed indicators specifically the environmental aspect with the involvement of stakeholders at a watershed level.

1.2 Research Questions

1.2.1 How to make use of baseline information concerning the Lam Nam Yang Part1 watershed (e.g. state of the natural resources and environments, perception of stakeholders, management and participation) and integrate into the indicators development process?

1.2.2 What are the key environmental issues from stakeholders' opinion?

1.2.3 What are the potential environmental indicators contribute to sustainable watershed management from stakeholders' involvement process?

1.3 Research Objectives

1.3.1 To identify the state of the Lam Nam Yang Part1 watershed.

1.3.2 To develop a set of environmental indicators for sustainable watershed management based on stakeholders' involvement process.

1.4 Scope of the Study

1.4.1 The study area will be at the Lam Nam Yang Part1 watershed in the Chi River Basin.

1.4.2 Environmental indicators will be developed through the involvement of stakeholders concerning sustainable watershed management.

1.4.3 The Driving force-Pressure-State-Impact-Response (DPSIR) will be used as a framework for development of indicators.

1.5 Expected Output/Outcome

15.1 The state of the Lam Nam Yang Part 1 watershed.

15.2 A set of environmental indicators resulting from stakeholders' involvement process

CHAPTER II
LITERATURE REVIEW

2.1 Sustainable watershed Management

Sustainable watershed management is defined as a process for improving and protecting the natural resources of a watershed by integrating ecological, economic, and social perspectives. Ecology perspective includes management of natural resources with water quality and water quantity being the primary focus, protection and enhancement of ecological services (source/headwaters, storage, conveyance, wetlands). Society perspective includes respect for community values, stakeholder participation and benefits, local economic development that has an awareness of global and local sustainability opportunities, maintaining a sense of history and place. Economic perspective includes cost-efficient projects & economic opportunities with no net-loss of ecological services, measurable results for environmental investments, and promotion of market-based investment in clean water. These three perspectives should be considered through communication and information sharing with stakeholders (Clear Creek Watershed Foundation, 2007).

The goal of sustainable watershed management is to align human uses of resources (e.g., forestry, agriculture, water storage and diversion, hydropower, navigation) with the available water supply to sustain watershed ecological function and human activities. Sound land use and water use management must include interventions at the watershed level, as well as at the government policy level to influence and foster improved management. Related policies must be adaptable to changing conditions and predicated on the recognition that functional watershed ecosystems are essential to sustainable development. The future of effective and sustainable watershed management demands cooperative ecosystem management by local stakeholders as well as national and even international governing bodies (Ecosystem Sciences Foundation, 2012). It can be concluded that the objective of watershed management is to maintain the watershed functions and with that to contribute to sustainable development and reduction of negative impacts in its region. It is a typical and valuable example how to make sustainable development

operational. Forest, land, water resources as well as environment could be constructively utilized in sustainable ways if those resources could be suitable used and being properly managed.

2.2 Indicators of Watershed health

Indicators are measures of environmental quality that are used to assess the status and trends of conditions of the watershed, and to monitor how well the watershed performs its function. It is a simple question to ask how we measure the health of the watershed. Is our watershed we live in healthy? The answers are not so simple because watershed is a very complicated system; it involves many aspects of the environment. All things affect and influence on each other; air, soil, water, wildlife, plants and people. One way to check the watershed health is to use the indicators. The use of indicators has become a useful regulatory tool; however the challenge is to find relevant indicators that have a significant impact of the watershed. Any groups of indicators can be used depend on the desire outcome and why indicators are being selected (Gray and Logan, 2008).

Environmental indicators reflect the principal issues and component of the environment in a given area. They can be presented on their own or as part of sustainable development indicators, in which case they can correspond to the environmental dimension of those indicators (Quiroga, 2009). The OECD gives the definition of an environment indicator "is a parameter, or a value derived from parameters, that points to, provides information about and/or describes the state of the environment, and has a significance extending beyond that directly associated with any given parametric value. The term may encompass indicators of environmental pressures, conditions and responses" (OECD, 1997). The environmental indicators reflect the status and tendencies of, for example, biota and biodiversity, the quantity and quality of water, the quality of breathable air, pollutant load and the supply of renewable energy, the availability and extraction of natural resources (such as forests, fisheries, agriculture), urban pollution, the production of solid waste, the use of agrochemicals, or the frequency and intensity of natural disasters (Quiroga, 2009).

Simply put, environmental indicators are those that describe and demonstrate the principal environmental components and their states in the watershed.

The Muskoka Watershed Council provides the desired outcome of watershed health to inform the public with the suite of indicators. This suite of indicators reflects the advice from stakeholders with respects to key aspects of watershed health and help in providing a feedback to adjust the programs and policies revision. The desired outcomes and ecological integrity of the watershed health can be defined as the quality of the lakes and river should be swimability, drinkability, fishability, the air should be breath-ability, the watershed should have healthy natural areas, the watershed should have sustainable physical environment, and should support the community values (Muskoka Watershed Council, 2003).

It is suggested that the set of indicators to measure watershed health should be refined overtime to better reflect the linkages among components of the ecosystem. Not all indicators used at a national scale are suitable for use at a jurisdictional or regional scale. There may be some that can be aggregated up from a regional scale to a national scale and some that cannot. Environmental Service City of Portland (2005) defined watershed conditions into three elements: landscape factors, watershed health attributes, and human influences. These elements are shown in Table 2.1 to help in understanding the factors affecting watershed conditions.

Table 2. 1 Factors affecting watershed conditions

Landscape Factors →	**Watershed Health Attributes (Potential indicators)**	←**Human Influences**
Climate	**Hydrology**	Landuse
Physiography	Hydrograph alteration	Impervious surfaces
Lithology/soils	Floodplain presence and connectivity	Dam impacts
Watershed morphology	Groundwater	Water withdrawals
Hydrology		Drainage network
Vegetation	**Physical habitat**	Channel alterations
	Floodplain quality and connectivity	Vegetation management
	Riparian condition: with composition and fragmentation	Wetland alteration
	Stream connectivity	Outfall discharges
	Channel condition and habitat structure:	Exotic species
	- Habitat types	Harassment
	- Bank erosion	Harvest
	- Channel substrate (fine/coarse)	Hatchery management
	- Off-channel habitat (tributary	Spills and illicit discharges

Landscape Factors →	Watershed Health Attributes (Potential indicators)	←Human Influences
	and side channels) - Refugia (depth, boulders, undercut banks and woods) - Large wood	
	Terresterial habitat Wetland habitat **Water Quality** Water temperature Dissolved oxygen Nutrients and chlorophyll *a* Total suspended solids Toxic contamination of water, sediment and biota Groundwater quality Other 303 (d)-listed TMDL parameters Other parameters (as determined by weight of evidence) **Biological Communities** Biotic integrity Benthic communities Salmonid population structure (abundance, productivity, spatial structure, diversity) Species interaction (predation, competition, exotic species, ect.) Riparian wildlife Terrestrial wildlife Plant communities	

(Source: Environmental Service City of Portland, 2005).

2.3 Stakeholders' involvement in watershed management and indicator selection

In the past decades, stakeholders' involvement in the environmental management was only a need for government agencies to inform the public about the environmental concerns or issues, and the decision they have made rather seeking the real participation. Later, stakeholders' involvement in environmental management has become more importance and gained interest from all around the world. The stakeholders involvement have been said to be a critical factor to success or failure of the programs or projects. The role of stakeholders' involvement in environmental management process has shifted continuously from top-down approach to bottom-up in recent years. The degree of stakeholder involvement in watershed management activities will vary between watersheds. In some watersheds stakeholders may want to be involved in all activities and aspects of watershed management, while others they may only want to be involved in some points such as the creation of management plan or the implementation process.

The US EPA defines stakeholders in watershed management as “a person (or group) who is responsible for making or implementing a management action, who will be affected by the action, or who can aid or prevent its implementation (US EPA, 2011). Types of stakeholders in watershed management can also be defined into 3 categories:

- Primary Stakeholders are the people who live, own land and or use watershed resources. They include the local community, governmental and non-governmental bodies.
- Secondary Stakeholders are people who are trade with watershed resource owners and obtain commodities from the watershed.
- Tertiary stakeholders include people who live far away from the watershed but receive resources produced from the watershed and may include water consumers in towns, importers of timber products, food, and etc (Mutisya, 2011).

As noted earlier, stakeholders are not only local people, not only organizations and formal groups, and not only the users of natural resources. They include governments and their agencies, as well as people, organizations, institutions and markets, which are not necessarily located close to the natural resource that is being managed. They include individuals, communities and informal networks. They include people and institutions that impact directly but also indirectly on the resources even without using them, and they include people who may not even be aware that they have a stake in the management of these resources. Stakeholders change over time, new stakeholders can enter a resource management system, while others may lose their role or interest (Renard, 2004).

The survey of literature finds that there are some lessons learned from a stakeholder involvement in selecting indicators from previous experiences. Burger (2009) compiled several different levels of stakeholder involvement in indicator selection (bioindications) together with case studies to show the importance of communication and collaboration. The level of involvement ranges from level of informational, Intergovernmental with Outside Scientists, Stakeholder Involvement and Stakeholder-Driven, and Stakeholder Collaboration respectively. Each category differs

in many aspects including stakeholders input which are considered to be the most important for indicator selection. The proper way to improve the process of indicator development and selection was try to involve local people and stakeholders in early stage, identifying all the relevant stakeholders in before framing of the indicator selection problem, and gaining stakeholder input as much as possible in ways they believe they can contribute (Burger, 2009).

The importance of stakeholders' involvement for indicator selection is shared by the assessment of Fraser, *et. al.* (2006) on the impact of participatory processes in three different case studies. They assessed the environmental management projects where community input has been used to identify sustainability indicators. In all three case studies are considerably different in social, economic and environmental contexts. The first case focuses on forest management in Coastal British Columbia, Canada, which engages stakeholders to select indicators to solve the conflict over mismanagement of local resources. The second case is in Botswana where the pastoralist communities are poor and the environments are severely degraded. The local people identify key indicators to understand desertification for sustainable rangeland management. The last case is from the States of Guernsey, in the United Kingdom's Channel Islands, where is home of relative homogeneous community that the government established key indicators to monitor the overall effect of economic transition and globalization. The three case studies represented a wide range of experiences that participatory processes in identifying and monitoring sustainability indicators may affect environmental management in 3 main reasons:

1. Sustainability indicators identification and collection not only provide valuable databases for making management decisions, but the process of engaging people to select indicators also provides an opportunity for community empowerment.

2. Multi-stakeholder processes must formally feed into decision-making forums or they risk being viewed as irrelevant by policy-makers and stakeholders.

3. If ecological boundaries are not the same with political jurisdictions, it is necessary to be flexible when choosing the scale at which monitoring and decision-making occurs and needs an awareness of major environmental pathways in that landscapes (Fraser, *et. al.*,2006)

Based on the review of international initiatives to develop sustainability indicators for catchment management, Walmsley *et al*. (2001) mentioned that the common thread to all the indicator sets was the participation of stakeholders. They recommended that although expert opinion is required to develop a set of indicators at first, but the core indicators that are finally decided upon, should meet the requirements of stakeholders in the catchment. Moreover, the indicator sets cannot meet all the needs of all the stakeholders, but an attempt should be made to include the requirements of stakeholders in general. Stakeholders who should be approached with regard to the development of indicators for sustainable catchment management include major stakeholders, such as regional offices, catchment management agencies, local authorities, water forums, and service providers. The review concluded that in developing indicators for catchment management, each situation is unique, and that no two indicator sets will be exactly alike (Walmsley *et al*., 2001).

The US EPA (2011) stressed that the importance of stakeholder involvement in watershed management helped in building trust and support for the process and product, sharing of responsibility for decisions or actions, creating solutions more likely to be adopted, leading to better, more cost-effective solutions, forging stronger working relationships, and enhancing communication and coordination of resources (US EPA, 2011) . Therefore, developing watershed indicators in the context of stakeholder-based can be applied to enhance watershed management efforts.

2.4 Concepts of building indicators

2.4.1 Indicator Frameworks

Reed *et al.* (2006) provided a summary of sustainability indicator from reviewing of literature and divided proposed frameworks into top–down and bottom–up paradigms. They summarized that there are strengths and weaknesses in both approaches. Indicators that emerge from top–down approaches are generally collected rigorously, scrutinized by experts, and assessed for relevance using statistical tools but often fails to engage local communities. In contrast, indicators from bottom–up methods tend to be rooted in an understanding of local context and are derived by systematically understanding local perceptions of the environment and society.

However, there is a danger that indicators developed through participatory techniques alone may not have the capacity to accurately or reliably monitor sustainability. The researchers emphasized the importance of participatory approaches setting the context for sustainability assessment at local scales, but stress the role of expert-led methods in indicator evaluation and dissemination. Examples of methodological frameworks for developing and applying sustainability indicators at a local scale can be summarized as follows:

Bottom–up

- The Soft Systems Analysis which builds on systems thinking and experiential learning to develop indicators as part of a participatory learning process to enhance sustainability with stakeholders.
- Sustainable Livelihoods Analysis is the analysis that develops indicators of livelihood sustainability that can monitor changes in natural, physical, human, social and financial capital based on entitlements theory.
- The Natural Step is the way of developing indicators to represent four conditions for a sustainable society to identify sustainability problems, visions and strategies.

Top–Down

- Panarchy Theory and Adaptive Management is the framework that based on a model that assesses how ecosystems respond to disturbance, it suggests that key indicators fall into one of three categories: wealth, connectivity, diversity. Wealthy, connected and simple systems are most vulnerable to disturbances.
- Orientation Theory is developing indicators to represent system "orientators" (existence, effectiveness, freedom of action, security, adaptability, coexistence and psychological needs) to assess system viability and performance.
- Pressure-State-Response (PSR, DSR and DPSIR) is a framework which identifies environmental indicators based on human pressures on the environment, the environmental states this leads to and societal responses to change for a series of environmental themes. Later versions replaced pressure with driving forces (which can be both positive and negative, unlike pressures which are negative) (DSR) and included environmental impacts (DPSIR).

- Framework for Evaluating Sustainable Land Management is a systematic procedure for developing indicators and thresholds of sustainability to maintain environmental, economic and social opportunities with present and future generations while maintaining and enhancing the quality of the land.
- Well-being Assessment is divided into four indices to measure human and ecosystem wellbeing: a human well-being index, an ecosystem well-being index, a combined ecosystem and human well-being index, and a fourth index quantifying the impact of improvements in human well-being on ecosystem health, and
- Thematic Indicator Development is identified in each of the following sectors or themes: environmental, economic, social and institutional, often subdividing these into policy issues. (Reed *et al.*, 2006)

As mentioned above, many frameworks have been applied to develop sets of indicators. In this research, the DPSIR framework will be employed in developing a set of indicators in the watershed systems. This framework tends to be used more often for identification of and reporting on environmental indicators, rather than the full spectrum of sustainability indicators. Walmsley (2002) discusses that the DPSIR framework deals more specifically with natural environmental issues and the influence of humans on the environment, rather than the economic aspects such as employment, empowerment, local needs, etc. The literature indicates that this approach has not yet been widely implemented in the watershed context. However, the DPSIR is mentioned and has been applied, within the framework of EUROCAT Project, in six European catchments, to address various stressors of the marine environment (Karageorgis, *et. al*., 2005). The DPSIR framework is also used as a framework in environmental assessment in the fifth Global Environment Outlook (GEO-5) for providing information of global environmental state and trends to world leaders and delegates attending the Rio+20 Summit in *Rio* de Janeiro (UNEP, 2012). The chain of casual links starting with "driving forces" (economic sectors, anthropogenic activities) through "pressure" (pollution, emission, waste) to "state" (physical, chemical, and biological) and "impact" on ecosystems, human health and functions) leading to "responses" of the society (Kristensen, 2004). The DPSIR framework is shown in Figure 2.1.

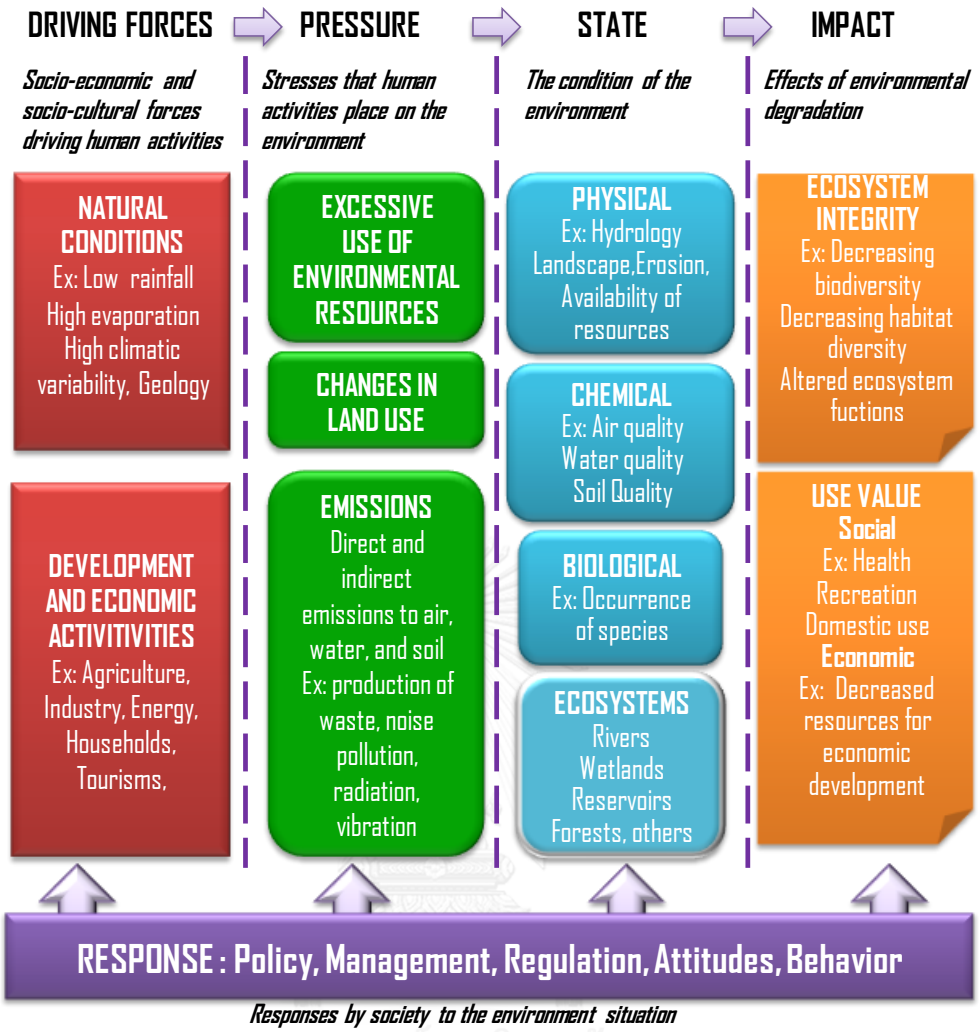

Figure 2. 1 The DPSIR assessment framework
(Source: adapted from Wamsley, 2002; EEA, 2003; and Kristensen, 2004)

The DPSIR is a suitable tool for organizing environmental information and for presenting causal links between environmental indicators to decision-makers. It indicates the chain of links from the causes of environmental problems to their impacts and society's responses to them in an integrated way.

2.4.2 Criteria for indicators selections

There are many criteria for watershed indicators selections recommended by many organizations. Three basic functions of indicators are identified: simplification, quantification, and communication. Dawson (2011) summarized several well known scientific and data management organizations, such as Statistics Canada, Eurostat, and

UN-Water, that have outlined basic quality assessment criteria for statistics employed as indicators. Table 2 summarizes the agreement among these agencies regarding characteristics of good indicators.

Table 2. 2 Summary of criteria for indicators by select organizations.

Statistic or Indicator Characteristics	UN-Water (2006)	Eurostat (2003)	OECD (2003a)	IMF (Carson 2001)	Statistics Canada (2002)
Measurability	√				
Responsiveness	√				
Methodological soundness				√	
Analytical soundness	√				
Cost effectiveness	√		√		
Accessibility of data for users	√	√	√	√	√
Ease of interpretation (clarity for users)	√	√	√		√
Policy relevance	√				
Relevance to users' needs		√	√	√	√
Accuracy		√	√	√	√
Timeliness		√	√	√	√
Comparability in space and/or time		√		√	√
Coherance Within/across datasets Over time Across boundaries		√	√	√	√
Reliability				√	
Creditability or integrity of statistical data			√	√	

(Source: Dawson, 2011)

From the summary of criteria for selecting indicators by Dawson (2011), these characteristics can be used to guide the development and selection of indicators. While it would be difficult to meet completely all of the suggested criteria, consideration should be given to which among these best apply in a specific situation. Different types of indicators; e.g. descriptive, showing trends, communication, assessment, and predicting future; serve different purpose. Many issues are interesting to the agencies and their stakeholders, so it's important to choose indicators that are within the research's scope to measure and use. The simple indicator criteria generally used in Thailand is the SMART criteria which are Specific, Measurable, Attainable, Relevant and Time bound. It is noted that indicators should be clearly defined, measurable in quantitative and qualitative terms, be achievable in terms of available

resources, be relevant for current issues, and be sensitive to change within policy time-frames (OECD, 2001).

2.4.3 Indicator Development Efforts

There are various institutions and organizations have put efforts in developing sets of indicators to monitor and compare environmental conditions at different scales; e.g., national, regional, river basin, watershed, and local scales.

In 1995, the Commission on Sustainable Development (CSD) approved a work programme on indicators of sustainable development comprising using the Driving Force - State -Response Framework. There was a list of approximately 130 indicators organized in this framework where, driving force indicators represent human activities, processes and patterns that impact on sustainable development; state indicators indicate the "state" of sustainable development; and response indicators indicate policy options and other responses to changes in the state of sustainable development. The indicators were then intended for use at the national level by countries in their decision-making processes. It had been recommended that not all of the indicators could be applicable in every situation so that countries would choose to use from among the indicators those relevant to national priorities, goals and targets (DPCSD, 1996).

OECD initiated a work on developing a set of environmental indicators in 1989. It aimed to be used at international and national levels for a state of the environment reporting, measurement of environmental performance towards sustainable development of the OECD member countries. The indicators are designed to measure environmental progress and performance, monitor policy integration, and allow effective international comparisons. The PSR approach was used to develop a set of indicators focus mainly to be used in national, international and global decision making, however, the approach can be applied to develop indicators at sub-national or ecosystem level. There are at least 10 key indicators for pollution and natural resources and assets issues that have been proven to be useful in charting environmental progress. They includes CO2 emission intensities, Indices of apparent consumption of ozone depleting substances (ODS), SOx and NOx emission intensities, Municipal waste generation intensities, Waste water treatment connection

rates, Intensity of use of water resources Intensity of use of forest resources, Intensity of use of fish resources, Intensity of energy use, and Threatened species (OECD, 2003).

The European Environment Agency (EEA) has developed the core set of environmental indicators since 1999. It has been used as the key information provider on environmental issues at the European level. The Driving Force-Pressure-State-Impact-Response (DPSIR) framework has been used in developing the core set of indicators together with policy questions. Indicators that related to environmental issues air pollution including stratospheric ozone; climate change; nature protection and biodiversity; terrestrial environment; water; and waste and material flows (European Environmental Agency, 2003).

In 1972, the governments of Canada and the United States signed the binational Great Lakes Water Quality Agreement (GLWQA) expressed the commitment of Canada and the United States to restore and maintain the chemical, physical and biological integrity of the Great Lakes basin ecosystem. Since then, a suite of Great Lakes indicators was developed to support the State of the Lakes Ecosystem Conference and State of the Great Lakes reporting. In 2010, the Great Lakes indicator suite was reviewed using the Driving Force-Pressure- State-Impact-Response (DPSIR) framework to help select, organize and report on indicators. More than 47 indicators (out of 84) were kept and 30 new indicators were adopted. The ten top-level reporting categories of indicators are Economic & Social, Pollution &Nutrients, Invasive Species, Resource Use &Physical Stressors, Water Quality(chemical integrity), Aquatic dependent life (biological integrity), Landscapes & Natural Processes (physical integrity), Human, Fish & Wildlife, and Restoration & Protection, respectively (Environment Canada and U.S Environmental Protection Agency, 2011).

At the Sub-regional level, the Asian Development Bank, United Nations Environment Programme (UNEP) and Institute for Global Environmental Strategies (IGES) initiated the National Performance Assessment and Subregional Strategic Environment Framework for the Greater Mekong Sub-region countries. This assessment and framework intended to assist the GMS countries to continue to strengthen their EPAs by drawing sustainability indicators and making a stronger link between EPA and broader sectoral performance assessments within governments. The

selection of a core set of indicators in application of PSR model will help each country to link EPA, State of Environment (SOE) reports and National Sustainable Development Strategies (NSDS). The set of indicators was used at the national level but it could be extended both to local and sub-regional levels. The potential indicators of hydrological, irrigation, hydropower, navigation, fisheries, and tourism used in assess environmental performance in Safeguarding the Mekong's basins are identified (Asian Development Bank, 2006).

For the catchment level, Walmsley *et al.* (2001) conducted literature and internet search to identify organizations around the world that might involve in catchment management, or addressed the problem of information management at a catchment or watershed level. The study found that only 5 organizations had developed, or were in the process of developing, indicator sets that were available for review including the Fraser Basin Council (Canada), the Murray-Darling Basin Commission (Australia), the Tennessee Valley Authority (USA), the United States Environmental Protection Agency and the World Resources Institute. All of the reviewed indicator sets were developed using an issues-based approach and each indicator set was unique, reflecting the policy, both national and organizational, upon which it had been based. The 5 organizations are as follows:

- The Fraser River Basin in Canada developed and used sustainability indicators as an important tool to accomplish the sustainability goals. The Council was in the process of identifying a set of sustainability indicators with a draft set of 40 indicators using the Council's Charter for Sustainability as a framework. The indicators chosen were goal-based and comprised of 26 goals under the four directions specified by the Charter.

- The Murray-Darling Basin Commission (MDBC) developed a set of indicators in 1998, for assessing progress towards the Basin Sustainability Plan objectives. An initial set of 130 indicators was reduced to 30 and were tested to evaluate their efficacy. Of the 30, only 16 were recommended for use in the Basin and only 5 indicators were suitable for rapid implementation due to the general lack of compatible basin-wide data sets. The Commission was working towards

implementing a goal-oriented framework to find out which indicators would be further developed.

- The Tennessee Valley Authority (TVA) established a set of core performance indicators for each of the three main goals which are supplying low-cost, reliable power to the nearly eight million people living in the region; stimulating economic growth; and supporting a thriving river system as part of the Strategic Plan for 2000 to 2005. The indicators supporting the thriving river system goal was the basis for catchment management within the Tennessee River. Within this Strategic Plan, the TVA developed a set of indicators that deal with watershed condition. A Watershed Condition Index based on four physical elements: i.e. reservoir ecological health; stream ecological health; water quality assessments, and reservoir shoreline vegetation condition; was used to assess the overall water quality conditions as an outcome measure.

- The US Environmental Protection Agency established a set of 12 national environmental goals on safe drinking water and clean waters towards the national goals. A series of milestones for each goal had been developed with a 10-year target to be reached at 2005. Five objectives for meeting the goals were conserve and enhance public health; conserve and enhance ecosystems; support uses designated by the states and tribes in their water quality standards; conserve and improve ambient conditions, and prevent or reduce pollutant loadings and other stressors. In 1996, eighteen indicators had been chosen and had been used as a basis for the Index of Watershed Indicators. The Index intended to provide a complete descriptive technique for characterizing the condition and vulnerability of water resources at a catchment level; establishing a national baseline on the condition and vulnerability of aquatic resources, and making information readily available. The 15 indicators had been split into condition indicators or state indicators and vulnerability indicators or pressure indicators.

- The World Resources Institute (WRI) developed a set of 15 indicators that characterize catchments in terms of their ecological value, current condition and vulnerability to potential degradation from human activities. The indicators were to provide information about major watersheds on a global scale. The set of 15 indicators included 23 data sets that measure catchment characteristics and potential

human activities that affect rivers and lakes. The global data sets embraced variables such as land use, land cover, aridity, forest extent and loss, erosion, endemic bird species distributions, population density, and protected areas (Walmsley et al., 2001).

Watershed indicators can also be reviewed from the researches on the Integrated Water Resources Management approach worldwide. Although these studies are mainly focusing on water resources but many have shown the importance of ecological integrity of other resources of the river basin or watersheds. For instance, the study from Chaves and Alipas (2007) in Brazil, they developed the Watershed Sustainability Index (WSI) using the hydrologic, environment, life, and policy indicators using pressure-state-response model in a matrix scheme. All indicators were given a value and divided in scale scores to show the conditions of watershed. The research conducted by Kumambala et al. (2008), Juwana et al. (2009), and Catano et al. (2009) followed the previous work of Chaves and Alipaz's. From these studies, the researchers revealed the information gaps and problems concerning availability and quality of information for development of WSI and using of indicators. They concluded that integrated process of sustainability indicators could influence project development by helping to identify viable design alternatives that are environmentally and socially acceptable, and provided opportunities to meet varying demands within the basin (Kumambala *et al*., 2008; Juwana *et al*., 2009; and Catano *et al*.,2009).

In Thai context, Thailand's National Economic and Social Development Board (NESDB) initiated the operation for sustainable development and developed the indicators of the country's sustainable development in the year 2004. Then in 2005 the regional development indicators were established to reflect local problems and needs. As for the year 2006, the sustainable development indicators of 3 pilot watersheds from the total of 25 watershed areas were developed including Ping, Moon, and Chao Phraya watershed areas. It was found that indicators for sustainable development at the watershed levels was not complete and further development and improvement of sustainable indicators should be modified in many issues. These include lack of issues concerning development in transferring local culture and wisdom, community lifestyles, consumption pattern, community economy,

distribution and expansion of resources; and no systematic accumulation of data for specific database of indicators and responsible agencies, and lack of appropriate methods to be used at the watershed level (NESDB, 2006).

The Office of Natural Resources and Environmental Policy and Planning (ONEP) published a National Environmental Performance Assessment Report in 2011. This report shows the development of a set of indicators for monitoring and evaluation the environmental performance of the country. The DPSIR and PSR frameworks are used to prioritize the key issues and define the suitable indicators. The 8 priority environmental concerns (water resources, water pollution, climate change, deterioration of soil, forests and wildlife resources, coastal and marine resources, air pollution and waste) and 24 indicators were identified (ONEP, 2011).

Other indicators sets in Thailand can be found from organizations such as the National Statistical Office Datasets (statistics of all sectors, i.e. statistics on population, economic, social and environment), the well-being indicators developed by NESDB and the sustainable city indicators developed by Department for Environmental Quality Promotion (DEQP, 2007). Some Sets of Indicators used by organizations to monitor watershed health and to be reviewed can be found in Appendix A. These sets of indicators can be used as a starting point to provide communication and information sharing with relevant stakeholders, and also used to help in identifying environment indicators in this research.

2.4.4 Participatory process in indicator development

Participation is important not only because it helps to identify key environmental issues from the different stakeholders' perspectives, but also because it can offer options for addressing those issues. If participation is open and transparent, it is more likely that interests of different stakeholders, including interests of poor, vulnerable groups and women will be recognized and better reflected in the formulation of policy responses. Concepts of participation have widened to include not only the rural poor but also other sectors of civil society. The World Bank's Learning Group on Participatory Development defines participation as "a process through which

stakeholders influence and share control over development initiatives and the decisions and resources which affect them" (World Bank, 1996).

A participatory approach can be used when developing indicators. Involving experts and key stakeholders in identifying issues, interpreting data and developing indicators not only strengthens their relevance, credibility, and clarity, but also the possible of their actual use in decision making. A larger number of issues may come up during a stakeholder process such as identifying and selecting key issues, obtaining and analyzing data, developing indicators. A participatory approach can help in narrow down too much information and the list of indicators by ensuring that the ones selected are relevant, reliable and understandable. It also engages people in the process, which can lead to shared responsibility for the state of the environment and society, leading to greater possibility for change. When using a participatory approach, it is useful to consider who needs to be involved, and when and how to include them. Experts, stakeholders and policy-makers are general categories of critical actors in the process. As shown in figure 2, participatory processes occur across the spectrum of indicator development, from an initial identification of broadly-held values and issues that inform indicator selection, to more focused tasks of setting indicator targets and criteria for performance (UNEP, 2008). Communicating with stakeholders, and understanding how they value things is important, therefore developing an effective participatory approach requires careful planning so that the people who need to be involved are involved in an appropriate way.

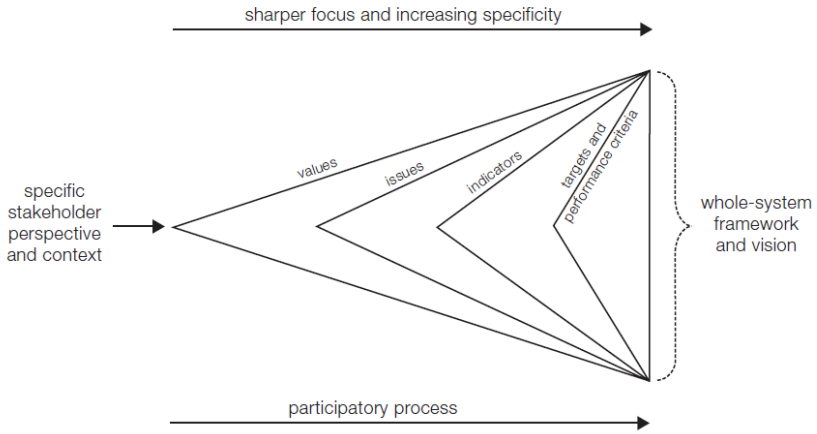

Figure 2. 2 Participatory processes across the spectrum of indicator development (Source: Pintér, Zahedi and Cressman, 2000 cited in UNEP, 2008b)

To improve the process of indicator development that involves stakeholders, Burger (2009) suggested the followings:

1. Involve stakeholders early and often in the selection of indicators.

2. Make a special attempt to identify all the relevant stakeholders before framing the indicator selection problem.

3. Gather stakeholder input concerning the ways they believe they can contribute most to the development of indicators.

4. Involve stakeholders in not only the problem formulation phase, but also in the final selection

5. Consider the possibility that stakeholders may continue to contribute to monitoring activities (Burger, 2009)

2.4.5 Identification of Stakeholders

As previously mentioned that stakeholders are those responsible for making or implementing a management action, who will be affected by the action, or who can aid or prevent its implementation. There are three key principles to enhance stakeholders' participation and their contributions recommended by the UNEP (2008a) which allows better formulating and implementing policies and strategies. They are

1. *Inclusivity* means that a full range of stakeholders representing different groups of interest should be included, including marginal and vulnerable groups.

2. *Pertinence* means stakeholders whose interests are significantly affected by the issues should be included, and

3. *Gender perspective* refers to the meaning that women and men must have equal access to all stages of the participatory process, and it is important to respond to the demands from women and men.

Stakeholder analysis is suggested to be very helpful in order to assure that the different stakeholders are represented. It includes 3 elements which are key issues or problems that will be discussed throughout the process, stakeholder long list, and

stakeholder map, respectively. Figure 2.3 shows the identification of stakeholders, their roles and interests.

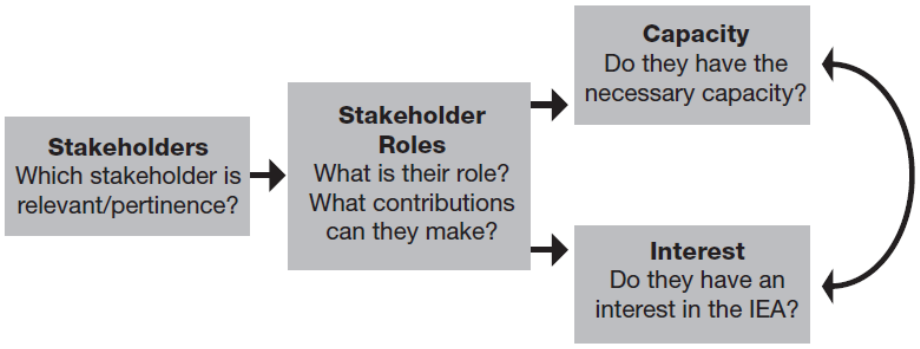

Figure 2. 3 The identification of stakeholders, their roles and interests
(Source: UN habitat, 2002 cited in UNEP, 2008a)

Once stakeholders are classified and selected, it is recommended to verify if any major stakeholder groups are missing based on additional information. In order to keep stakeholders actively engaged in the process, it is important to offer incentives that respond to their interests, such as: listening and taking into account their points of view; keeping them informed of the activities and results of the process; and developing different activities to keep close relationships with the stakeholders (UNEP, 2008a).

2.4.6 Flow of indicator development

Referring to the Integrated Environmental Assessment Training Manual Module 4 (UNEP, 2008b), indicator development in many cases begins with a conceptual framework, followed by the selection of indicators based on criteria of suitability. Indicator development is often a repeated process, where a large number of environmental or sustainable development issues are narrowed down in successive rounds of dialogue with stakeholders and experts to a few high-level measures. An example of the process used for indicator development in South Africa can be seen in Figure 2.4.

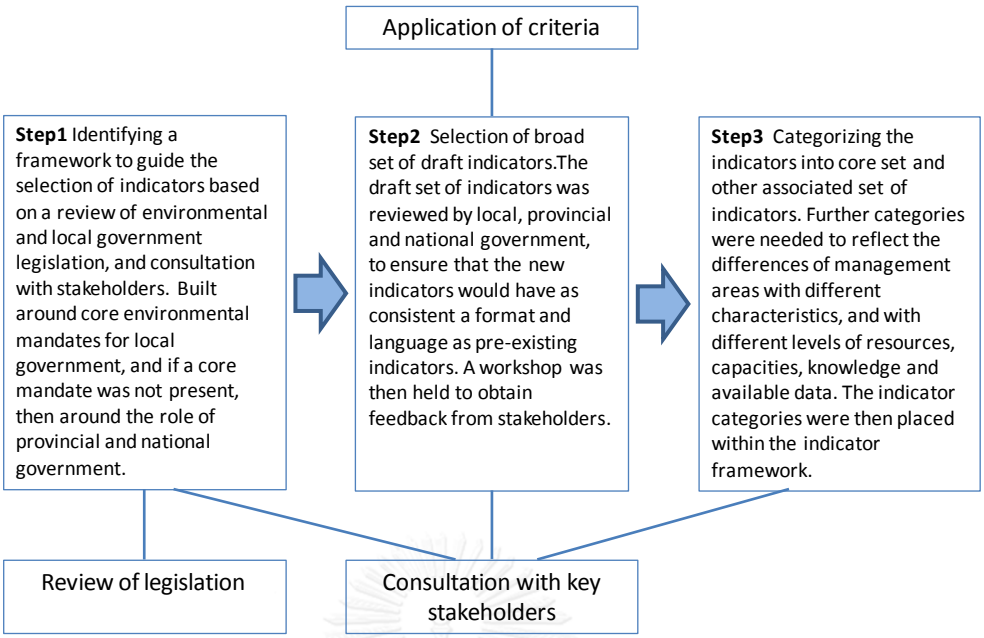

Figure 2. 4 Example of an indicator development process from South Africa (Source: Palmer Development Group 2004 cited in UNEP, 2008b)

From the above example, the participatory processes used are consultation with stakeholders and key stakeholders and a workshop in the identifying a framework, selecting the draft set of indicators, and categorize the core set of indicators and also obtaining feedback from stakeholders.

2.4.7 Tool to help assessment of Criteria and Indicators

Multi-Criteria Analysis (MCA) is a decision-making tool developed for complex problems that include qualitative and/or quantitative aspects of the problem in the decision-making process. To reach a general consensus in a multidisciplinary stakes can be very difficult to achieve. By using MCA the members don't have to agree on the relative importance of the Criteria or the rankings of the alternatives. Each member enters her or his own judgments, and makes a distinct, identifiable contribution to a jointly reached conclusion. The MCA can be applied to criteria and indicators selection process both from a 'top-down' perspective as well as in a more 'bottom-up' context. In applying the MCA method in this research, it will be used in the process of ranking and rating of indicators outline in the Mendoza *et. al*. (1999)

and also from other relevant MCA reports. The simple techniques to identify and select relevant Criteria and indicator are Ranking and Rating. Ranking involves assigning each decision element a rank that reflects its perceived degree of importance relative to the decision being made.

CHAPTER III
RESEARCH METHODOLOGY

3.1 Methodological Framework

The objective of this research is to develop a set of watershed indicators specifically the environmental aspect with the involvement of stakeholders at a watershed level and also proposes reasonable recommendations which reflect stakeholders' concerns regarding to the application of the indicators. The proposed conceptual framework is shown in Figure 3.1.

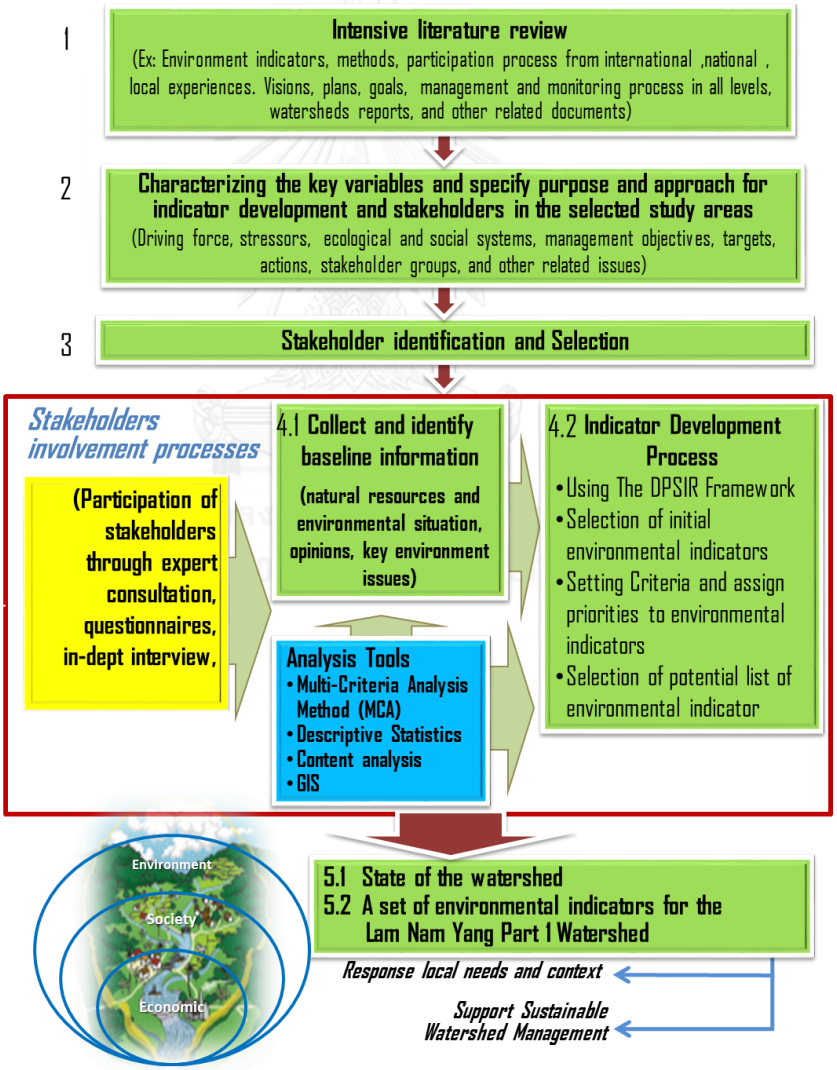

Figure 3. 1 Conceptual Framework of environmental indicators development of the Lam Nam Yang Part1 Watershed

3.2 Research Method and Data Collection

The research was carried out using both quantitative and qualitative research methods for the indicators development with the help of stakeholders. Research methods were completed by using several data collection techniques which can be summarized as follows.

3.2.1 Desk Review

Desk Review or intensive literature review was carried out to gather related information, concepts of watershed sustainability, environmental indicators, methods and approaches used in developing indicators, participation of stakeholders, existing indicator, experiences from local, national and international related to the research. In addition, data of visions, plans, goals, management and monitoring process of the watershed helped in specifying scope of the indicator development direction.

3.2.2 Observation

This study conducted direct and indirect observation to find the real condition to perceive the actual situation of overall areas and to verify the data accuracy obtained from the desk review. These two types of observations included field surveys, informal taking session with people and organization representatives and regional meeting participation observation. The obtained data was essential to the study and could be analyzed with the other methods. The data from observation, for examples, the features of land use on the basins, seasonal resources and environment problems, lifestyles and behavior of people living in the watershed, contribution and remark of people in the basin, land use management and relevant data were note-taken and video recorded in each observation.

3.2.3 Questionnaire Survey

1) Questionnaire Design

In this questionnaire design, it was designed questioning the opinions of people about the condition of natural resources in the Lam Nam Yang Part1 Watershed, and participation of local people. The scope of the questionnaire is

developed from previous research, documents, and informal interviewed with stakeholders, to cover the desired contents and the purposes of the study. Afterwards, the questionnaires would be discussed with 2 dissertation advisors to improve the content for better clarification including the content consequence and appropriate language that the responders could have better understanding. The questionnaires conducted had both close ended questions, which was the multiple-choice questions, and open ended questions that the responders had chances to opinionate alternatively. The questionnaire consisted of 5 parts which are

Part 1: Basic information of the responders

Part 2: The economic and social status of the responders

Part 3: Responder's health and environmental hygiene

Part 4: Comments on natural resources and environment in the watershed, and

Part 5: Comments on the natural resource and the environment management for the watershed sustainability.

2) Pretest

The questionnaires were distributed to 31 samples living outside the study area, to check and test its reliability and duration spending while taking the questionnaire in order to process in the actual situation. From the pretest conducted, the samples spent 35-40 minutes in completing the questionnaires, then the questionnaires would be analyzed by the Reliability Analysis method using statistical program. The questionnaire was tested for its reliability reflecting in the Alpha Coefficient. Then, the result of analysis of 31 questionnaires were adjusted to make it appropriate to apply in the field with the Cronbach's Alpha equivalent to approximately 0.9.

3) Samples and Sampling Methods

Multistage sampling method including clustering was used to determine the group of samples in the study. The selected households in the Lam Nam Yang Part1 Watershed were acquired by random sampling from households' data from administrative districts and municipalities and also contact with the main leader of each community. The selected sample households were chosen to be the representative of the whole watershed. The sample size of this study used the table of Krejecie & Morgan (Krejecie and Morgan, 1970) at confidential level of 95% (Table

3.1). According to the Department of Provincial Administration (2013), there were 57,700 households living in the Lam Nam Yang Watershed Part1. Therefore, the sample households having to interview, ranging from 381 to 382, in which 385 interview samples were collected in this study.

Table 3. 1 Table to Determining Sample Size by Krejcie and Morgan (1970).

Population Size	Sample Size	Population Size	Sample Size	Population Size	Sample Size
85	70	440	205	4000	351
90	73	460	210	4500	354
95	76	480	214	5000	357
100	80	500	217	6000	361
110	86	550	226	7000	364
120	92	600	234	8000	367
130	97	650	242	9000	368
140	103	700	248	10000	370
150	108	750	254	15000	375
160	113	800	260	20000	377
170	118	850	265	30000	379
180	123	900	269	40000	380
190	127	950	274	50000	381
200	132	1000	278	75000	382
210	136	1100	285	100000	384

The researcher and 3 research assistants that could communicate in local language conducted the interview. Before distributing the questionnaires to the interviewees, the interviewer explained to the interviewees about the purposes of the survey and the required information in details. The data collection from the direct interviews and the period of the data collection was from June to September 2014. The questionnaires were distributed directed to 385 respondents across the watershed as shown in Figure 3.2. The data collection from the questionnaire was organized for further data analysis.

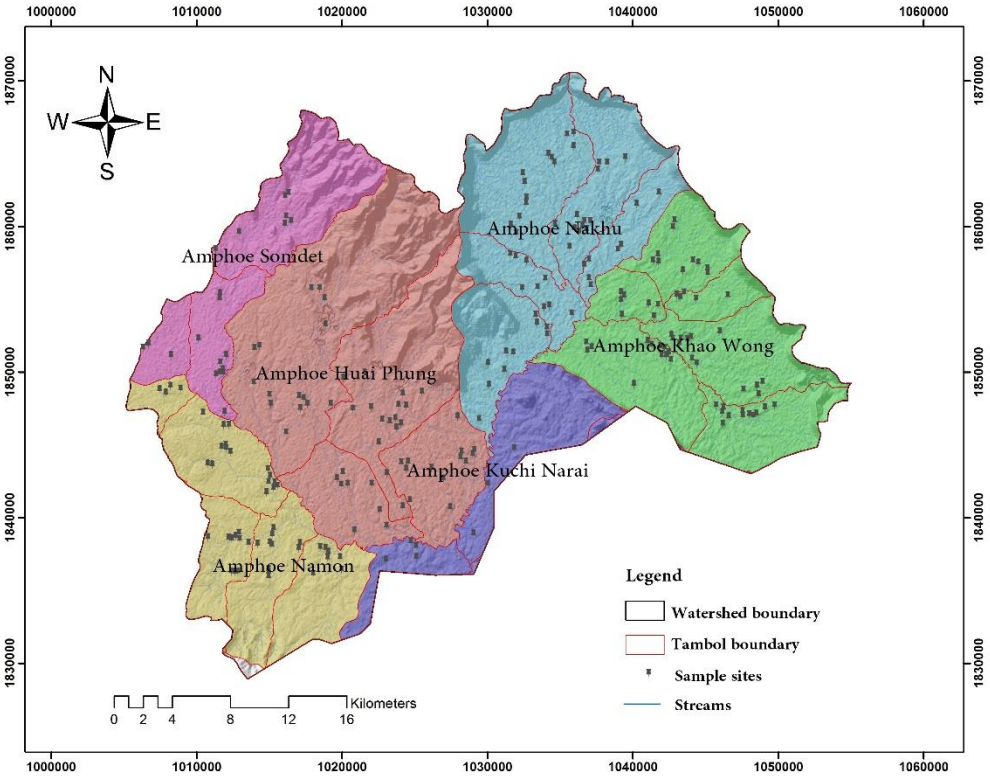

Figure 3. 2 Sample sites for questionnaire survey

3.2.4 Key informant interview

The purpose of key informant interviews is to gain overview background, status of environmental situation, and roles and responsibilities of related agencies relevant to watershed management. The purposive and snowball sampling methods were applied where key informants are identified and selected based on the criteria that they have particular experience engaging with the watershed management activities. Key informants in this study include 25 people from government agencies, local organizations, private sectors, and individuals.

Key informant interview was carried out using semi-structure interview which being open-ended question. The key informant interview was done to collect information of the basic data of the responders, perceptions on natural resources condition in the watershed, roles and responsibilities in watershed management, their understanding of the watershed management, opinions on the condition of natural

resources and environment in the watershed, key environmental issues and causes of the problems, trends in environment condition, and participation natural resource and the environment management. The data obtained from the key informant interview was then verified and validated. List of guiding interview question are presented in appendix C.

3.2.5 Expert Consultation

The purpose of expert consultation was to collect opinions and suggestions for the indication development process to be applied in this study, and to select the set of indicators. The researcher selected the experts using purposive sampling technique, by their experiences in the indicator development process. The number of the expert interviewees was 9, including 2 from academic institutions, and 7 from various organizations. List of guiding interviewed is shown in appendix 4 consisted of

1) Problems of obstacles of the previous indicator management and monitoring

2) The principles and framework of the development of environmental indicators in the basin and the relevant organizational participation.

3) Possibility and the appropriateness of the potential indicators that are currently available (both from international and domestic organizations) to be used for indicator development in this research.

4)Opinion on criteria and guidelines for the selection of environmental indicators, the priority and weighing of indicators.

5) Target of the indicator

6) Recommendation in applying indicators in the watershed in this study.

7) Select the set of environmental indicators for the Lam Nam Yang Part1 watershed.

The DPSIR framework will be used as an outline for experts to help in developing indicators. The DPSIR organizes indicators into five categories: Driving force, Pressure, State, Impact and Response indicators, where Driving force (D) refers to human activities and natural factors that may have an environmental effect on watershed; Pressure (P) is the direct effect of the driving force; State (S) is the condition of the watershed resulting from both natural and human factors; Impact (I)

means the environmental effect of a human or ecological pressure; and Response (R) refers to human response (e.g. habitat restoration, pollution reduction) usually to a pressure or state categories as shown in Figure 3.3.

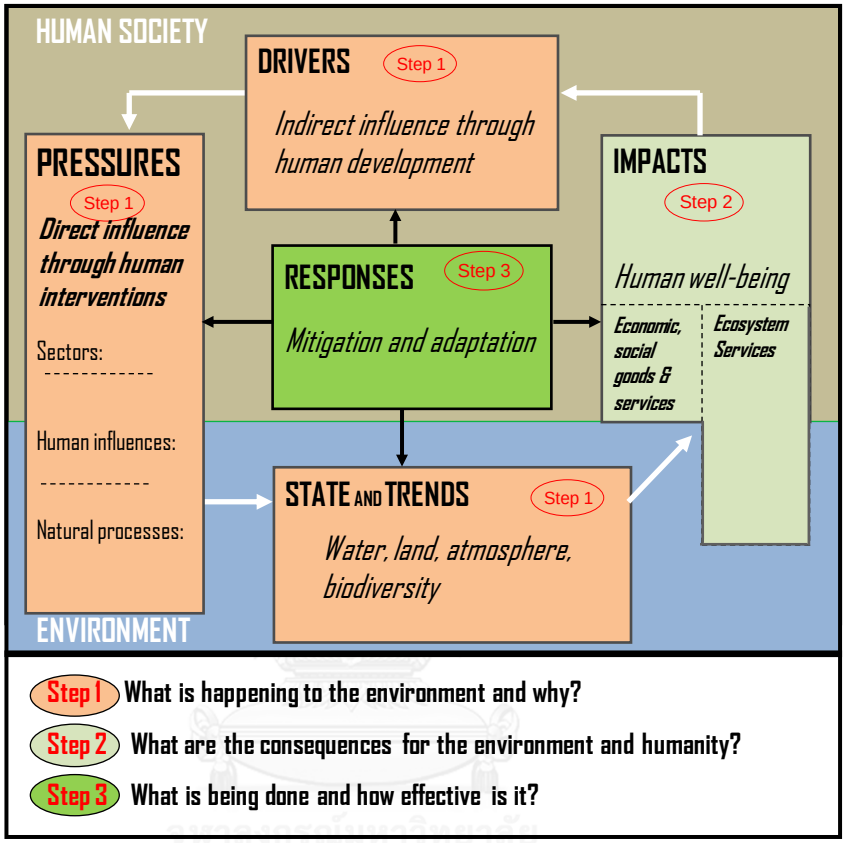

Figure 3. 3 The DPSIR Framework for developing environmental indicators (Source: UNEP, 2012)

3.2.6 Local experts consultation

Local experts were engaged in the indicator development process to help selecting and weighing of potential indicators using the in-depth interview method. Stakeholders and local experts were selected by purposive sampling technique as it was to focus on the representatives who was involved and experienced in managing or applying the indicators. The name of the representative was suggested by relevant agencies. The number of the representatives chosen was 12, consisting of 7 government agencies, 3 local organizations, and 2 individuals from Yang sub-basin committee. The key local experts were interviewed for 2 rounds:

Round 1: each local experts was asked to choose the indicators in the list of indicators which the expert selected, with the criteria that researcher provided to gain the potential indicators

Round 2: each local experts was asked to weigh the potential indicator in the order of significance using the Multi Criteria Analysis (MCA) in rating method to determine the weight and the priority of indicators, and asked for other comments related to the implementation of the indicators.

3.3 Data Analysis

After the data collection from each procedure from the study, the data were analyzed with the methods and statistics as shown below.

3.3.1 Desk review and observation

The data from desk review and observation were organized, analyzed, synthesized and concluded descriptively, and again the data would be taken to analysis with the data from different methods.

3.3.2 Questionnaire survey

All the data from the questionnaires would be checked for the completeness, and prepared for the statistical analysis. The basic information of the responders like gender, age, job, educational background, income, land ownership, attitudes toward natural resource and environmental condition in the watershed, natural resource management and the watershed sustainability were analyzed. The results from this process was used for the preparation of baseline information of the study area in accordance with the objective of the study and used as the data for DPSIR of the key environmental issues, and the indicator development process.

3.3.3 Key informant interview

The data from the key informant interview were classified, analyzed, synthesized, and interpreted to gain information on natural resource and environmental situation and other related information of the Lam Nam Yang Part1 Watershed.

3.3.4 Expert consultation

The data from expert consultation process were classified, analyzed, synthesized, and interpreted and used in the local experts consultation.

3.3.5 Local experts consultation

The data from the stakeholder's consultation from 2 rounds were analyzed and used to help in indicators selection and setting priority.

3.4 Overall process of the study

The overall process used in this research is shown in figure 3.4.

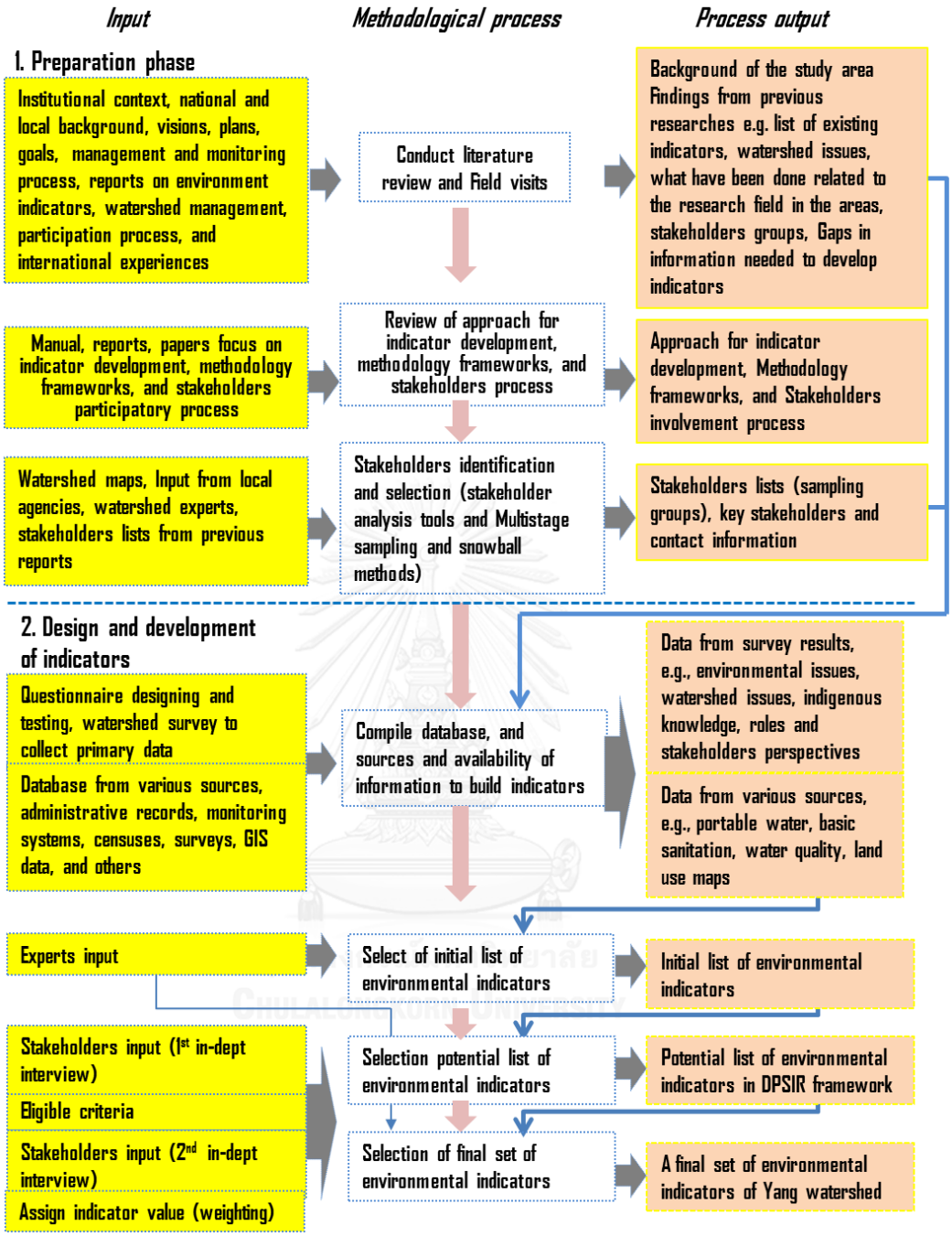

Figure 3. 4 Process of environment indicator of the Lam Nam Yang Part 1 watershed

CHAPTER IV
RESULTS AND DISCUSSION

4.1 State of the Lam Nam Yang Part1 watershed

The state of the Lam Nam Yang Part 1 on natural resources and environment and the management aspect was analyzed from the literature review, results from survey, and results from key informants' interview. The state of the Lam Nam Yang Part1 watershed can be summarized as follows.

4.1.1 Setting of the area

The Lam Nam Yang Part1 is a watershed located in the Yang Sub-basin that belongs to Chi River Basin in the North-East of Thailand. It encompasses the areas of 6 districts: Nakhu, Kuchi Narai, Namon, Somdet, Huay Phung, and Khao Wong of Kalasin province (Coordination and Management of Lower Chi River Basin Division, 2010). The total area is approximately 1,079 km^2 (674,375 rai), where the watershed area is mainly used for annual crop production and agricultural activities. The main river is the Yang River which originates from Kalasin province and carries approximately 1,336.1 km3 of surface runoff per annum through lower parts of the Sub-basin in Roi-Et Province. The Lam Nam Yang Part 1 watershed occupies 26% of the Yang Sub-basins. The setting of the watershed is shown in figure 4.1.

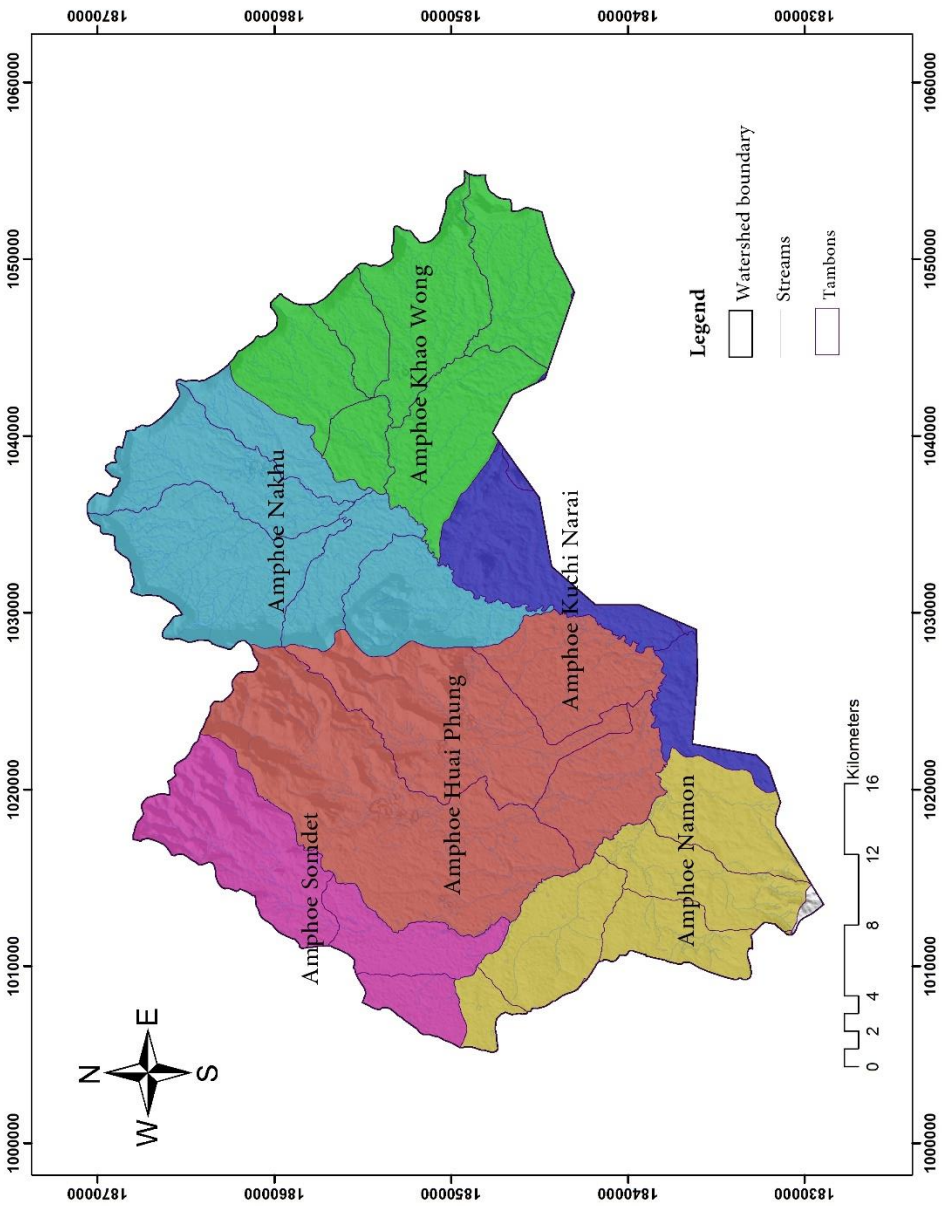

Figure 4. 1 Political boundary of the Lam Nam Yang Part1 Watershed

4.1.2 Topography

The topography of the watershed consists of high mountain area of Phu Phan mountain ranges, the areas of the northern and eastern sides heighted approximately 500 m MSL, and flattens to undulating hills with the average height 200 m MSL. The lowland of the watershed is the agricultural land for rice cultivation whereas the higher region can be found with agricultural crops like cassavas and sugar canes.

4.1.3 Climate

The general climate of the Lam Nam Yang Watershed Part1 is hot during summer and cold in winter under the influence of the northeast and the southwest monsoons. To additional, the depression storm blowing from the South China Sea causes heavy rain during rainy season. The effect of those two monsoons causing 3 seasons: summer, winter and rainy season. The watershed has yearly average rainfall approximately 1,384.6 mm. The highest rainfall of 295 mm. normally occurs in August. The average temperature is 26.7℃. The highest monthly average temperature is 35.4℃ in April while the lowest one is 16.9 ℃ in December. The annual relative humidity average is equivalent to 71 percent. The highest monthly average of relative humidity is 94 percent in September, and the lowest monthly average of relative humidity occurs in March with 39 percent (Coordination and Management of Lower Chi River Basin Division, 2010).

4.1.4 Geology

The Lam Nam Yang Part1 Watershed is located in the Khorat Plateau consisting of sedimentary rock of Khorat Group, which contains siltstone, sandstone, mudstone and conglomerate. The formation of rocks are classified as Phu Kradung Formation, Phra Wihan Formation, Sao Khua Formation, Phu Phan Formation and Khok Kruat The geology map of Lam Nam Yanh Part1 is shown in Figure 4.2 (LDD, 2010).

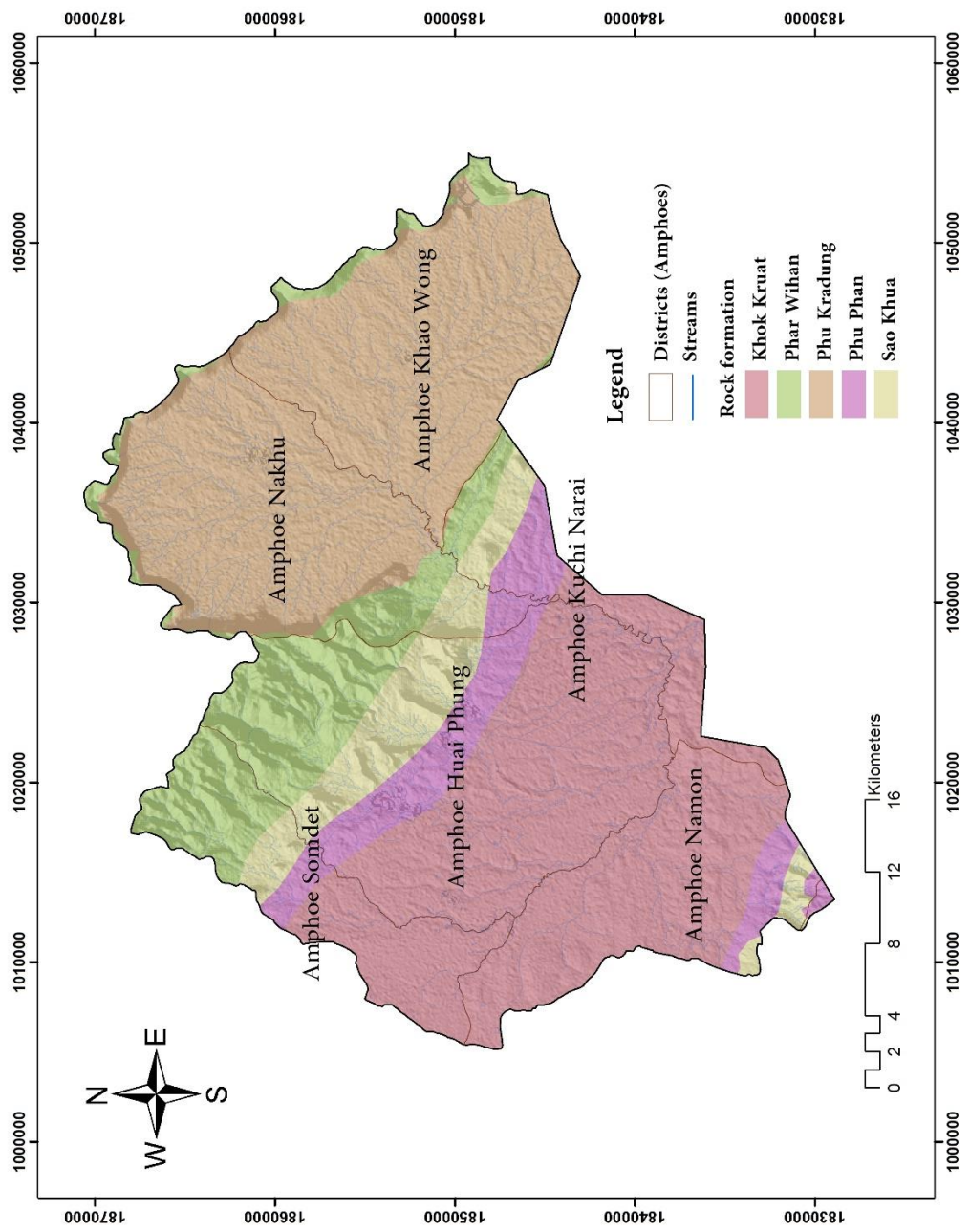

Figure 4. 2 Geology map of the Lam Nam Yang Part1 Watershed

4.1.5 Watershed Classification

The Lam Nam Yang Watershed Part1 can be classified into 5 watershed classes (watershed class 1 to watershed class 5) according to the cabinet resolution on watershed classification of the Chi River Basin in 1988. Among these five classes, watershed class 1 and 2 are important parts of the watershed area and are head water of the river system. These areas are usually at high elevations and have very steep slopes and should be remain in permanent forest cover. The boundary of watershed class 1 has an area of 55.27 Km^2 or 5.12 percent of the total watershed area, watershed class 2 of 94.69 Km^2 or 8.77 percent, watershed class 3 of 41.21 Km^2 or 3.82 percent, watershed class 4 of 212.40 Km^2 or 19.68 percent, and watershed class 5 of 675.38 Km^2 or 62.59 percent, respectively (ONEP, 1988). The watershed classification of the Lam Nam Yang Part1 is shown in the figure 4.3 (ONEP, 2013).

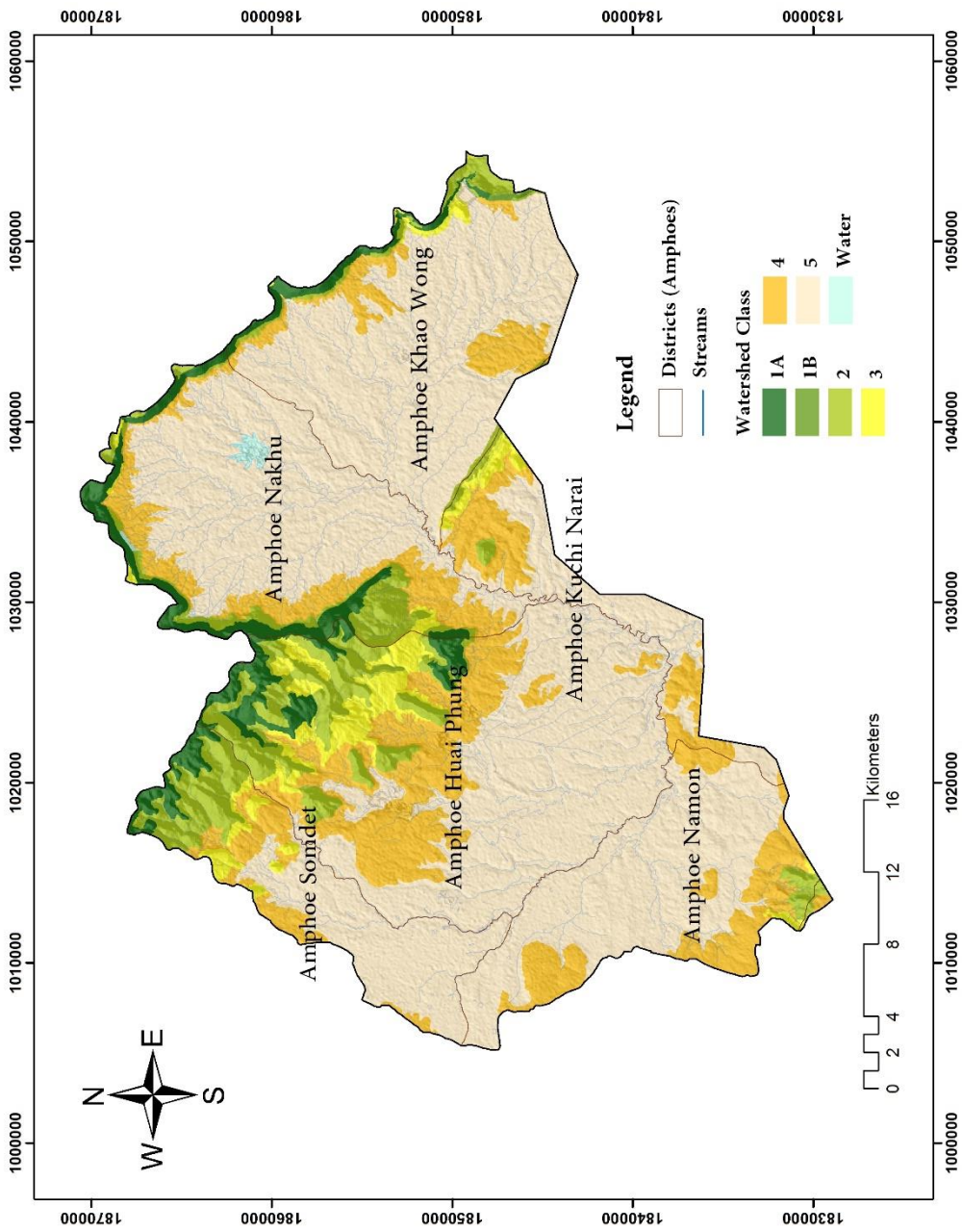

Figure 4. 3 Watershed classification of the Lam Nam Yang Part1 watershed

4.1.6 Social and Economic

1) Population

The Lam Nam Yang Watershed Part1 has approximately 59,680 households and 202,170 people or equivalent to the average of 3.38 people per 1 household. The average population is about 187 individuals per km2 (Department of Provincial Administration, 2556).

2) Labors and Flow of Labors

The sample people (86.7 percent) interviewed with were in the working age, born and have lived in the Lam Nam Yang Part1 watershed for more than 40 years. However, some people immigrated from other regions, districts, and provinces due to moving in with either husband or wife after marriage, study and public service work. People move out to work in different areas seasonally after the harvesting season. The main reason of migration and flow of labors in the Lam Nam Yang Part1 watershed is to find works and to gain more income during dry season. Local people said they wanted to fine more money to prepare for the next crops.

3) Occupation and Income

About 87.8 percent of the sample people work as farmers, 4.4 percent as a labor, and 7.8 work in other occupations. Most of the total income of the household with the main occupation is approximately 71,600 Baht, and from secondary income about 30,400 Baht. About 55.3 percent of the household have sufficient income for the spending but no saving, and 13.8 percent have sufficient income with remaining saving, whereas 30.9% have insufficient income for spending.

4) Land Tenure

The average land holding from survey data is 12.18 rai per household. About 84.9 percent has ownership in the land in terms of title deeds, 10.06 percent has certificate utilization (NS.3K) and 3.4 percent has no permission, and 1.64 percent has other land holding forms.

5) Agricultural Activities

The agriculture in The Lam Nam Yang Part1 Watershed has 2 major zones which are non-irrigated (rain fed) and irrigated zone. Sticky rice is the main crops for

consumption and jasmine rice is planted for trade, it is because of the internal and external markets' demand and its saline soil resistance. Cassava is the second most planted after rice though its selling price is unstable, but it is easy to maintain and fast to harvest. Other major crops are sugarcane, soybeans, peanuts and green beans, and some vegetable crops. The fruit trees as mango, papaya, sweet tamarind, banana and others are also cultivated in this area. Animal husbandry like cows and buffaloes, pigs, ducks and hens as well as rice-fish culture are consider as the supplementary agricultural production (LDD, 2010).

6) Public gathering

The sample people from the survey are the economic organization members estimated 77.7 percent which are village funding group, saving division and various professional groups. About 61.8 percent is the members of the social group such as funeral assistance association, elderly care group, leading volunteer group and others.

7) Important Industries

The Lam Nam Yang Watershed Part1 is mostly agricultural land, therefore, the industries and manufactories are agriculture-related and produce progressed cultivated products like sugar factories, flour and rice mills and other agricultural products.

4.1.7 People Health

1) Illnesses

Many of the sample people (55.8 percent) have ill family members. The most illnesses found are respiratory diseases (25.5 percent), gastrointestinal diseases (22.3 percent), muscular diseases (18.2 percent), dermatitis (5.7 percent), blood diseases (4.4 percent), and disease of eyes, ear and teeth (3.4 percent) and others (20.5 percent) respectively. The causes of the illnesses are from the environment (weather, dust and smoke) 35.8 percent and working condition 30.1 percent. About 75.8 percent of the people go to the hospital for medical treatment when they are sick while others go to public health communities (17.4 percent) and 3.4 of them purchase the medicine themselves, whereas 1.3 percent of them do not do anything to receive the treatment.

2) Water Drainage

The majority of the sample people (61.8 percent) have direct drainage in the household by discharging wastewater on the ground and 34.5 percent discharge wastewater to the public water sewer, while 2.6 percent discharge wastewater to the natural water sources.

3) Disposal of household waste

Many of the sample people (59 percent) dispose waste in the garbage bags waiting for collecting from the municipalities, while 35.1 percent burn the waste, 3.6 percent dump waste in land area, and 1.8 percent do other method of disposal.

4.2 Natural resources and environmental situation in the Watershed.

4.2.1 Forest Resources

4.2.1.1 Types of forest

The forest in The Lam Nam Yang Watershed Part1 are classified into 4 types that are semi evergreen forests, dry dipterocarp forests, mixed deciduous forests and grassland forests. The important plants are such as *Shorea obtuse* (Jig), *Shorea siamensis* (Hung), *Dipterocarpus tuberculatus* (Goong), *Dipterocarpus obtusifolius* (Chart), *Dipterocarpus intricatus* (Sabaeng), rubber woods and any other woods. For the plants on ground cover, there are such as *Vietnamosasa pusilla*, *Imperata cylindrica*, *Vietnamosasa ciliate*, *Saccharum spontaneum*, *Phragmites karka* and so on.

From the key informant interviews, local people classify the forest into 6 types: 1) Phu Forest (forest located in the highland and mountainous areas)

2) Dong Forest (evergreen forests and mixed deciduous forests, the forests with dense large trees denser than other types of forests),

3) Coak Forest (dry dipterocarp forest located in the center with its features of wavy shapes and land made up of sand and gravel)

4) Lao Forest (new forest after the land invasion),

5) Ya Forest (forests having dense cogon grass, kans grass and tall reed after Dong forest destruction) and,

6) Boong Tam Forest (riverside forests that are flood-prone areas)

4.2.1.2 Legal forest

1) National Reserved Forest

In The Lam Nam Yang Part1 Watershed, there are 6 national reserved forests under the National Forest Act 1964 that are Gaeng Ka Am Forest, Dong Pu Si Tan Forest, Dong Mae Ped Forest, Huay Pha Forest and Phu Lo Forest. The national reserved forests in the basin covers the areas of 396.06 km^2 or 247,535 rai (36.7 percent of the basin areas), and are divided into 3 areas namely forest conservation areas (zone C), economic forest areas (zone E) and agricultural forest (zone A).

2) National Parks

The upper areas of The Lam Nam Yang Part1 Watershed, there is Phu Phan National Park. The park is covered by dipterocarp forest, mixed deciduous forest and evergreen forest. The floras found are *Shorea obtuse, Shorea siamensis, Dipterocarpus obtusifolius, Dipterocarpus tuberculatus, Vitex pinnata, Haldina cordifolia, Xylia xylocarpa, Dillenia ovata* Wall, *Ochna integerrima, Careya sphaerica, Terminalia Triptera, Pterocarpus macrocarpus ,Writhtia tomentosa and Anisoptera costata,* etc. The faunas found are wild elephants, Sambar deer, boars, phayre's langur, Malayan sun bear, lesser bamboo rat, smooth-coated otter, yellow bittern, crested serpent-eagle, Indian roller, streak-eared bulbul, red chameleon, butterfly lizard, skink, and golden tree snake etc (DNP, 2015). The Phu Phan National Park occupies around 64.57 km^2 or 40,356.54 rai, estimated5.98% of the Lam Nam Yang Part1 watershed area.

3) Wildlife Sanctuary

In The Lam Nam Yang Part1 Watershed, there is Phu Si Than Wildlife Sanctuary that is covered by dry dipterocarp forests, mixed deciduous forests, dry evergreens and grassland forest. The floras found are *Shorea obtuse, Shorea siamensis, Dipterocarpus obtusifolius, Dipterocarpus tuberculatus, Pterocarpus macrocarpus, Afzelia xylocarpa, Anisoptera costata, Hopea odorota, Memecylon floribunda,* and so on. The faunas found are jackals, Pangolin, Asian palm civet, flying squirrels, shikras, green-billed malkohas, Bengal monitor, flying lizard, sandstone gecko, red-billed blue magpies, etc. The Phu Si Than Wildlife Sanctuary occupies 6.44 km^2 or 4,026 rai , estimated 0.59 % of the Lam Nam Yang Part1 watershed area (DNP, 2016)

The legal forests in the Lam Nam Yang Part1 watershed is shown in figure 4.4.

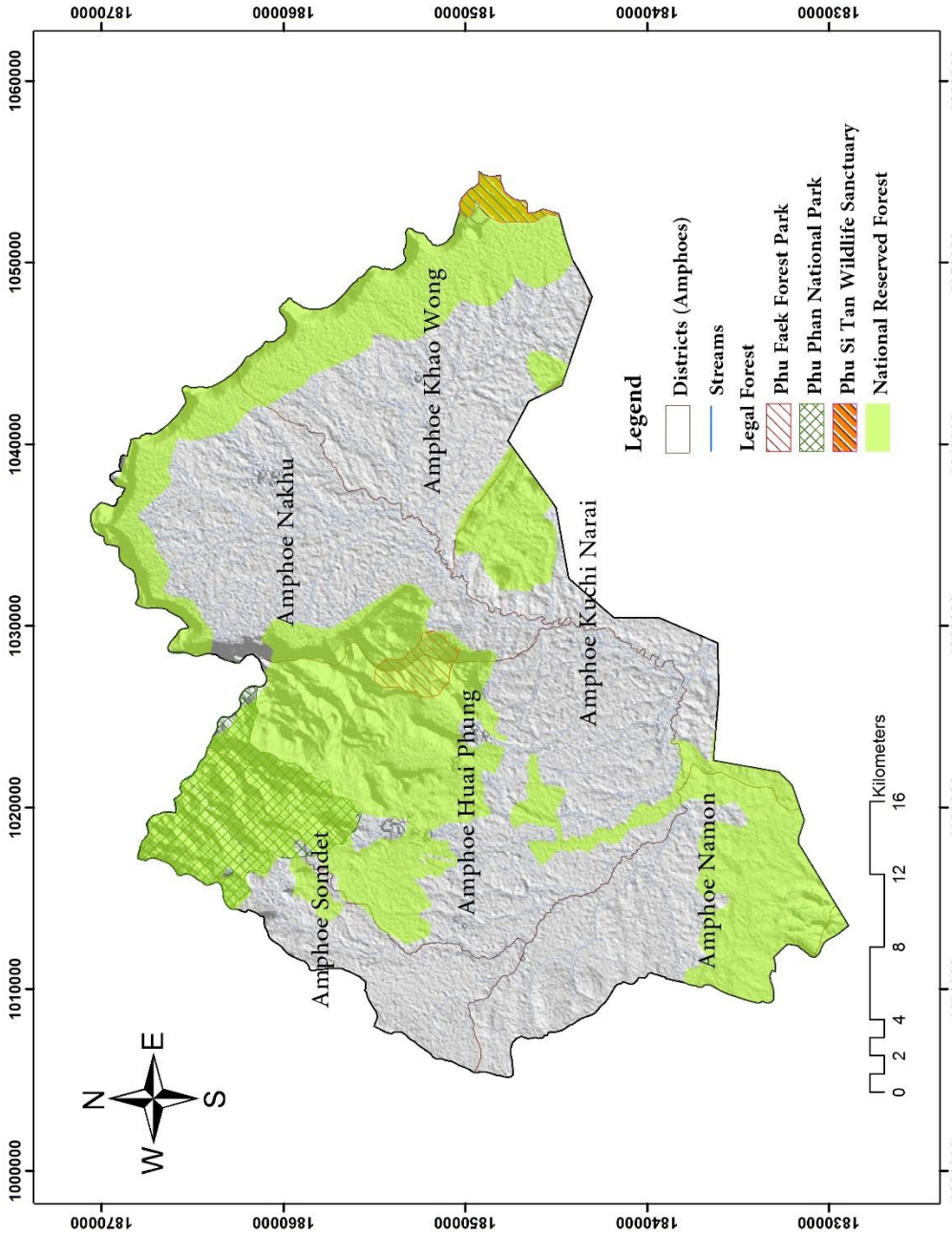

Figure 4. 4 Legal forests in the Lam Nam Yang Part1 watershed

4.2.1.3 Current situations of forest resources

Forest in the Lam Nam Yang Part1 watershed are threatened and destroyed by the human activities and natural disaster. The current forest area is about 226.70 km^2,

estimated 21% of the watershed area. The forest area remained is only 57.24 % of the area declared as the National reserved forest (LDD, 2010). It could be found that the areas were changed from forest to agriculture like paddy field, corn, cassava, sugarcane, papaya, rubber and others as shown in figure 4.5.

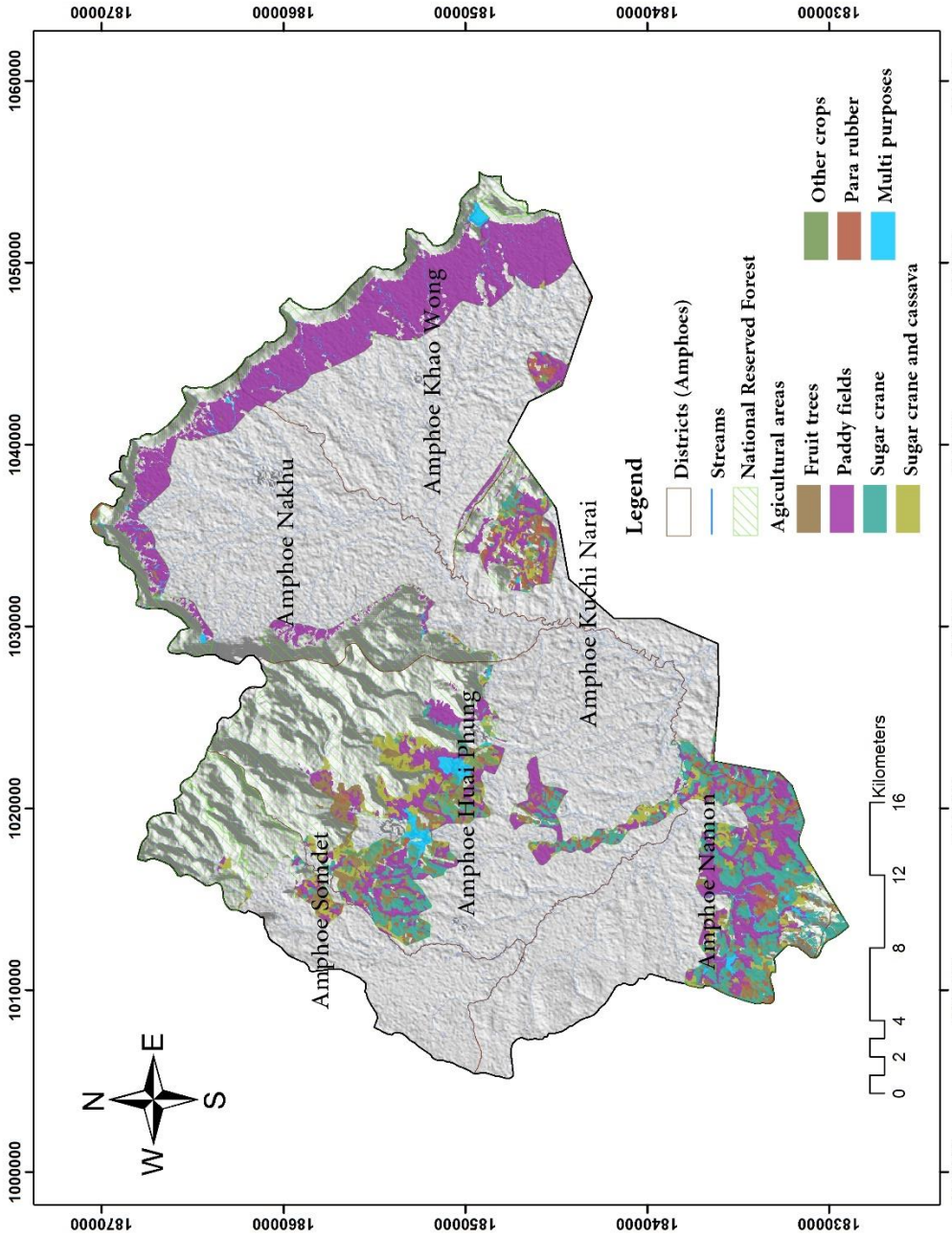

Figure 4. 5 Agricultural area in the Nation reserved forests in the Lam Nam Yang Part1 watershed

Key Informants provided the information that in the past, the area of the forest of the Lam Nam Yang Watershed Part1 was quite fertile. The village located near the forest areas get the benefits from the forest like wild product collection for food and

medicine and cohabitants. Also, it is used for the animal husbandry like cows and buffaloes. Wild products like bamboo shoots, mushrooms, melienthas, rattans and ant eggs would be sold to middlemen who also would sell the products in the market. The changes of the lifestyle affected the forest usages “In Khao Wong district, most of the people are PhuThai who are very mentally attached to the benefit of forest usages. However, everything has changed from asking the admission of forest ghost when entering the forest for wild product collection and no entering the forest during night to all-day forest entering without asking admission from forest ghost. It is changed because of the economic difficulties. Also, the way of tree cutting has been changed because trees are cut in various forms according to the demand of user and entrepreneurs.”

For the forest situations in the Lam Nam Yang Part1Watershed, it is found to be in crisis due to the government approach promoting cash crop cultivation and monoculture like hemp, cassava and sugarcane to villagers 10 years ago. As a result, the vast and abundant land where a lot of animals herding and people could make a benefit of its had got the problem of forest trespass causing soil degradation after cash crop cultivation and monoculture promotion (LDD, 2010). Key Stakeholders also stated that the reasons of deforestation in Dong Mae Ped reserved forest were caused by illegal deforestation and burning of forests despite the effort of reforestation that did not equate to the problems. Presently, the forest trespass is done by not villagers but entrepreneurs for agricultural benefits such as cassava, sugarcane and rubber cultivation. To additional, there is also the tree cutting at the areas of paddy field where there is variety of plants and trees such as Yang trees cut for the house construction and trade. These huge trees are the heritages from grandparent generation, and some of the tress are about 100 years old. Some of forest trespass is for the specified monastery in Khao Wong district. The problems of illegal economic wood theft like Siamese rosewood that is very expensive is the motive of increasing illegal logging in the Lam Nam Yang Part1 Watershed and neighboring areas.

Wildfire is one of the most important problems in the Lam Nam Yang Part1 Watershed. Consequently, wildfire takes place every year in the Phu Phan National Park and other places where forest areas are dipterocarp forests, mixed deciduous forests and dry evergreens. The main reasons of burning of the forest is because

people near the Phu Phan National Park and in neighboring areas want to collect wild products and for livestock which are hard to control; as a result, the condition of the forest in the Phu Phan National has been worsened its biodiversity and caused plant and animal endanger from the previous ecosystem (DNP, n.d.). The statistics of wildfire in the Lam Nam Yang Part1 Watershed show the number of occurrences of 358 times and the areas destroyed of 2,848 rai from 2005 to 2013 (Figure 4.6) . The causes of wildfire are from the burning of rice fields, wild product collection, animal hunting, animal husbandry, tourism, conflict, illegal logging, and accidents and so on.

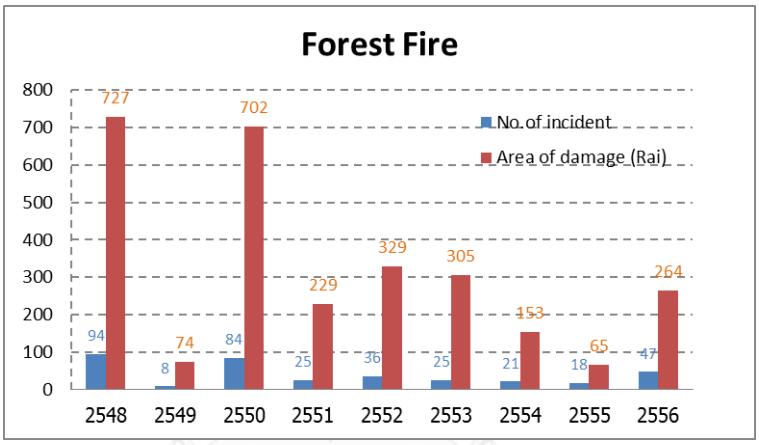

Figure 4. 6 Total incidents and area damaged by wildfire (2005-2012)
Source: DNP (2013)

From the interviews, it was found that most people opinionated about the destruction of forest that it was caused by illegal logging in the conservative areas (46.5 %), overexploitation of forest products (46.0 %), forest fire (40 %), agricultural expansion into forest land (20%), various development projects (11.4%), human settlement in forest areas (9.9 %), unclear of boundary of the forest (6.5%) and others (2.1 %) as shown in figure 4.7.

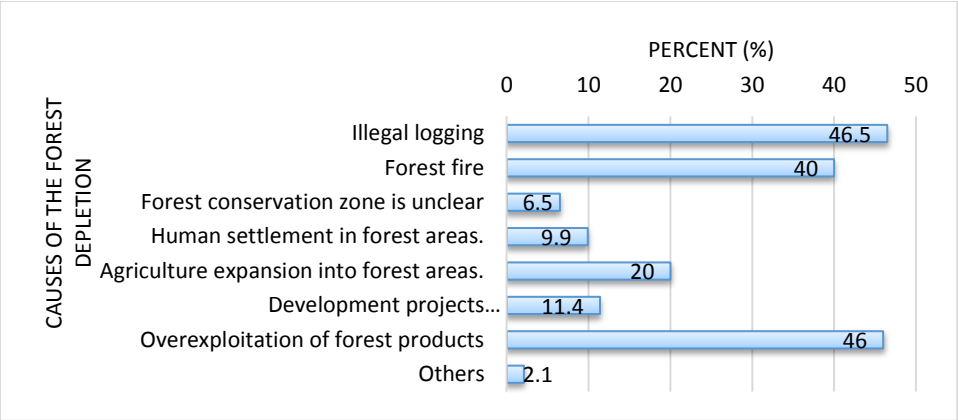

Figure 4. 7 Causes of forest depletion

Key informants commented that forest area destruction in the watershed caused inclement weather, the rise in the temperature in the areas and arid weather. Moreover, it affected the amount of water in soil and ground water, making soil easy to erode because there was no roots lying below the surface. In past 5 – 10 years, there was a flash flood around the banks of the Yang River causing soil erosion especially on the banks where there was no forest covered as it could be seen at Lam Huay Lua and Yang river that had sedimentary deposit and fast water flowing. One informant shared his experience that "During summer (March and April) of my childhood, water in streams was as height as the head level unlike now that there is almost no water that anyone can walk through. It is caused by the deforestation for agriculture like cassava, rubber and sugarcane cultivation, and the surface of soil is not fertile anymore." "The deforestation also affected the reduction of biodiversity. Due to the degradation of the habitants, the abundance of wildlife animals and aquatic animals showed the sign of scarcity. In the past the villagers could collect the wild products and herbs for medication, there is few of these products now. Also, the forests and animals are natural non- renewable resources, and it is pity that these cannot be maintained for new generations".

From the survey of the people's comment on the deforestation problems, most of them thought that the deforestation caused drought and lack of moisture (67.3 %), washing away of soil surface (41.3%), damage in the habitants and biodiversity (32.7 %), water runoff and severe soil erosion (24.2 %), lack of resources for carbon dioxide absorption (17.7 %) and other causes (1%) (Figure 4.8)

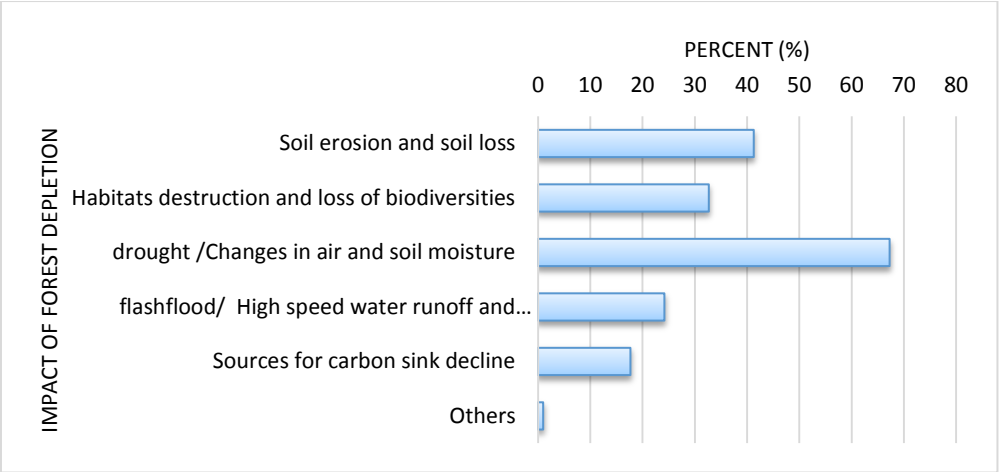

Figure 4. 8 Impact of forest depletion

Stakeholders' Suggestion on the Forestry Problem Solution

Data gathered from survey and in-depth interviews shows that people thought about forestry problems and gave some valuable suggestion on problem solution as follows:

1. Relevant agencies and people must preserve the current condition of forest as much as possible, especially the administrative forest areas; the community forestry like Coke Forest, Boong Forest and Tam Forest will be taken care of by the relevant institutes cooperating with the village to restore the degrading forest quickly by studying about the original ecosystem of the areas to promote the various local plant and plant for feeding animal cultivation for forest restoration and its absolute ecosystem,

2. It must be clarified in the forestry legislation in accordance with current situation and must issue equal rights amendment for entrepreneurs destroying the forests, loyal officers and clear forest boundary.

3. There should be measures to prevent the forest area where wildfire occurs frequently and is wildfire-prone; one must promote the participation of cooperated surveillance and wildfire prevention as well as safety training in case of wildfire occurrence for people living near the Phu Phan National Park and the Pu Si Tan Wildlife Sanctuary,

4. Relevant agencies should promote the jobs and improve the quality of people's lives to have working opportunities to prevent the deforestation or the rate of forest destruction, and

5.There should be projects and activities to promote and bring awareness to people in the basin to take care and cherish the forests and to value the forest and how the disaster can be caused if wrongly using the forest resources.

4.2.2 Biodiversity

4.2.2.1 Flora

The forests in the Phu Phan National Park, Phu Faek Forest Park and Phu Si Than Wildlife Sanctuary are the forests that classified as dry deciduous forests, mix deciduous forests and dry evergreen forests. In the dry deciduous forests, there are important trees that are *Shorea obtuse*, *Shorea siamensis*, *Dipterocarpus obtusifolius* and *Dipterocarpus tuberculatus*. In the dry evergreen forests, the important trees are found such as *Hopea odorota*, *Anisoptera costata*, *Memecylon floribunda*, etc. In the mix deciduous forests, the important trees are found like *Pterocarpus macrocarpus*, *Afzelia xylocarpa*, *Lagerstroemia* spp. and so on. In Phu Si Than Wildlife Sanctuary, there are pastures and abandoned farms caused by forest clearing for farming before the establishment of wildlife sanctuary, and they were abandoned. Then forest ecological succession occurred where there are important trees: *Imperata cylindrical*, *Eupatorium odoratum*, *Writhtia tomentosa* and *Croton oblongifolius* (DNP, 2016).

4.2.2.2 Fauna

The animal habitats in the Lam Nam Yang Part1 Watershed are the Phu Phan National Park and the Phu Si Than Wildlife Sanctuary. From the information of DNP (2015), there are 190 different species of wildlife in the Phu Phan National Park that are classified into 53 species of mammals, 70 species of birds, 37 species of reptiles, 17 species of amphibians and 13 species of freshwater fish. These consist of wild elephants, sambar deer, Indian muntjacs, boars, phayre's leaf monkeys, Malayan sun bears, large-spotted civets, Southern pig-tailed macaque, lesser bamboo rats, smooth-coated otters, Berdmore's ground squirrels, dog-faced fruit bats, yellow bittern, crested serpent eagles, Chinese francolins, greater coucals, Indian rollers, streak-eared

bulbuls, ashy drongoes, Richard's pipits, red jungle fowls, Asian common toad , Common Puddle Frog, Dark Sided Frog, Asian painted frog, spiny-tailed house gecko, Gecko, Red chameleon, Butterfly lizard, Skink, Golden tree snake , Common Bronzeback, and Laotian Wolf Snake etc.

Also, in the freshwater, the variety of fresh water fish species could be found like minnows, *Puntius brevises*, *Osteochilus vittatuses*, *Hampala dispars*, dwarf snakeheads, walking catfish, trichopsises, etc. The animal found in the the Phu Si Than Wildlife Sanctuary are total 233 species consisting of 41 species of mammals, 127 species of birds, 44 species of reptiles and 21 species of amphibians (DNP, 2015)

Key stakeholders provided the information that elder people living near Dong Mu Forest (parts of the forest is in the Phu Si Than Wildlife Sanctuary) stated that there were a lot of boars lived and were the good source of food leading to name of the forest in the past. Besides, there were a large number of wild animals such as deers, elephants, tigers, monkeys, birds, rabbits and so on, that is in accordance with the study of Rangsikosai, *et al*. (2009) stating about the abundance of wildlife in Puu Pha Pug Dee Forest, in Khao Wong district. Many key informants were concerned about the wildlife and aquatic animals in the Lam Nam Yang Part1 Watershed that are greatly few in number compare to the past due to the decline in habitats in forest and water sources and animal immigration into the deep jungle that cannot be seen. "In the past, there were productive forest and rich in natural resources. Also, there were a lot of animals in the forest that were sources of food for the community. However, a number of animals drastically decreased, and the forest became so degraded. The animal of the Kalasin province like banteng listed as endangered species, was very difficult to be found in Thailand and Tiny scale barb *(Thynnichthys thynnoides)* fish that decreased to the point of invisibility. The other species of animals that used to be seen a lot like Painted Chorus Frog and swamp eels are hardly found"

From the survey, it can be seen that most people opinionated about the decline in the plant and animal species (both terrestrial and aquatic species) that it was caused by the destruction of habitats and ecosystems (57.9%), climatic change (41.3%), overexploitation of the forest (36.1%), wildlife hunting (23.4%), illegal trading of forest products and wildlife (19.5%), invasive species (10.1%) and other reasons (2.1%) (Figure 4.9).

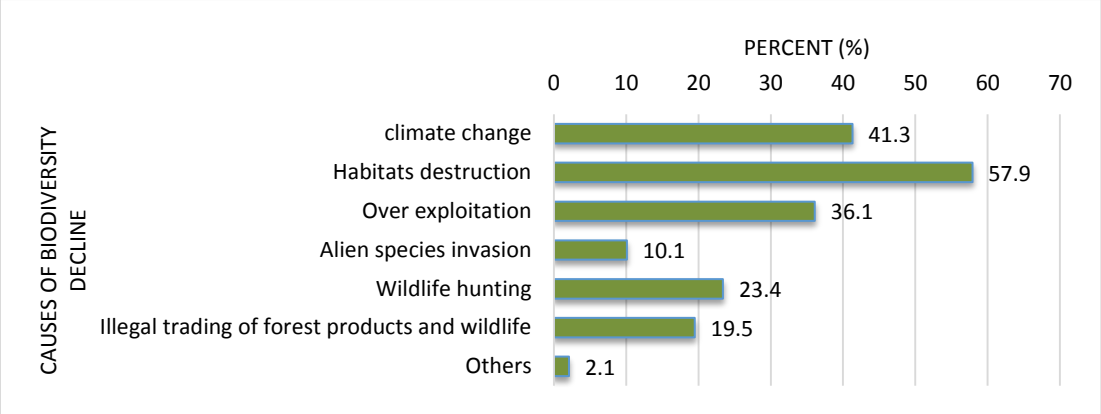

Figure 4. 9 Causes of biodiversity decline

The decline in plant and animal species affected the species are at risk of extinction the most (61.4%) , caused ecological imbalance and instability (37.9 %), affected the livelihood of people in local communities (34.8 %), resulted in food security (23.9%), reduced the ecosystem productivity (21.3%) and caused other difficulties (1%) (Figure 4.10).

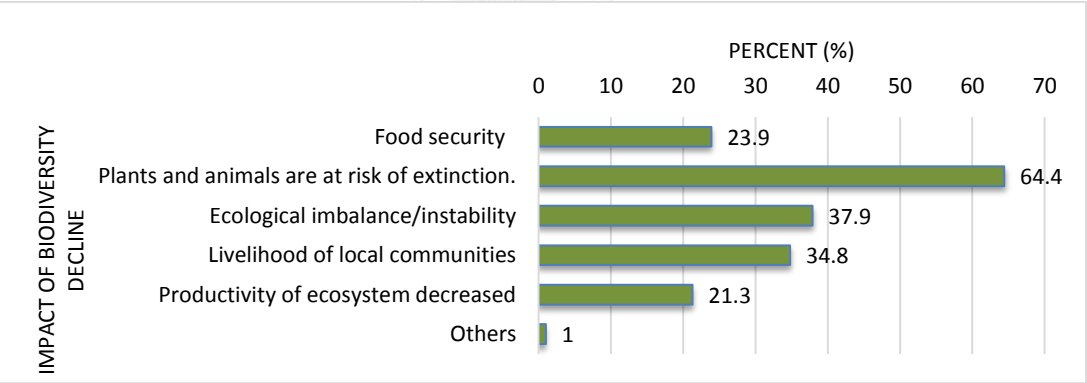

Figure 4. 10 Impact on biodiversity decline

Most of the people opinionated that solutions must be done by prevent animal hunting, wildlife raising and purchasing. They also suggested to stop consuming the wildlife, stop deforestation and reforest that would be publicized and raised awareness to understand the relationship of forest and animal resources. It should also to educate people, students, college students, young people and tourists how important of the plant and animal diversity to the ecosystem in order to preserve the natural habitats and water sources, and rehabilitate the forest for its original abundance. It was

suggested to be done by replanting a lot of trees because the forest areas is the sources of habitats, food, animal shelters and other benefits. Also, relevance agencies should enhance and strictly enforce the laws and regulation related to forest and wildlife on illegal actions.

4.2.3 Soil Resources

4.2.3.1 Soil

It was found that most of the soil was formed on the low alluvial terrace and the relatively new alluvial terrace, and some soil was formed on the floodplains and levees while some was formed on land after erosion and mountainous plateau. Also, some soil was found to be formed on high to medium-height alluvial terraces, mountainous areas, water sources and others. The soil groups on the Lam Nam Yang Part1 Watershed is shown in figure 4.11, and the most found soil was 1) The soil group no. 22 that was relatively sandy soil, low in fertility, long-term dehydrated and water logged during rainy season damaging plants that do not need water, 2) The soil group no.17 that was low in fertility, highly acidic in some areas, long-term dehydrated and water logged during rainy season damaging plants that do not need water, 3) The soil group no. 62 that was commonly found in slope complexes of more than 35 percent (highly slope) and could lead to severe topsoil surface runoff when doing agriculture, dehydration, rocks and debris scattered around the soil surface in some areas, and 4) the soil group no. 41 that was relatively dense sandy soil, low in fertility, long-term dehydrated, and water logged and topsoil surface runoff during long rainfall causing grooves in the planting field (LDD, 2010)

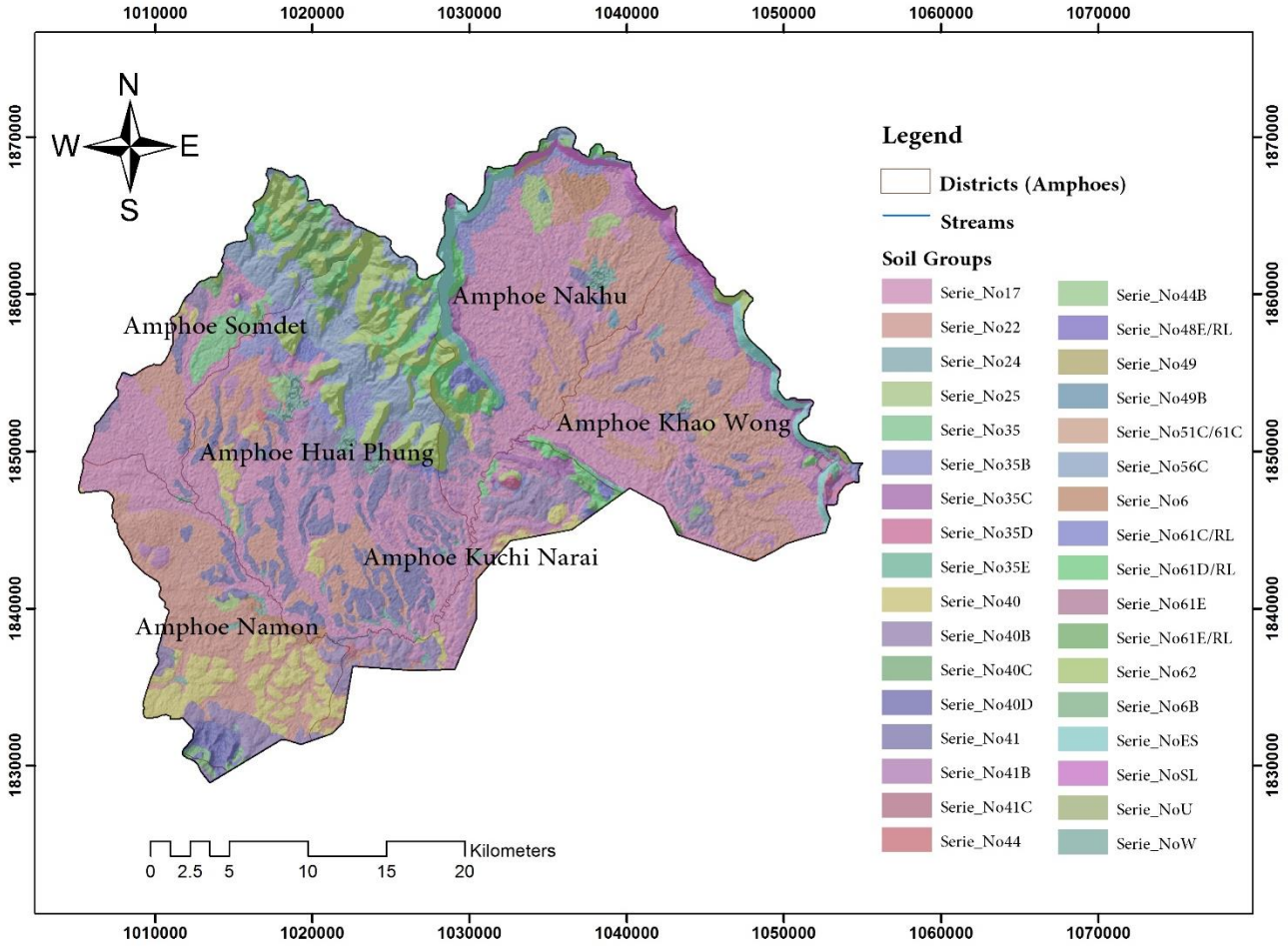

Figure 4. 11 Soil groups of Lam Nam Yang Part1 watershed

4.2.3.2 Land use

According to LLD (2010) data, it was found that land use in the Lam Nam Yang Part1 Watershed can be classified as follows

1) Residential area covered the areas of approximately 49.94 km^2 (31,212.5 rai) estimated 4.6 % of the total areas in the watershed such as villages, institutional lands, and factory.

2) Agricultural areas covered the area of 747.23 km^2 (467,019.76 rai) or 69.29 % of the total the watershed areas, with varieties of cultivation that are paddy fields, sugarcane cultivation, mixed farming

3) Forest areas covered the areas of 226.70 km^2 (141,687.5 rai), estimated 21 % of the total areas in the watershed.

4) Multi-purpose areas covered the areas of 54.47 km^2 (34,043.75 rai), estimated 5.05% of the total areas of the watershed as rivers, reservoir and natural water resources. (Figure 4.12)

The land use in the Lam Nam Yang Part1 Watershed the agricultural areas covered the majority of land where there were the great number of rice cultivation and had tendency to expand the areas in the upcoming future because of the government promotion and continuous rise of the price of rice in the market. The second-most planted was sugarcane due to the suitable weather and the huge sugar factory near the areas making transportation easy and not distant. Also, sugarcane is the renewable energy plant species in the production of gasohol with the high demand in the market. Hence, the rise or the decline in sugarcane plantation depends on the need of sugar factories and situation of world sugar market. It can be replaced by planting other crops such cassavas, maize, etc. (LDD, 2010). The forest areas like groves, wetlands and grassland were the second most areas covered after the agricultural areas.

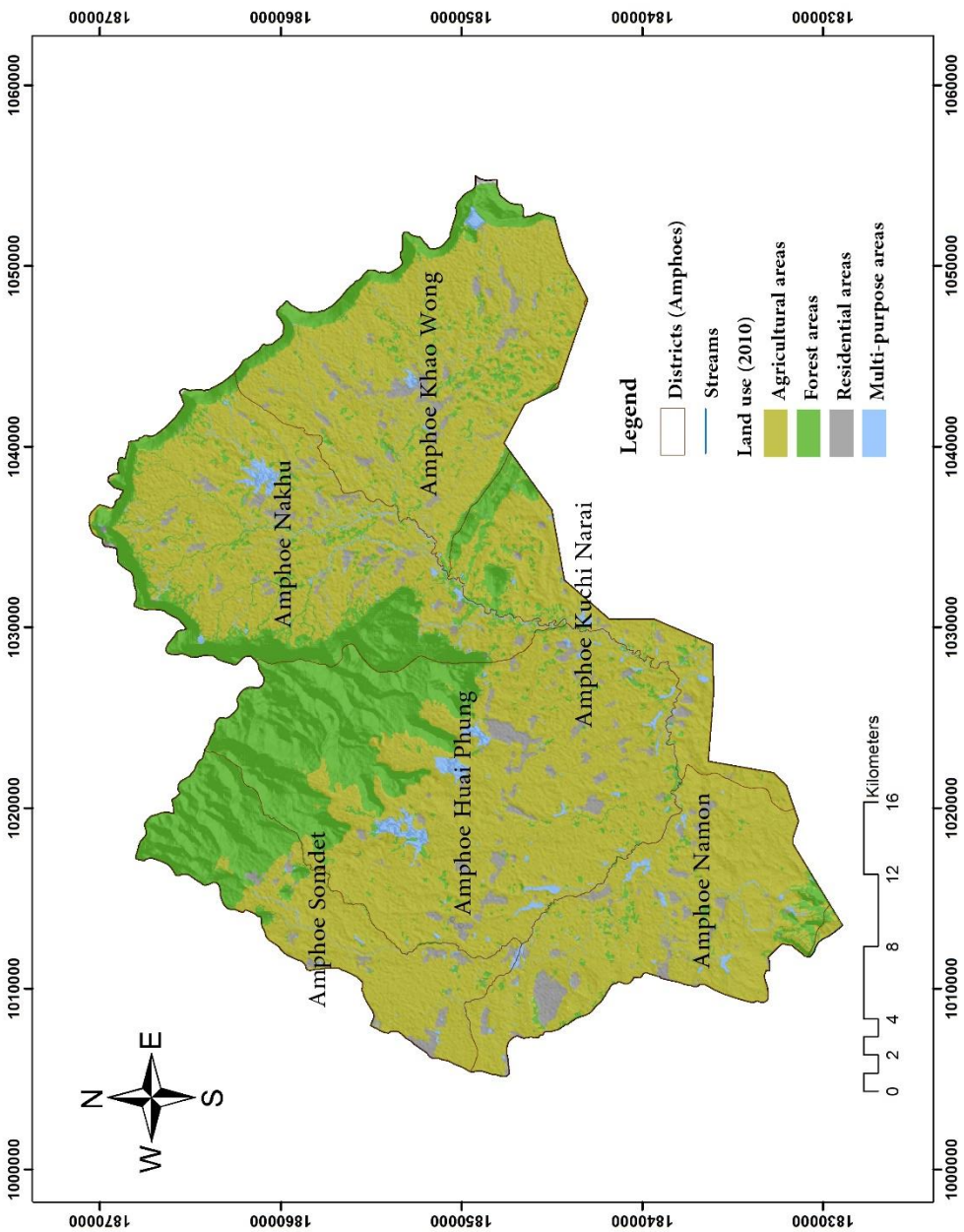

Figure 4. 12 Landuse in the Lam Nam Yang Part1watershed

4.2.3.3 Soil erosion

Soil erosion in the watershed was one of the most significant problems causing soil degradation such as the soil surface erosion, the loss of soil nutrients, the reduction of soil abundance, the limitation of agricultural machinery, the decrease of product yield per unit area and the shallowness of the water. Hence, it is essential to prevent the soil erosion for more sustainable soil resources maintenance. Generally, the soil erosion in Thailand is caused by rainfall as the main factor; however, the natural erosion is not severe on less sloping land where there are a lot of things to cover soil or on the highly sloping land with thick soil cover that rainfall cannot pour into. It is very severe if it is on the highly sloping land without any covers. The human activities accelerated more intense effects to environment and economic (LDD, 2010).

The soil erosion rate in the Lam Nam Yang Part1 watershed can be figured in the following:

1) Mild level covering the areas of 965.40 km^2 (603,375 rai) , estimated 89.5 % of the total areas in the watershed, with the rate of soil erosion ranging between 0 - 2 tons per rai yearly. Soil groups no. 22, no. 40, no. 62, etc. are found in this area.

2) Moderate level covering the areas of 103.89 km^2 (64,931.25 rai) , estimated 9.63 % of the total areas in the watershed, with the rate of soil erosion ranging between 2 -5 tons per rai yearly. Soil groups no. 35, no. 36, no. 40, etc. are being found in this area.

3) Severe level covering the areas of 8.36 km^2 (5,225 rai) , estimated 0.77 % of the total areas in the watershed, with the rate of soil erosion ranging between 5 -15 tons per rai yearly. Soil groups no. 35, no. 40, no. 61, etc. are being found in this area.

4) Highly severe level covering the areas of 0.76 km^2 (475 rai) , estimated 0.07 % of the total areas in the watershed, with the rate of soil erosion ranging more than 20 tons per rai yearly. Soil groups no. 47, no. 61 etc. are being found in this area.

The soil erosion map of the Lam Nam Yang Part1 watershed is shown in figure 4.13.

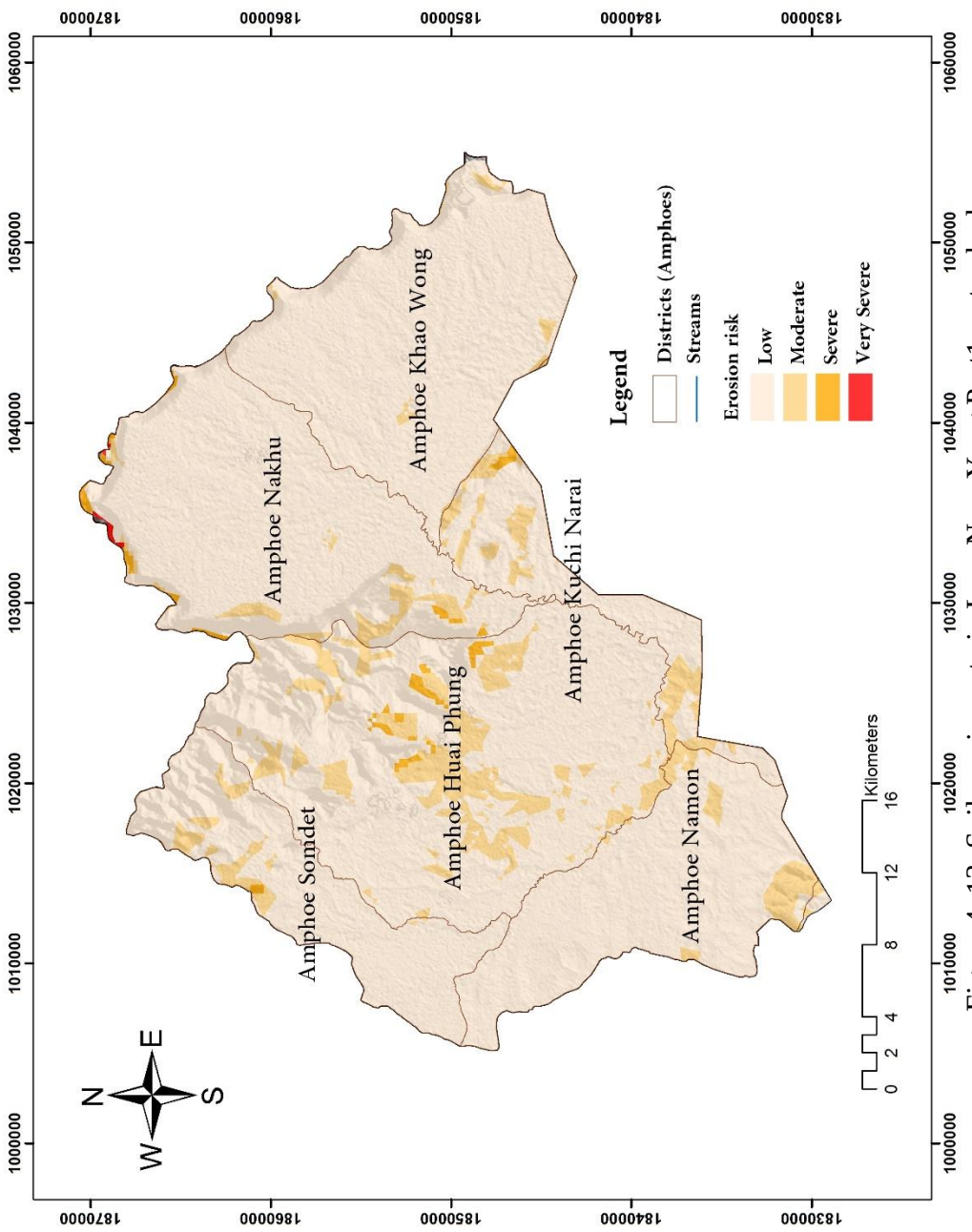

Figure 4. 13 Soil erosion rate in Lam Nam Yang Part1 watershed

According to the survey, most people thought that the problems of soil erosion and loss of topsoil were the consequences of deforestation and riparian by 51.7 percent, followed by natural setting and natural occurrence by 40.3 percent, agriculture activities by 33.2 percent, excavated of top soil/ road building/ area filling by 24.9 percent, and others by 5.2 percent (Figure 4.14).

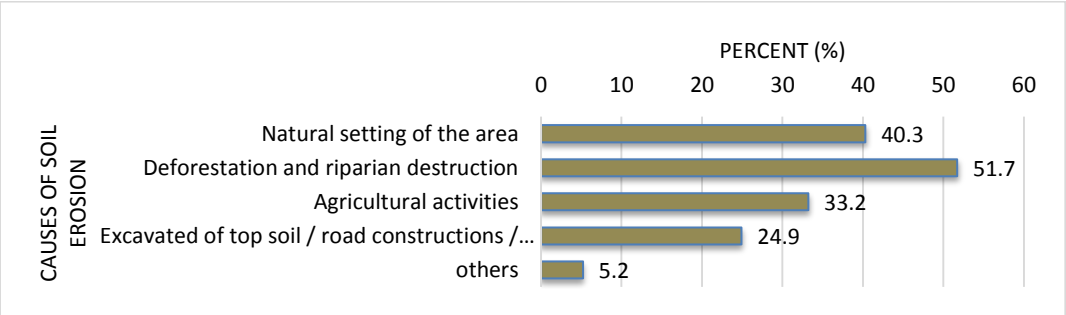

Figure 4. 14 Causes of soil erosion

The key informant related to land development discussed that beside the degradation of soil, the impact of soil erosion in Lam Nam Yang Part1 Watershed also caused a direct effect on other aspects of environment as well, for example, the decreased in fertile area for cultivation. This problem could lead to increased risks of deforestation since people needed more fertile areas. The soil sediment would flow into rivers and water sources, making the water sources shallow and muddy, which was improper for consumption. This could be seen from the shallowness water in some parts of Yang river, and in Huay Mano, Huay Fa and Huay Phueng reservoirs, etc. Also, the direct impact on agriculturists was the washed away fertile soil, affecting on the agricultural production by the need for higher soil improving cost.

Data from the survey presented that the problem mostly caused an impact on the shallow water sources (storage and drainage potentials decreased) by 57.7 percent, followed by the contamination of water sources and water quality degradation by 40.8 percent, impact on the aquatic life by 30.6 percent, the decrease in crop yields by 29.9 percent, impact on the quality of life and property by 20.8 percent and other impacts 0.8 percent (Figure 4.15).

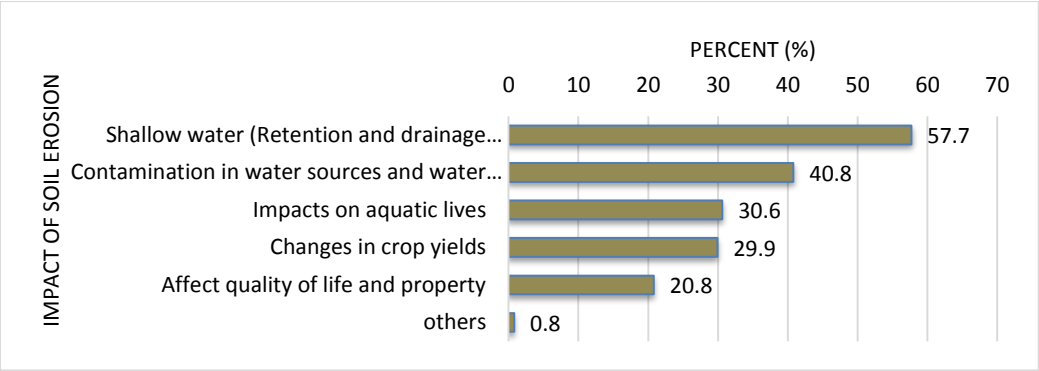

Figure 4. 15 Impact of soil erosion

People thought that the problem of soil erosion and loss of topsoil should be solved by the reforestation, planting cover crops, and so on. Also, farming in areas with high slope should be avoided. However, if any farming was carried out in such areas, there should be measures in order to conserve soil and water qualities to suit local conditions, for example, plowing and planting horizontally across the slope, planting vetiver grass, preparing soil steps, preparing ditches surrounding agricultural areas, preparing soil sediment trap systems along the watercourses or ditches to trap soil sediment, not to flow downwards, planting vetiver grass and trees along the riverbanks, and encouraging agriculturists to applied the principles of His Majesty the king as a serious actual practice in soil and water conservation manner.

4.2.3.4 Soil Deterioration

The problem of soil deterioration caused the soil conditions to change from the original to a condition that is no longer propitious to agricultural production due to the unsuitable soil properties for growing plants, and the loss of soil structure, resulting in a tightly compressed soil, lack of porosity in soil, lack of abundance, or decreased amount of nutrients and be in an imbalance condition. The key informants related to the soil resources concluded that the causes of soil deterioration in the Lam Nam Yang Part1 Watershed were as followed.

1) Farming by removing the plants that covered topsoil let the rain washed out the topsoil with plenty of abundance away by the rain water. Also, the deforestation made the uncovered soil's temperature raised, and increasing the

dissolving speed in various organic materials. In the Lam Nam Yang Watershed Part1, for sugarcane and cassava farming, the farmers would expose the bare topsoil.

2) Also, burning plants or grass grown in the fields destroyed the minerals and microbes lived in the soil that were beneficial for crops, causing less accumulation of organic matter in soil.

3) Planting a single plant species for a long time without improving and fertilizing soil could lose certain minerals in soil, reducing the crop yield.

4) Farming in the high areas without preparing soil trap boundaries, especially cultivating near the hillside, could encounter the washed away topsoil's abundance due to the rain erosion. In the Lam Nam Yang Part1 Watershed, this effect could be seen in the areas of Huay Phueng district, Somdet district, Khao Wong district, which were areas surrounded by mountains.

5) People in the areas lacked knowledge about the proper way to apply fertilizers, especially for chemical fertilizers. Most farmers applied too much fertilizer for the needs of plants.

Soil degradation issues could be confirmed by the interview from another key informant who explained that the causes of soil degradation in the Lam Nam Yang Part1 Watershed were the lacks of knowledge about soil in farmers. "They used the soils regardless of soil conditions, and applied a lot of chemicals. As a result, the soil degradation occurred earlier than usual in the areas. Currently, it was found that there are a lot of remained chemicals. When the plant infected with diseases, the farmers applied a lot of chemicals, causing chemical contamination in crop yields and higher cost of chemical uses, then crops were not worth the investment". "I also do the farming. From my experience and what I am currently facing, it can be seen that soil has gotten worse in quality dramatically due to nature of the areas themselves and the lack of adequate maintenance. Shortages of natural materials, for example cattle manure, because nowadays, people do not usually adopt such animals anymore. There are no trees and leafs to be degraded into natural compost. These causes acid soil and hardened soil, which need more maintenance, and increase the costs of remediation. The increase in contamination in environment affects the amount of aquatic animals. From my observation, there is a diminishing amount of aquatic animals that can be seen or caught. It is also found that several fishes infect with diseases, even the human

also have chemical contaminated in their body as well. Around three to four years ago, in the district where I live, there was a blood test by volunteers sent by public health center, and the results of the blood test showed that there was high volume of chemicals in our bodies. Thus, the society began a campaign to stop the use of chemicals, and people seemed to be starting to realize the danger of chemicals. As a result, they were careful and used fewer chemicals for a while. However, today, people are still using a lot of chemicals as they did before because they do not realize the danger, because they do not expect that the chemicals can kills them at once, and they are too lazy to change their behavior. Anyway, if you look carefully, you will see that farmers have respiratory diseases, such as allergic, keen nose, rash, and so on, more and more."

According to the survey, most people thought that the lack of fertile soil was due to the excessive use of chemical fertilizers by 62.3 percent, followed by the burning of rice stalks and agricultural waste by 47.0 percent, the lack of conservative measure and poor maintenance by 45.2 percent, the consecutive mono cropping for a long time by 32.5 percent, the natural occurrence (poor soil structure) by 31.7 percent, bare soil (the removing of topsoil that let the rain washed away the fertilize soil) by 27.5 percent, and other reasons by 1.0 percent (Figure 4.16).

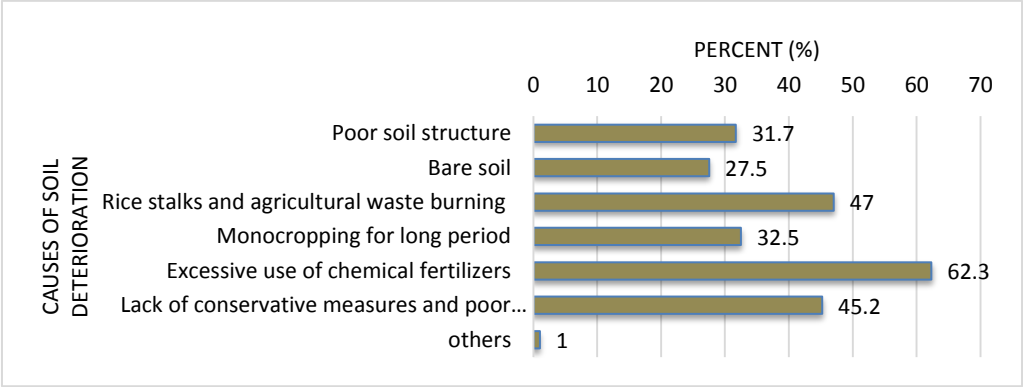

Figure 4. 16 Causes of soil deterioration

The key informant who was a local scholar and a lecturer on the sufficient agriculture said that in the Lam Nam Yang Part1 Watershed, especially in Namon and Huay Phueng districts, the problem of the lack of soil fertility caused by the topsoil that was washed away by the rain because there were no trees, no composted leafs, and excessive use of chemical fertilizers and herbicides by farmers. Currently,

farmers required to use more chemicals due to unfertilized soil condition. The previous need for chemical fertilizers may be one bag per four to five rai, but the current need for the chemicals was more than four bags per rai, causing the increase in costs in order to get the same volume of yield. Some areas were quite sandy, but the amount of organic materials and minerals that are beneficial to plants were less, affecting the plant growth and reducing the yield per an area unit. In some areas that had compact soil, especially the rice area contained fine sand with low amount of organic materials; plant's roots could not pierced into the soil. Improving and maintaining soil quality needed more costs, which was a burden to farmers as the higher production costs.

According to the data from the survey, people thought that this problem affected the decrease in crop yields by 64.7 percent, followed by more expenditures for land and soil improvement by 48.8 percent, the further needs for using chemical and pesticide by 46.8 percent, the contamination in soil by 41.0 percent, the increase in forest encroachment by 20.0 percent, the increase in soil erosion via rain or wind by 14.0 percent, and others by 2.0 percent (Figure 4.17).

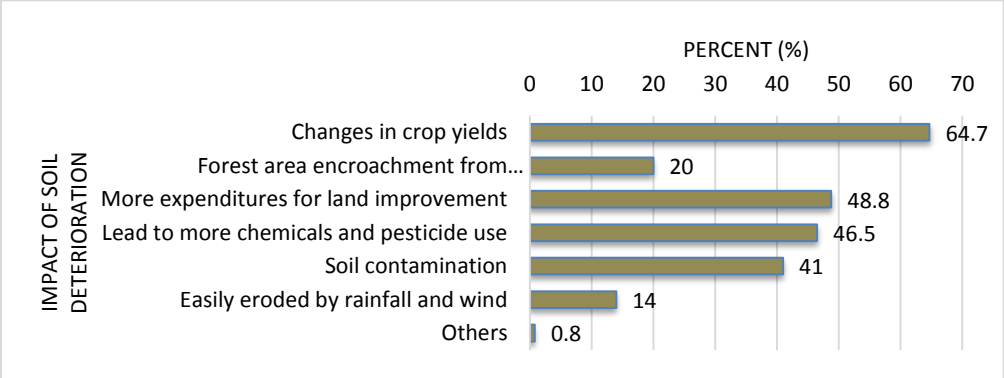

Figure 4. 17 Impact of soil deterioration

About the solutions for soil degradation, most people thought this problem should be solved by encouraging farmers to use bio-fertilizers and natural manure or compost instead of using chemical fertilizers, planting topsoil cover crops, planting diverse crop species, encouraging to do farming in the suitable land areas, adopting the sufficient agriculture principles bestowed by His Majesty the King (Klang-Din Project) and so on.

4.2.4 Water Resources

4.2.4.1 Water sources

The main water sources in the Lam Nam Yang Part1 Watershed included Yang river, Lam Pha yang river, Huay Mano, Huai Fa, Huai Sa tod, Huai Luo and Huai Phueng, etc. These were natural water resources for consumption for rural residents, as well as for agriculture. Also, the groundwater was the water from the bored wells**.**

4.2.4.2 Water quantity and sediment

1) Water Quantity

The Lam Nam Yang Part 1 had the total surface runoff about 439.7 million cubic meters per year (LDD, 2010).

2) Sediment

In the Lam Nam Yang Part1 Watershed, there was no official sediment monitoring station. However, with the measurement near the outlet of the watershed in Ban Kaeng Yaw, Kuchinarai district, Kalasin province, a total of 106,984 tons of sediment was found, with highest sediment amount of 45,312 tons in October, and the lowest sediment amount of 64 tons in April (LDD, 2010).

3) Groundwater

The Lam Nam Yang Watershed Part1 in Khao Wong district, Kalasin province, was supported by sedimentary rocks, Khorat rock groups, Phu Kradueng rock series, including siltstone, sandstone and conglomerate. It provided moderate water amount of about 2 - 10 cubic meters per hour, as fresh water with about 500 milligram of total dissolvable substances per liter. Along the watershed from Khao Wong district to Nong Sung district, Mukdahan province, was supported by Phra Wihan, Sao Khua and Phu Phan rock series, including siltstone, sandstone and conglomerate. It provided water amount less than 2 cubic meters per hour, with high opportunity to find dry wells. Most of the water was fresh water with less than 500 milligram of total dissolvable substances per liter (Coordination and Management of

Lower Chi River Basin Division, 2010). The rate of groundwater potential release rate is presented in Figure 4.18 .

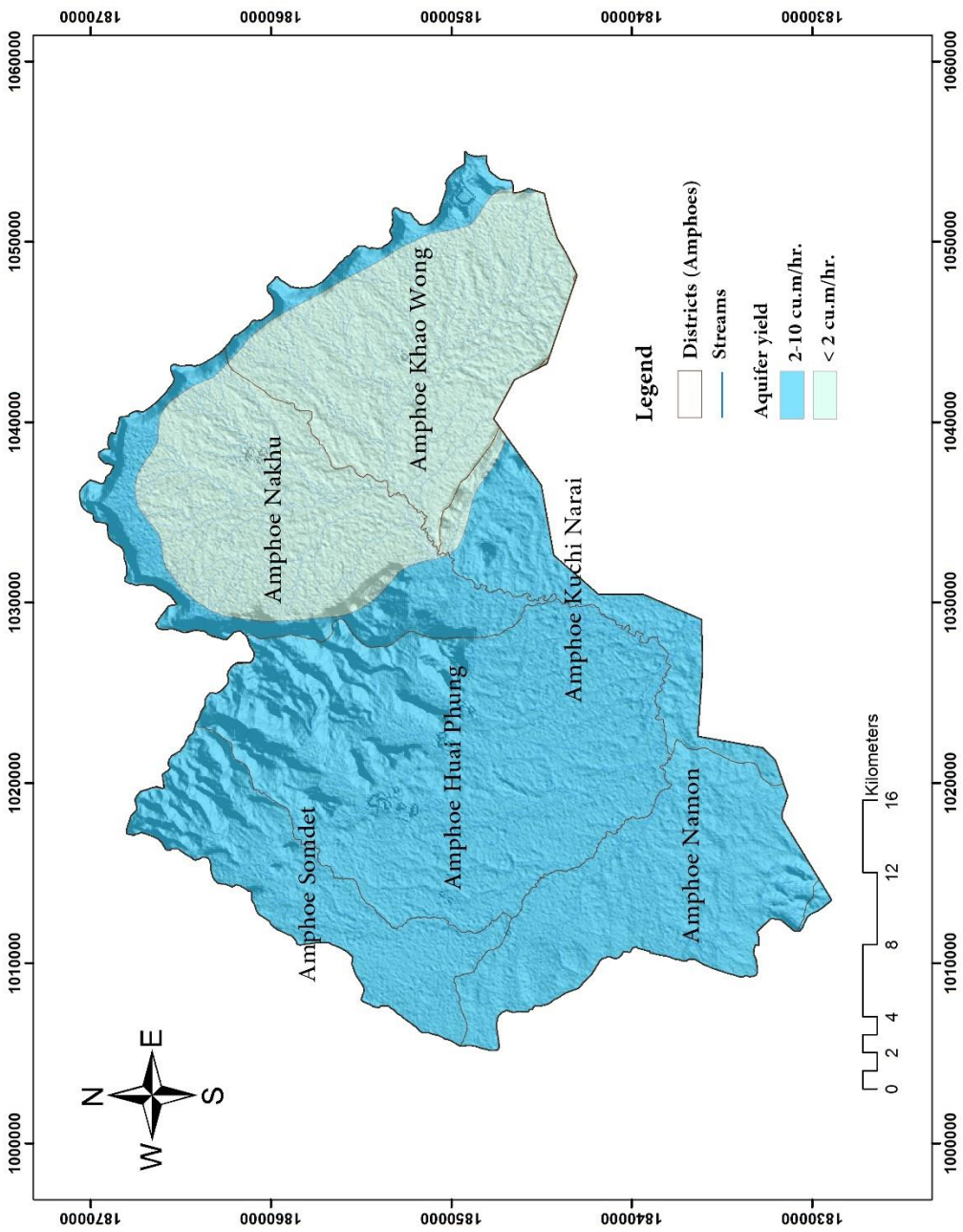

Figure 4. 18 Groundwater potential release rate in the Lam Nam Yang Part1 watershed

Coordination and Management of Lower Chi River Basin Division (2010) predicted that the demand for groundwater in the whole Yang Sub-basin for

consumption would increase, but the demand for groundwater for industrial systems would decline.

4.2.4.3 Water quality

1) Surface Water Quality

The Yang river is the main river in the Lam Nam Yang Part1 Watershed. It is the river used for agriculture, livestock and fisheries. Also, it is the water source used for public consumption as well as many activities. However, there is no permanent water quality monitoring station in the Lam Nam Yang Part1 watershed. So, water quality measurements were performed when problems occurred. However, near the outlet of the Lam Nam Yang Part1 watershed, there is a water quality monitoring station at Som Sa Art sub-district, Kuchinarai district. It was found that in recent years water quality was in a fair standard (class 3) based on classification of surface water by Pollution Control Department (REO 10, 2015). The causes of water quality degradation were the contamination due to agricultural activities, the aquaculture, the increase in garbage and waste volumes, as well as discharges from point sources such as the agricultural process factories.

2) Groundwater quality

From groundwater quality data in the watershed compiled by the Department of Groundwater Resources (2009) cited in LLD (2010), the quality of many groundwater wells exceeded the standards of groundwater for consumption in accordance with the Groundwater Act in 1977. In every sub-districts in the Lam Nam Yang Part1, the amount of acidity, alkalinity, chloride, total dissolved solids and total hardness were in the standard, while the concentration of iron was higher than the standard, except for Tambon Sai-nawang, Naku District, Tambon Namon, Namon District and Tambon Pha sawei, Somdet District.

4.2.5 Flood in the Lam Nam Yang Part1 watershed

The cause of flood in the Lam Nam Yang Part1 watershed was similar to other general watersheds in the Northeast, which was influenced by the Southwest monsoon from the Indian Ocean, causing rain during the rainy season since May to July, but

there was not much rainfall. Also, there were additional factors influenced by the typhoon from the South China Sea since July to October as well, because during a continuous heavy rain, the lowlands terrain usually flooded naturally, as well as the lowlands along the river. Some areas were flooded where the rivers are converged. Forest cover in the upstream areas and streamside were destroyed, causing the lack of water absorption and the lack of slowing the flow of water. Land use changed, roads constructions, weeds and aquatic plants are causes of water overflowed and the flood. Moreover, in the upper part of the watershed lacked of water reservoirs and flood management plan (KKU, 2010). Figure 4.19 shows the weeds and aquatic plants in the streams that may cause the blockage of the water flow leading to flooding.

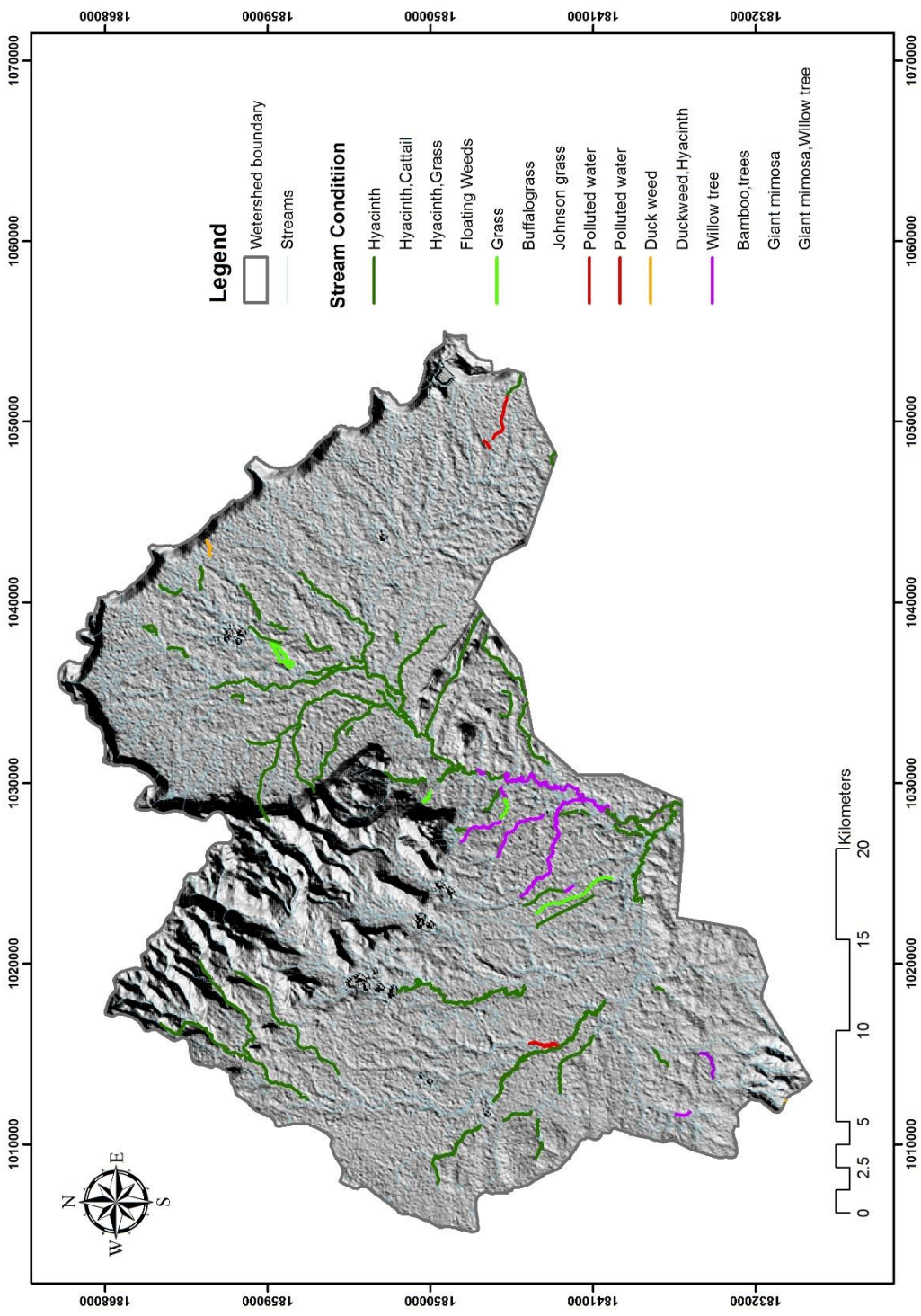

Figure 4. 19 Weed and aquatic plants in the stream in the Lam Nam Yang Part1 watershed

However, in the Lam Nam Yang Part1Watershed, the flooding issue was less severe because the area was in the upper part of the entire Yang Sub-basin, which would experience flooding problems as flash flood that did not take so long Flooding

often occurred with communities nearby the water sources, where there was rice farming on lowlands. People mostly do farming, fishing, animal farming, crops and fruit farming on uplands for living. The damages from floods affected the economy, society and environment. For example, agricultural products, especially rice, as well as buildings, houses, and infrastructures were damaged; people in the community had respiratory diseases; student missed school; some family's members worked far away, so families lacked warmth, and they were depressed mentally; water was polluted; there were mud and garbage left behind in the community (Kuntiyawichai 2012).

The flooding in the Lam Nam Yang Part1 Watershed during 10 years period can be seen in Figure 4.20 (GISDA, 2014).

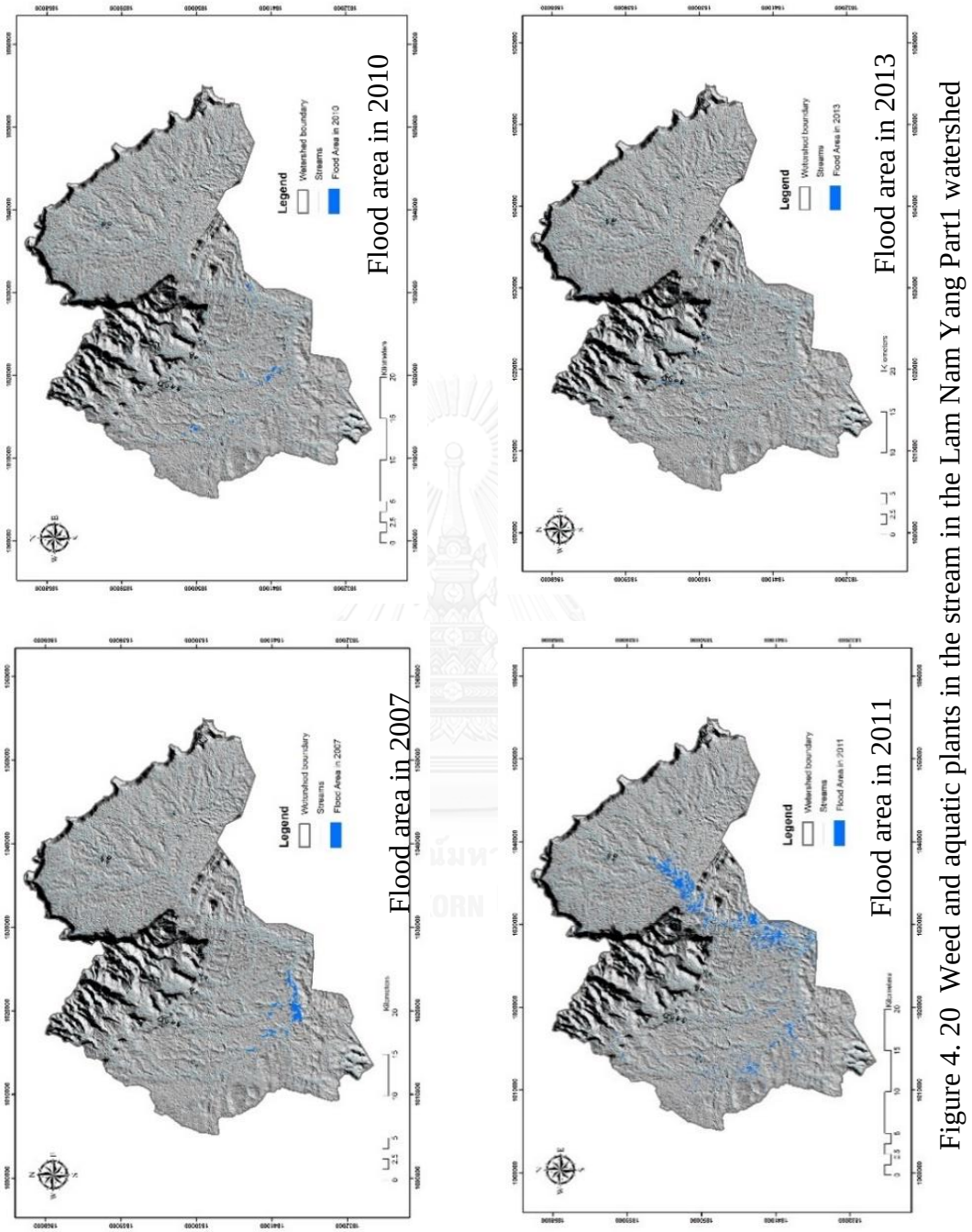

Figure 4. 20 Weed and aquatic plants in the stream in the Lam Nam Yang Part1 watershed

The results of the survey showed that most people thought that flooding problems caused by the natural settings of the area (lowland areas) by 33.8 percent,

followed by the deforestation (Nothing for slowing the water flow) by 28.8 percent, the shallow in water courses (the deposition of sediments, trees and weeds) by 20.8 percent, encroachment on water courses by 14.0 percent, the poor management by 13.5 percent, the constructing of road and water blockage constructions that obstructed the water flow by 11.9 percent, and others by 0.3 percent (Figure 4.21).

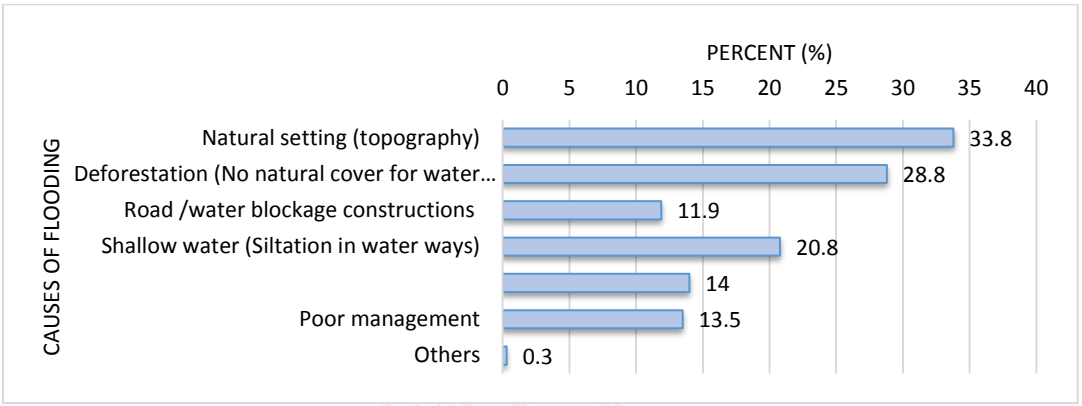

Figure 4. 21 Causes of flooding

This flooding issue impacted the health, such as various diseases that came up with water by 38.2 percent; followed by impact on agricultural production by 35.6 percent; impact on transportation and communication by 23.9 percent, impact on mental stress of people by 21.3 percent; impact on housing and properties by 16.6 percent; and others by 0.8 percent (Figure 4.22).

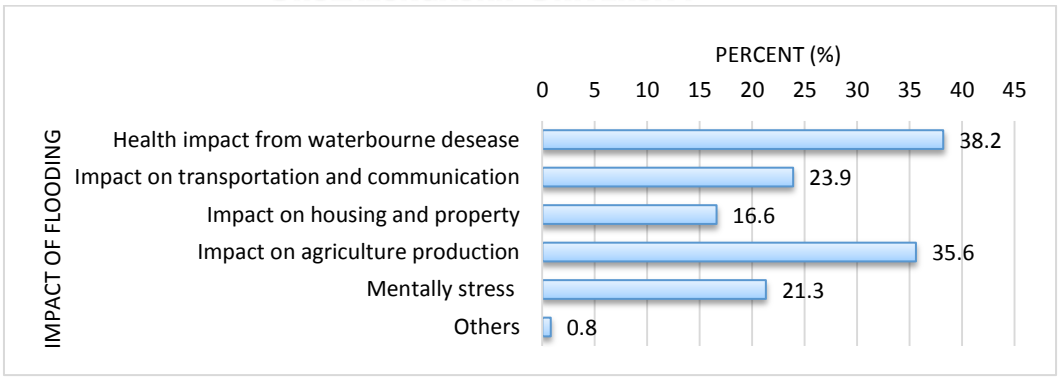

Figure 4. 22 Impact of flooding

4.2.6 Drought and water shortage

Drought in the Lam Nam Yang Part1 Watershed was the most serious issue. The drought caused by climate variability when it was not raining seasonally and the prolonged no-rain condition occurred, together with the change in ecosystem of the watershed, the result of the community expansion, the economic activities, including the expansions of agricultural areas in both within and without irrigation area. These increased the demand for fresh water. Water shortages occurred in the dry season, while the potential for water sources development for storing water in the areas was limited. Reservoirs, natural wetlands and available ponds were still unable to store sufficient water for the needs for agriculture, consumption and industry. The available water reservoirs and natural sources were shallow, could not store water effectively, which all affected the well-being and livelihoods of people lived in the watershed (Coordination and Management of Lower Chi River Basin Division, 2010). The causes of drought in the Lam Nam Yang Part1 watershed could be summarized as follows:

1) The distribution and variability of rainfall caused drought condition in the areas in the form of no-rain period. If the prolonged no-rain period occurred, even the areas along rivers might face the water shortage as well. As a result, the drought occurred with less number of rainy days, while there was no rain for a long time, especially in rainy season, the drought could occur. From the data over the last 10 years from 2000 to 2010, in the watershed areas, the average rainfall was 1,494.4 mm with an average of 109.1 rainy days. Although, during the last 10 years, the average rainfall and rainy days exceeded the average of the year 1971 to 2000, but the amount of rainfall in the watershed was found to be high in variability. Furthermore, in 2002 to 2003 and in 2005, the volume of rainfall in the watershed was unusual. It was found that the El Niño phenomenon resulted in the minimum number of rainy days in 2003, which was 1,218.5 mm of rainfall with total rainy days of 95 days. Such El Niño phenomenon caused the severe drought in the watershed (Khon Kaen University, 2011).

2) For the natural setting of the area and water sources, there was no large water sources development project in the Lam Nam Yang Part1 Watershed due to the unsuitability of the area. This caused the lack of water source storage, less water

storage in the areas, insufficient water storage during the rainy season and insufficient water storage for releasing water during the dry season into the drought areas.

3) The increase in population and the growth of the community caused more activities that required water usage from both agriculture and industry.

The impacts from drought influenced the economy, society and environment. This caused the damaged of agricultural yield due to shortage of water for agriculture, especially rice paddy, crops and fish ponds, affecting health and disease of local people in the communities, lack of clean water supply.

From the data of Land Development Department (2010), drought severity of the Lam Nam Yang Watershed can be shown in Figure 4.23.

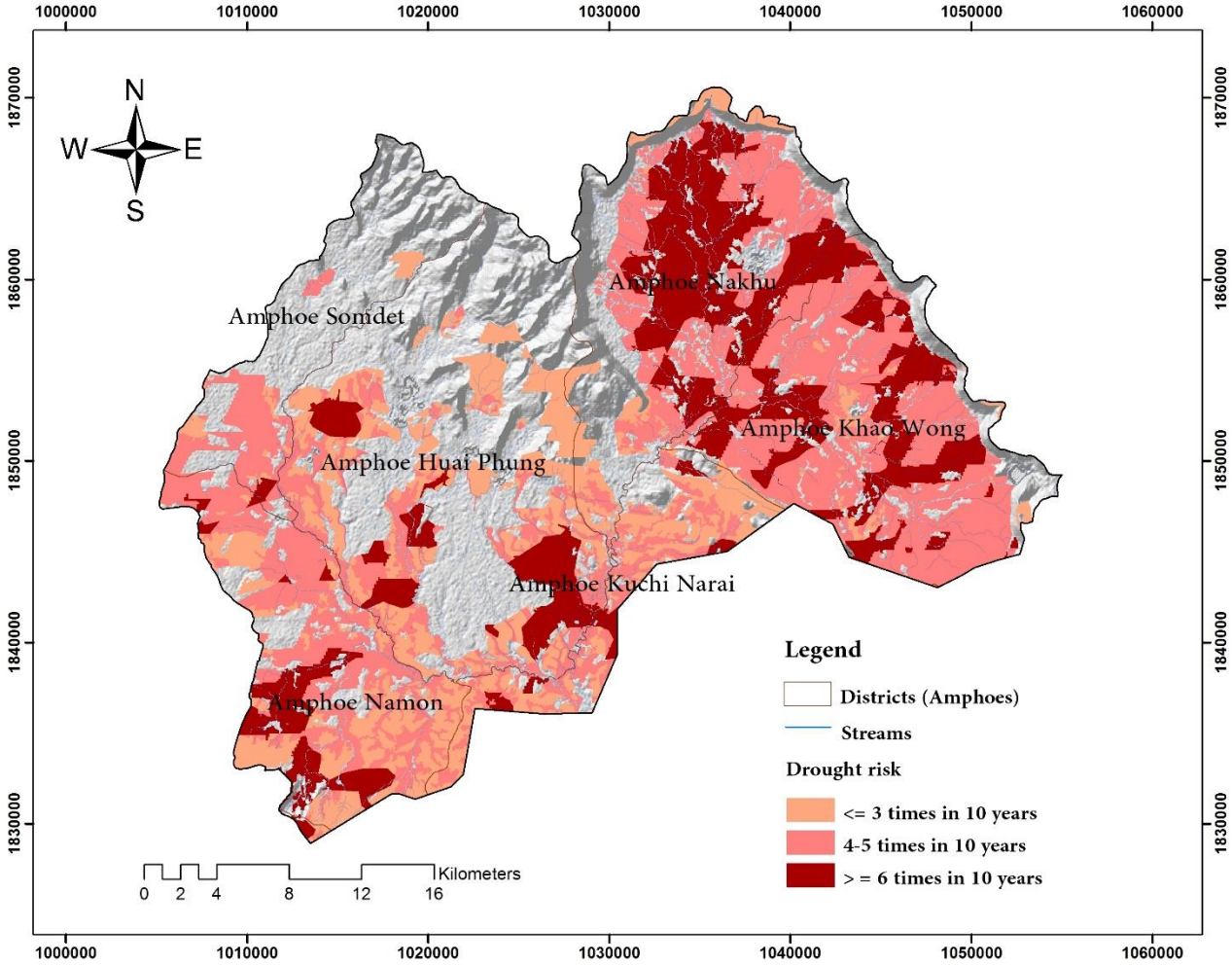

Figure 4. 23 Drought severity in the Lam Nam Yang Part1 Watershed

From the results of the survey, most people thought that the water shortages for agriculture caused by the deterioration of natural storage by 61.3 percent, followed by the insufficient storage by 53.3 percent, the climate variability (shifting in rain fall pattern) by 45.5 percent, the insufficient irrigated areas by 32.2 percent, the increase of agricultural areas by 21.8 percent, the increased water demand development by 21.0 percent, the sandy soil with low water retention by 17.4 percent, and others by 0.5 percent (Figure 4.24).

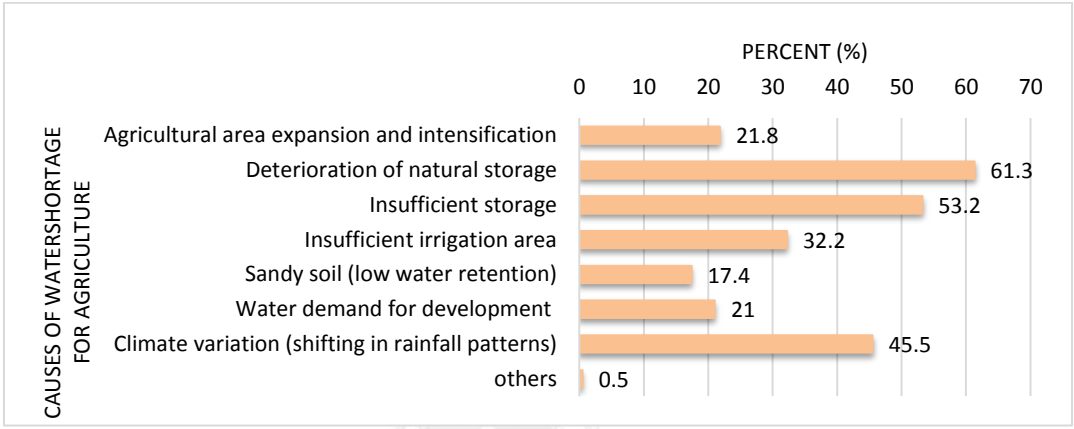

Figure 4. 24 Causes of water shortage for agriculture

This water shortage problem affected the decrease in agricultural yields by 68.1 percent, followed by drought and the dried land and could not be fully utilized by 50.6 percent, the insufficient water for cropping by 47.0 percent, socio-economic damages by 36.6 percent, water use conflicts by 23.6 percent, and others by 1.3 percent (Figure 4.25).

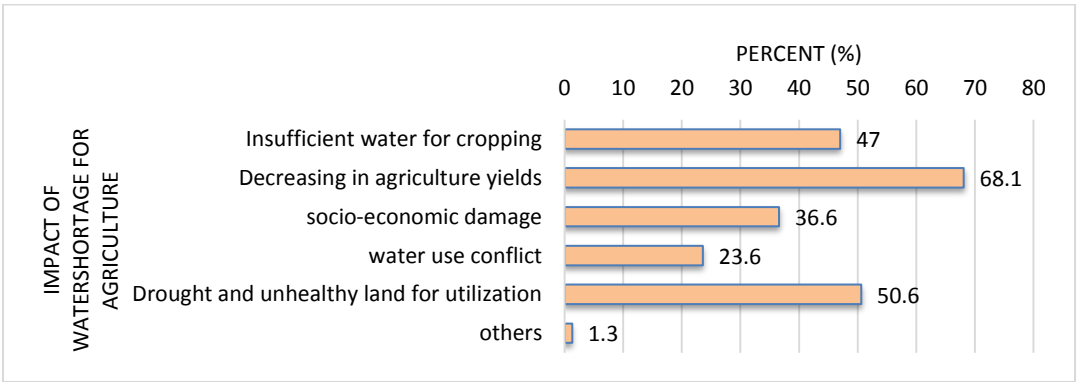

Figure 4. 25 Impact of drought and water shortage

In terms of insufficient water for consumption issues, most people thought that the causes were the insufficient storage by 47.5 percent, followed by the siltation in water courses (shallowness and degradation of natural water sources) by 44.2 percent, the climate variability (shifting in rainfall pattern) by 43.1 percent, insufficient water supply system by 23.6 percent, the quality of groundwater and surface water by 21.3 percent, and others by 1.3 percent (4.26).

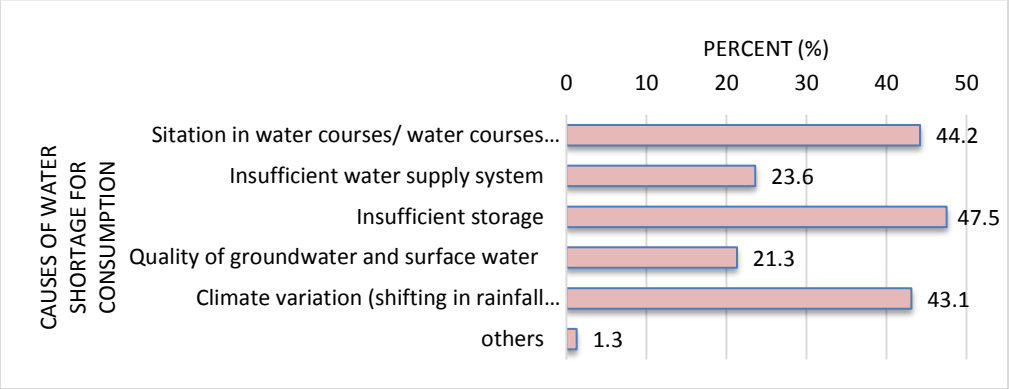

Figure 4. 26 Causes of water shortage for consumption

This problem influenced the increase in the costs for water consumption (more money to by water) by 50.9 percent, followed by health impact by 43.4 percent, the impact on animals by 36.9 percent, the livelihood and wellbeing of the people by 33.2 percent, the conflicts within the community by 16.1 percent, and others by 0.8 percent (Figure 4.27).

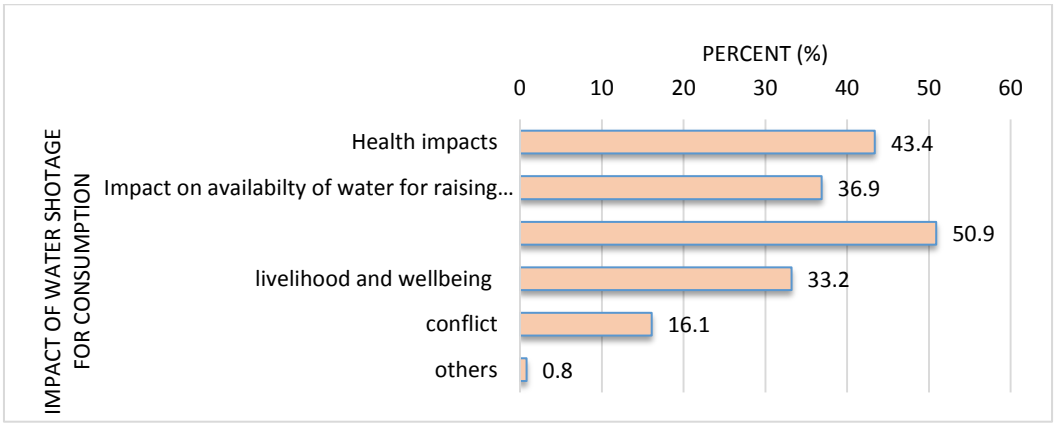

Figure 4. 27 Impact of water shortage for consumption

It was found that 20.08 % of survey people had insufficient water for drinking, and 18.2 % had insufficient water for households use.

4.2.7 Waste water

Sources of waste water in the Lam Nam Yang Part1 Watershed complied by Regional Environmental Office 12 (2014) were as followed.

1) The continued growth of the community, which mostly still had no effective waste water management system.

2) The increased changes in the use of land for agriculture, especially in the areas of upstream water sources. For example, sugar cane, cassava, rubber, etc., might be the major cause of the increase in soil erosion during rainy season.

3) The agricultural industrial, such as sugar industry, alcohol production, cassava industry, etc., release wastewater into the environment.

4) The increased use of fertilizers and chemicals.

The interview with the key informants found that, in the Lam Nam Yang Part1 Watershed, there was a complaint by farmers on the discharge of waste water from cassava starch industrial factory, which was a large industrial factory and sometimes discharged wastewater into public water supplies. The wastewater from the factory flowed into the reservoir, killing so many fishes. Farmers could not do fishery in the reservoir because of the fear that they would be harmed by contaminants in the wastewater. The incident happened several times, and it was a cause of conflicts between the people and entrepreneurs. Also, people did not trust in the operation of the relevant authorities as the role of an inspection.

Most people thought that wastewater problem was caused by the wastewater from industries by 32.7 percent, followed by the wastewater from households by 30.9 percent, the wastewater from agriculture by 15.3 percent, the wastewater from restaurants/hotels/ establishments by 14.0 percent, the natural occurrence by 14.5 percent, and the others by 1.0 percent as shown in Figure 4.28.

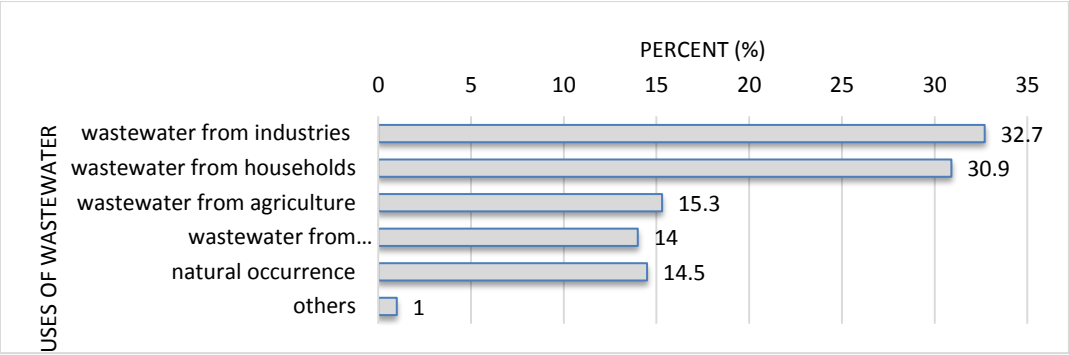

Figure 4. 28 Causes of wastewater

Thus, this problem affected the increase in disease by 37.4 percent, followed by the quality of water and soil by 30.4 percent, the impacts on aquatic life and depression of for people by 27.8 percent, the long term changes in ecosystem by 20.8 percent, the visual pollution by 8.6 percent, and others by 0.3 percent. (Figure 4.29)

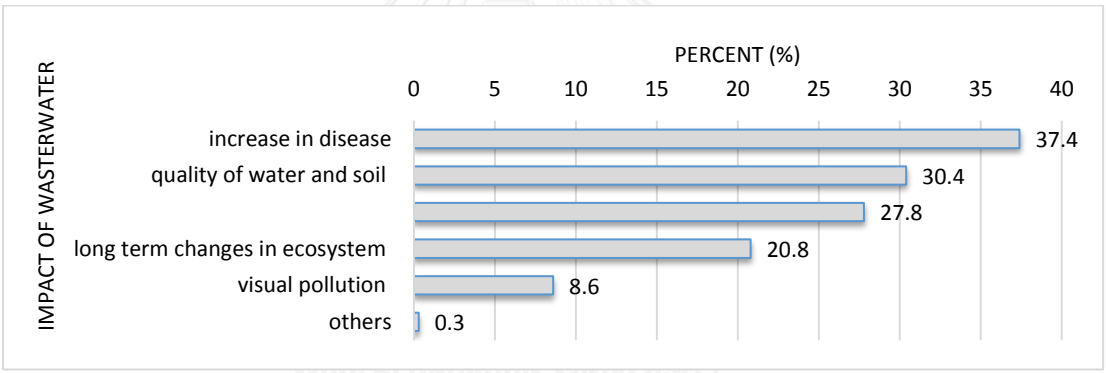

Figure 4. 29 Impact of wastewater

People recommended on how to solve the wastewater problem was to reduce the amount of soil sediment from the agricultural lands into water. For example, encouraging farmers to use appropriate amount of fertilizer; growing plants to absorb substances; reducing the use of hazardous chemicals; industrial factories had to manage their own waste water treatment to meet the standard, farms should not use sewage from toilet as fertilizers for rubber, sugarcane or rice plantations; and encouraging local authorities to create a proper wastewater management system.

4.2.8 Air pollution, odor and noise pollution

In Lam Nam Yang Part1watershed, most of the areas were agricultural areas as open spaces, and not so many auto motives and industries. Although, there were some smoke and noise from vehicles and factories, but they were not danger to public health. There mostly had smoke problems in dry season due to dusts from burning of agricultural materials, dusts from burning of solid waste in the community, burning of forests for hunting wild animals.

Interview data from the key informant who worked for the environmental agencies found that there were some complaints about dust and noise pollution problems occurred in the watershed. Most of them were the annoying from sugarcane carrying trucks and mini-tractors that carried the products to factories

According to data from the survey, most people thought that the air pollution caused by dust and smoke from the burning of agricultural residues (for example, rice stalks) by 48.1 percent, followed by the smoke from the workplaces/industries by 30.6 percent, smoke from forest/forest burning by 22.1 percent, dust from traffic by 16.4 percent, natural occurrence by 15.6 percent, and others by 1.0 percent. (Figure 4.30)

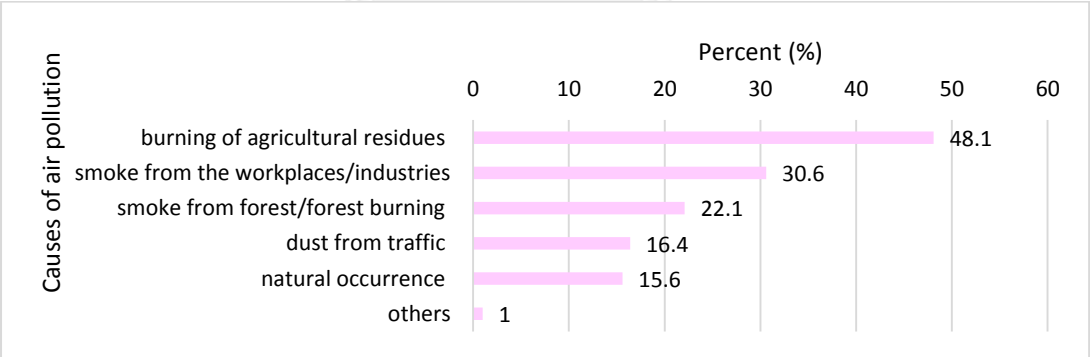

Figure 4. 30 Causes of air pollution

The problem affected health problems (for example, respiratory diseases) by 64.2 percent, followed by minor nuisance suffered by 24.9 percent, scenery and seeing by 18.7 percent, visual on transportation by 9.4 percent, and others by 8.6 percent. (Figure 4.31)

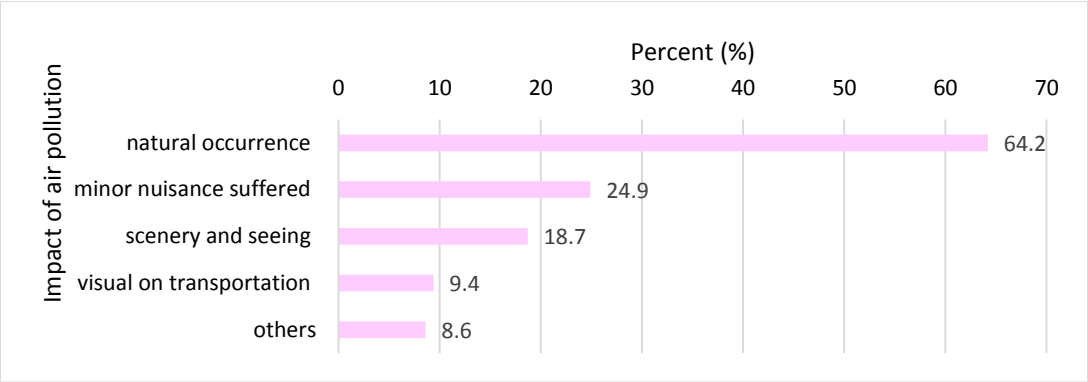

Figure 4. 31 Impacts of air pollution

The Lam Nam Yang Part1 Watershed was mostly open space. Most sources of odors were from industrial factories, such as sugar, tapioca starch factories, smell of the pile up of garbage from houses, wastes from natural leftover materials, such as sugarcane, etc.

Data from the survey found that most people believed the smell pollution caused by the smell of garbage by 39.0 percent, followed by the smell of wastewater by 26.2 percent, the smell from industries by 25.5 percent, the smell from agriculture and livestock by 21.8 percent, natural occurrence by 9.1 percent, and others by 0.8 percent. (Figure 4.32)

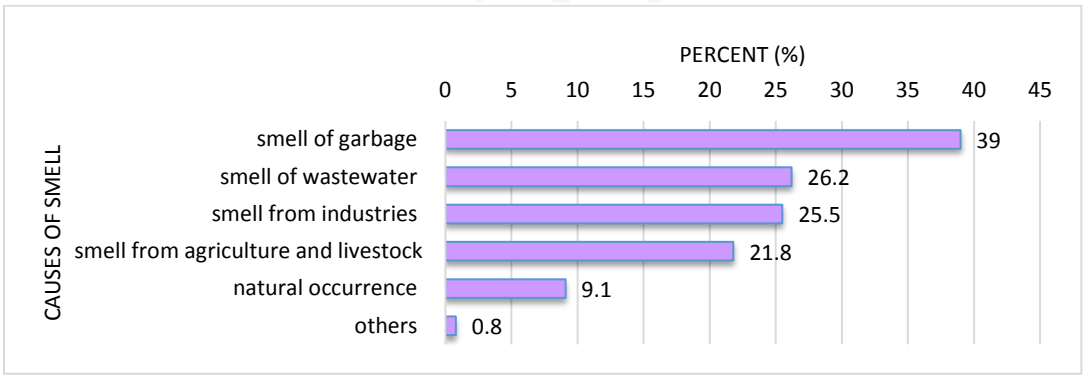

Figure 4. 32 Causes of smell

This problem affected health the most by 46.5 percent, followed by the risk of getting disease from the carrier animals, such as rats, flies and cockroaches by 39.7 percent, annoying disturbances by 28.8 percent, scenery problems by 9.4 percent, and conflicts in the community by 8.6 percent. (Figure 4.33)

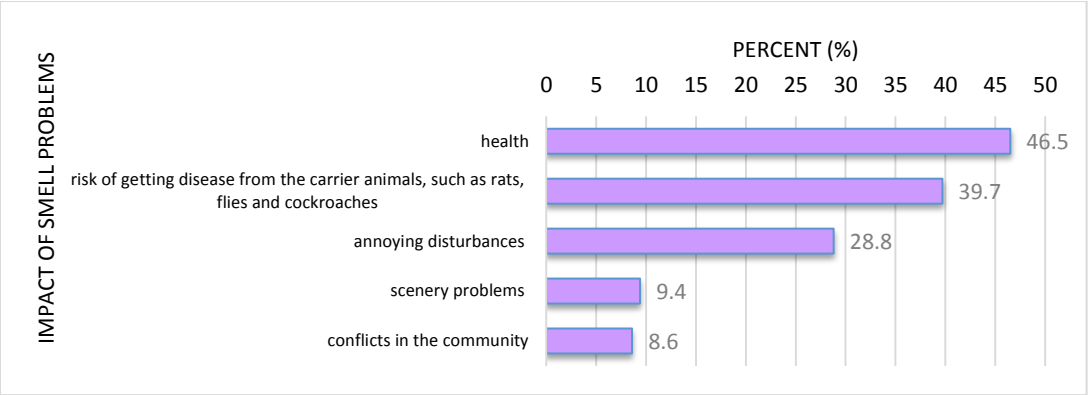

Figure 4. 33 Impacts of smell

Most people agreed that the problem of air pollution and odor should be campaigned to reduce burning by using landfill for agricultural materials instead. Also, for the matters related to industrial factories, the relevant authorities must enforce the law and control the factories to follow the standards.

4.2.9 Solid waste

From the interview with key informants, it was found that the problem of solid waste in the Lam Nam Yang Part1 watershed was not so severe. However, the volume of solid waste was more likely to increase every day. Generally, solid waste production rates typically varied in each different region based on activities happened in the communities. The urban communities' solid waste production rates were often higher than the far away local communities. In addition, the types of solid waste were different as well. In the Yang Part 1 Watershed, most people had their ways to deal with solid waste from households. Some households did not pay attention to the sorting of solid waste, prepared their own containers before burning the garbage. Some households had no garbage containers, but instead, they kept various types of garbage together in a bag before left them on a public sidewalk, street lawns, under the trees and in the streams. The most found of the solid waste dumped each day was fresh or wet solid waste, for example, food, meat and vegetable scraps, leaves, and fruit peel; followed by general solid waste, for example, scrap paper, plastic bag, snack pack, foam box. From improper solid waste management in public, the consequences were the smell of the garbage, the problems of flies and disease carrier

animals, the smoke from burning various types of garbage and wastewater problem. The solid waste management carried out by local governments was often done of by landfill.

There were leftovers from agricultural activities in the Lam Nam Yang Part1 Watershed, causing remaining things as the wastes. In some far away areas, in the area surrounded by high mountains, most people do farming at the end of the agricultural harvest season, and get rid of the rice stalks, leaves, and corn husks by burning them, resulting in smog, and increased risks of wildfire.

The interview with key informant revealed that there were not many complaints about the waste in the Lam Nam Yang Part1 watershed. The survey found that people thought that the issue of solid waste caused by the waste from households by 41.6 percent, followed by inadequate waste disposal areas by 40.0 percent, the residual waste/no waste storage by 36.6 percent, the agricultural waste by 21.0 percent, the establishments/ industrial factories by 15.6 percent, and others by 0.5 percent. (Figure 4.34)

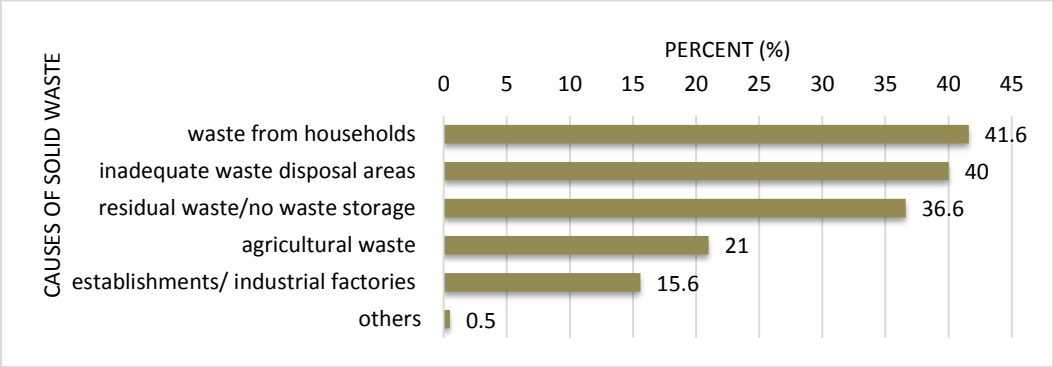

Figure 4. 34 Causes of solid waste generation

The problem affected the increase in disease by 58.2 percent, followed by the impact on health by 48.1 percent, the smell bothering by 34.8 percent, scenery issues by 20.3 percent, and conflicts in the community by 12.5 percent. (Figure4.35)

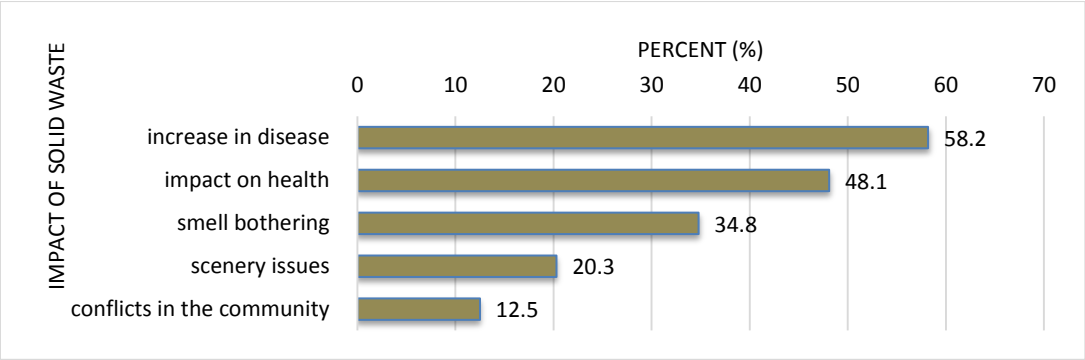

Figure 4. 35 Impacts of solid waste generation

4.2.10 Natural and cultural heritages

There were abundant of natural attractions in the Lam Nam Yang Part1 Watershed, such as rivers, streams, waterfalls, mountains, forests and wildlife. The discovery of ancient fossils, such as petrified dinosaurs, ancient petrified trees, petrified ancient fish and shellfish and many interesting archaeological sites. The important natural attractions and historical and archaeological attractions as the database of conserve natural resources and heritages of ONEP (2015) in the Lam Nam Yang Part1 watershed is shown in figure 4.36.

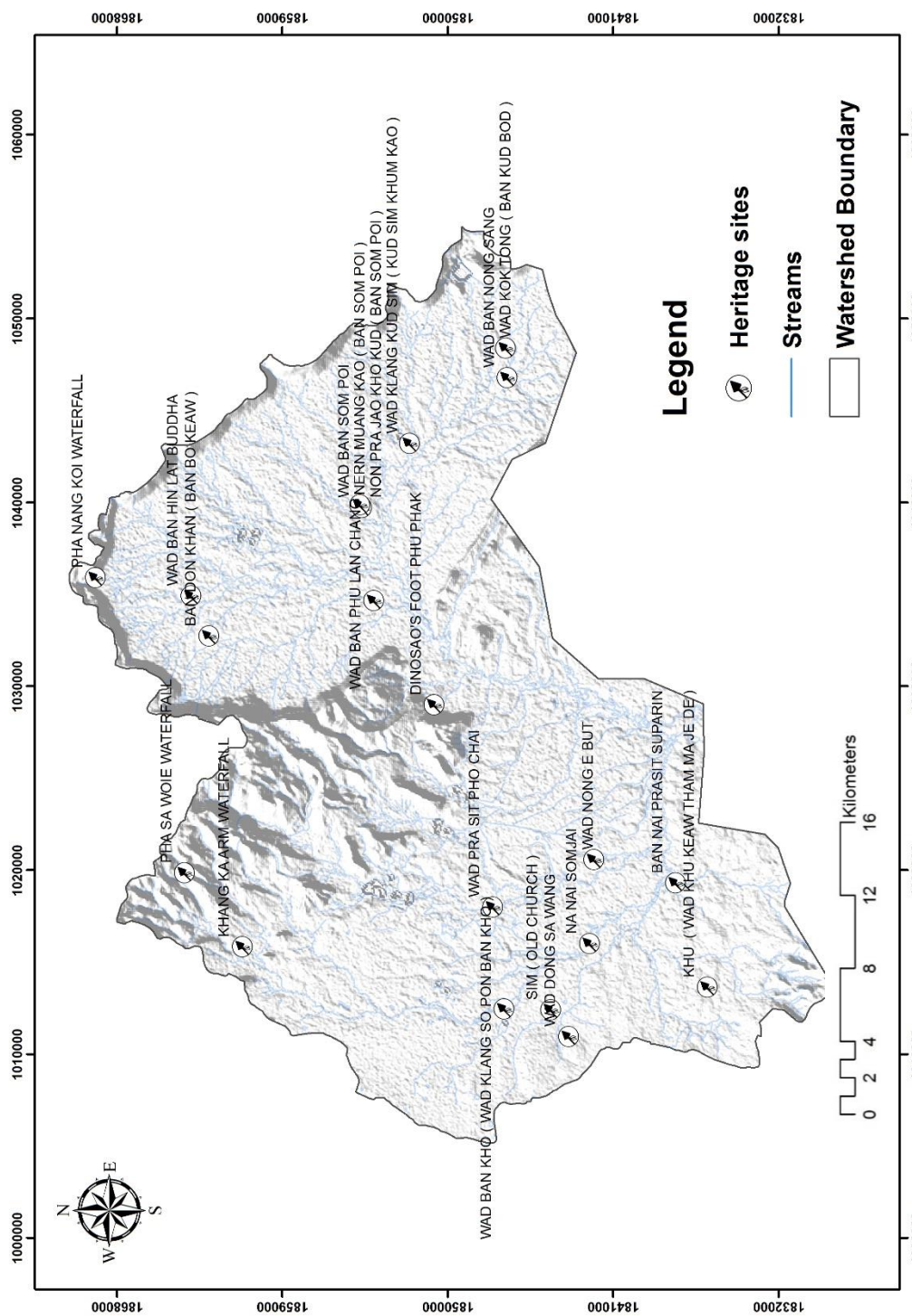

Figure 4. 36 Important natural and cultural heritages in the Lam Nam Yang Part1 watershed

Natural and cultural heritages in the Lam Nam Yang Part1 Watershed were one of the recreational area of the community, the study place for youth, and the attraction for tourists. Important tourist attractions were Tat Soong waterfall, Tat Thong waterfall, Pha Nang Khoi waterfall, Sawei, Kaeng Ka-am waterfall, Phuphaphung, Red Palm Cave, Dinosaur Footprints, 160 million years Rock Fish Museum, Fossils and petrified wood attractions, various temples. Moreover, in the Lam Nam Yang Part1 Watershed, there were cultural attractions, including Phrae Wah woven silk group, which was the arts of Chao Phu Thai handcrafts, and Culture Village, which was a village with a conservation of Chao Phu Thai culture, etc.

From the interviews with key informants, it was found that natural and cultural attractions in the Lam Nam Yang Part1 Watershed were not so popular. Most of them were known only in the locals, and did not have infrastructure or activities that supported the tourists, except in the route pass through Phu Phan National Park, for example, Pha Sawei and Khang Kra Arm waterfall. The natural and cultural resources in the areas were used for recreation and learning places in the community. However, several temples were deteriorated. The lifestyle of people who associate with temples for a long time had changed. Local authorities and people lacked knowledge and understanding of the importance and value of those attractions, leading to the destruction caused by ignorance. Today, many artistic sources were in a state of decline. The reasons might be due to the changes in values and patterns of thinking that it was old-fashioned. Some places left a few remained traces. In terms of culture, the good traditions were changed as well, which could be seen by young Phu Thai people in Khao Wong district who currently not wear silk woven fabrics that were the endemic uniqueness. If this continued, the natural, artistic and cultural environment would eventually decline.

Data from the survey found that most people believed the deterioration of the natural and cultural heritages caused by the natural degradation by 54.0 percent, followed by the lack of knowledge and understanding of the importance by 29.4 percent, the issue of intrusion for benefits by 18.4 percent, the building that against nature and the surrounding by 15.1 percent, the illegal excavation, demolition, relocation, and constructing various utility services by 14.5 percent, and others by 0.5 percent (Figure 4.37).

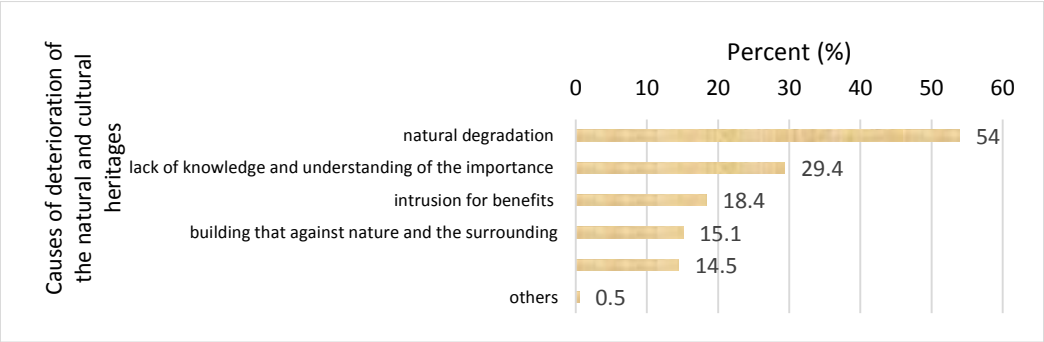

Figure 4. 37 Causes of natural and cultural heritages deterioration

The problem affected the national heritage being destroyed by 45.5 percent, followed by lessen community pride and solidarity by 41.3 percent, no recreational areas by 26.0 percent, scenic and aesthetic issues by 22.9 percent, the lack of income from tourism by 16.6 percent, and the conflicts in the community by 12.5 percent (Figure 4.38).

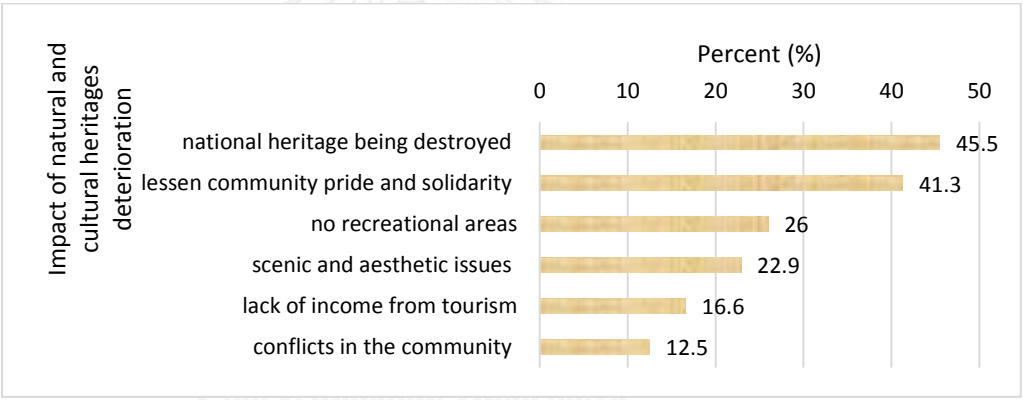

Figure 4. 38 Impact of natural and cultural heritages deterioration

4.3 The priority of environmental problems in Lam Nam Yang Part watershed

4.3.1 Key environmental issues in the watershed

Data from the survey found that most people paid highest attentions on problem of water shortage for agriculture, followed by problems of water shortage for consumption, lack of soil fertility, forest destruction, decrease in plant and animal species, and soil erosion and loss of topsoil, respectively by levels of awareness. Other minor problems that people focused on were the problems of degradation of natural environment and arts, problems of waste, odors, air pollution, wastewater and

flooding, respectively (Figure 4.39). Relevant stakeholders also confirmed that these key environmental issues were major threats of the Lam Nam Yang Part1 watershed.

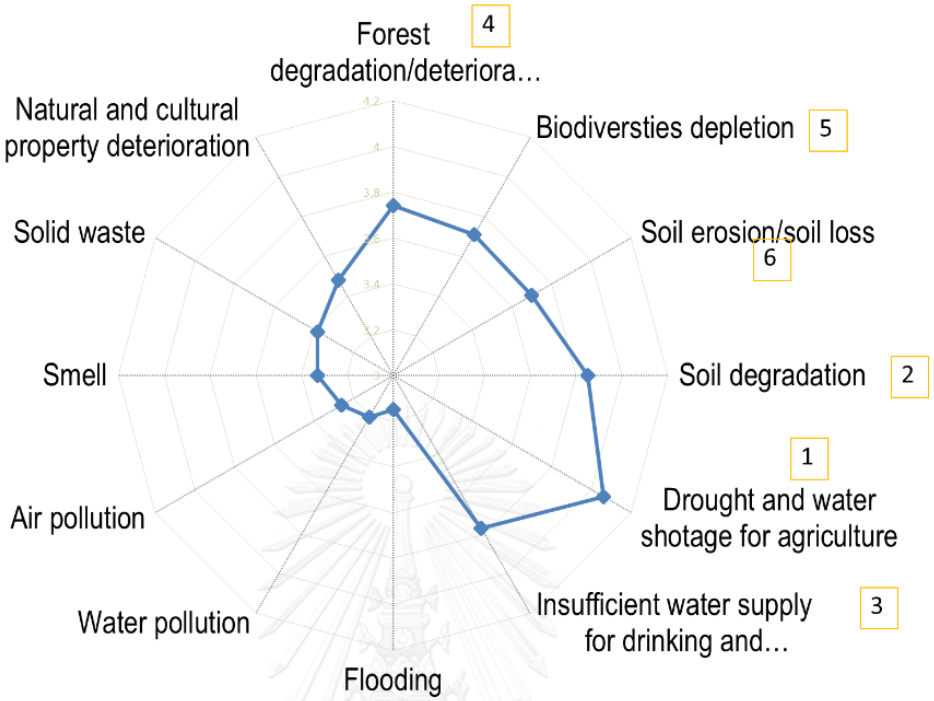

Figure 4. 39 Key environment issues in the watershed

4.3.2 Factors affecting the environmental solving problems

It was found that the main factor influencing the environmental problems solving in the watershed areas were the lack of funding, followed by inconsistent solution with wisdom and needs of the community, lack of public awareness and understanding, unserious problems solving of officials/authorities, lack of coordination mechanisms between central/local government/community organizations, respectively. Other minor factors with less public attention included poverty and unfavorable economic conditions, inefficient policies, inappropriate regulations/legislations, and increased number of population in the watershed areas, respectively (Figure 4.40).

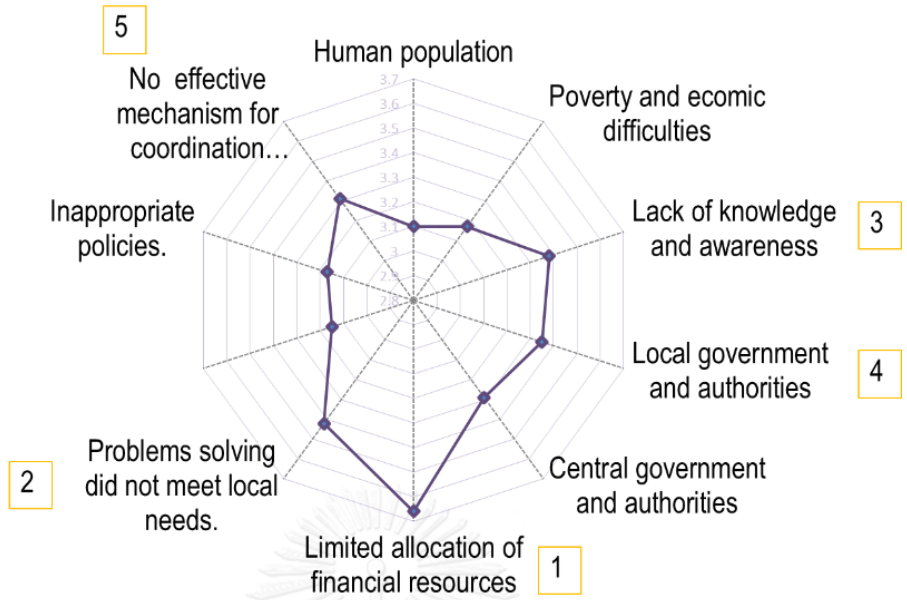

Figure 4. 40 Factors affecting the environmental solving problems

4.3.3 Impacts of environmental problems on watershed ecosystem and livelihood

People saw that the impacts of environmental problems occurred in watershed areas were climate variability (for example, no proper rain in seasons, humidity), followed by the impact on wildlife and aquatic life, severe natural disasters, less agricultural production, ecological changes, respectively by the levels of awareness. Other minor impacts were the impact on the safety of life and property, impact on quality of health, inappropriate recreational attraction, less opportunities to access and use resources, conflicts and competitions over resources, reduced value of property and land, no job, and unsuitable residential, respectively (Figure4.41).

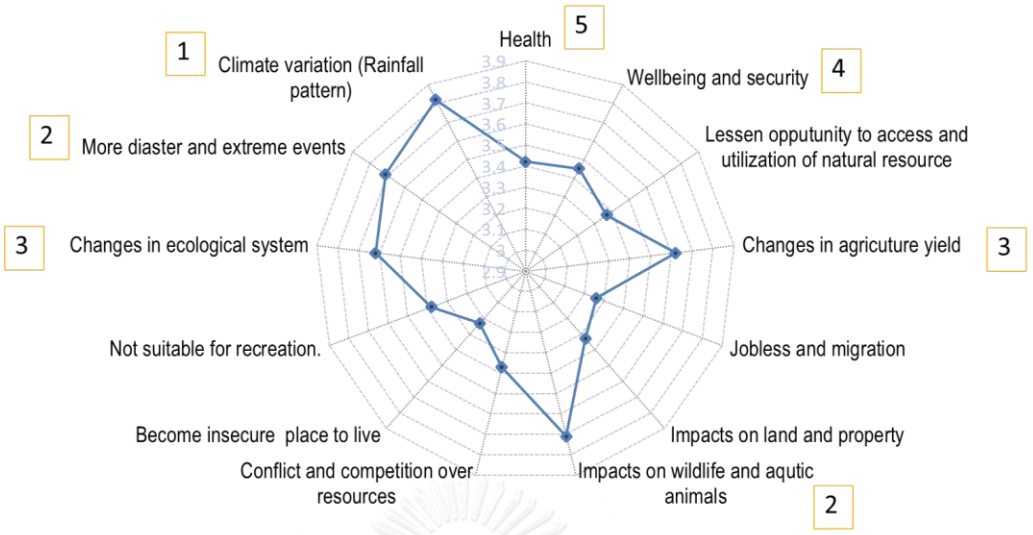

Figure 4. 41 Impacts of environmental problems on watershed ecosystem and livelihood

4.3.4 Importance of watershed resources

People were aware of the most importance of watershed areas as watersheds by seeing it as various resources of minerals, wood and others, followed by the importance of being the habitats of plants, wildlife and biodiversity, being the source of people's careers, slowing and controlling water flow, maintaining the pure air, circulating energy and nutrients, controlling the erosion of topsoil, being resources of surface water and groundwater, being sources of food and medicines, maintaining spectacular natural scenery and tourist attractions, being sources of learning for population, being the residential for people and society, being the recreation places, and being places with culture and tradition, respectively.

4.4 Management and Participation in the Lam Nam Yang Part1 Watershed

4.4.1 Stakeholders in the Lam Nam Yang Part1 Watershed

At a watershed level, the stakeholders are the keys to operate and implementing watershed management, they include government (all relevant line agencies and authorities at both national, provincial and district levels), civil society organizations (such as water user groups), local NGOs, academia (universities and

other research and development institutions) and the private sector. From review literature and preliminary interviews with local authorities, stakeholder groups in the Lam Nam Yang Part1 watershed can be divided into hierarchies shown in figure 4.42.

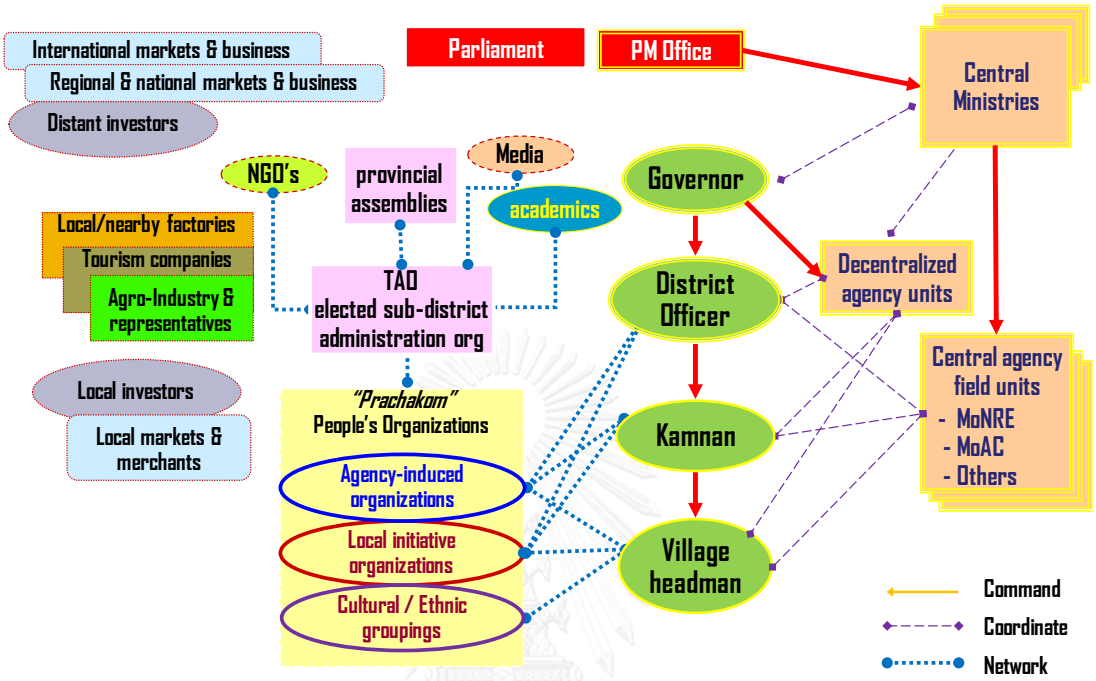

Figure 4. 42 Current stakeholders & institutional in the Lam Nam Yang Part1 Watershed (Adapted from Thomas, 2006)

Stakeholders of Lam Nam Yang Part1 Watershed were analyzed as follows:

1. Primary Stakeholders referred to groups of people/communities that were associated with the exploitation of natural resources in the watershed areas directly. Also, they might be affected by the development of a watershed in any way, which linked to the change in community life from the original. For example, forest officers, land officials, national park officials, pollution control officers, as well as organizations related to permissions, etc.

2. Secondary Stakeholders referred to groups of people/communities that were associated with the exploitation of natural resources in watershed areas indirectly. Also, they might be affected by the development of a watershed in any way, more or less, which was a result of the actions of the primary stakeholders. For example, buyers of agricultural products produced in the watershed areas, manipulators of

watershed and natural resources development plan, examiners of implementation for watershed development plan, related people of watershed studies and so on.

At the watershed level, there are central agency field units, administrative units, people's organizations, users groups, NGOs, and others. The list of the stakeholders groups in the Lam Nam Yang Part1 watershed is shown in Table 4.1, and roles of stakeholders' is shown in Table 4.2.

Table 4. 1 List of the stakeholders in the Lam Nam Yang Part1 Watershed

Government agencies	***Non-governmental agencies***
National Level	People's Organizations
Ministry of Agriculture and Cooperatives	*Watershed network groups*
Ministry of Interior	*Natural Resources and Environmental Protection Volunteer Network*
Ministry of Natural Resources and Environment	*Community forest network*
Ministry of Industry	*Assembly of the poor*
Provincial Level	*Alternative Agriculture Network – Esan*
Governor's Office	*The Village Heads Association*
Provincial Administration Organizations	*Water user groups* (*Industrial, Agriculture, and Commercial)*
Provincial Assemblies	Private Sectors
Provincial office of Natural Resource and Environments	*Provincial Chamber of Commerce*
Provincial Irrigation projects	*Agro-industry representatives*
Provincial Waterworks Authority	*The Federation of Thai Industries*
Provincial Electricity Authority	*Tourism companies*
Forest resource management office	Academic
Provincial Agricultural Extension Office	*Rajaphat Universities (Kalasin)*
Land Development Provincial Station	*Schools*
Provincial Fisheries Offices	NGOs
Provincial Agricultural Land Reform Offices	*Esan Cultural Lifestyle Association*
Provincial Public Work Offices	Media
Educational Service Area Office Regions	*Community Radio*
Regional Office of Fine Arts	*Editor of the local newspaper network Northeast*
Community Development Provincial Offices	Individual
Coordination and Management of Lower Chi River Basin Division	*Watershed Management Advisors/ Specialists/ Experts,*
District and Sub-district Level	*Local wisdom people*
Districts and sub-district agencies	
Municipalities, Sub-district (sub-district headmen, village heads)	

Sources: Department of Water Resources (2010) and Kuntiyawichai (2012)

Table 4. 2 Stakeholders roles in of Lam Nam Yang Part1 Watershed.

Stakeholders roles in watershed management	Types/groups of main stakeholders					
	community/agriculturists	Local authorities/community leaders	Government	Private organizations	Academic institutions	Private sector
1. Be the direct user of natural resources in the watershed.	√	√				
2. Be the definer of policy/measures for watershed development.			√			
3. Be the transferor of policy for decentralization.		√	√			
4. Be the sponsor helping and supporting the community in various terms to improve living quality.				√	√	√
5. Be the communicator for awareness and understanding on the conservation of natural resources and environment.					√	
6. Be the person with a relationship with the community, both vertically and horizontally.		√	√			
7. Be the overseer of laws and regulations implementation related to watershed areas.			√			
8. Be the encourager for public participation of local communities and partners.		√	√	√		
9. Be the operator preparing program/project for watershed development.		√	√			

(Adapted from ONEP, 2013)

Generally, people, agencies and organizations at various levels may be involved in watershed management. There are many executing and implementing agencies from central ministries working in watershed resources development and management. Each of the agencies has its own roles and responsibilities, in which some of them are shared responsibilities among different agencies. Roles of stakeholders in Lam Nam Yang Part1 watershed is presented in Table 4.3.

Table 4. 3 The roles of stakeholders of the watershed with the utilization

Group of watershed resources users	Forms of exploitation	Relationships of other stakeholders	Conditions of occurred problems	The need for watershed exploitation
1.Agriculturists (crops)	The use of land and water.	The use of land, water, production systems and market forces.	Soil decadence/water shortage/decreased productivity.	Optimizing the efficiency of land and water resources usage.
2. Farmers (livestock)	The use of land and water.	The use of land, water, production systems and market forces.	Soil decadence/water shortage/decreased productivity.	Optimizing the efficiency of land and water resources usage.
3. Group of water consumers	The use of land and water.	The use of land, water, production systems and market forces.	Soil decadence/water shortage/decreased production/collaborative ability/building regulations for water usage.	Optimizing the efficiency of land and water resources usage.
4. Group of resort/tourist accommodation entrepreneurs	The use of land and water.	The use of land, water, group of consumers, the use of resources in the watershed.	Water shortage/tourism activities affecting the environment.	The public promotion and development for public infrastructure and utilities.
5. Group of industrial entrepreneurs	The use of land, water and agricultural raw materials.	The use of land and water, the use of agricultural raw material, production system and market mechanisms.	Water shortage/pollution emissions to the environment.	The public promotion and development for public infrastructure and utilities.
6. Forestry Agencies	The management of forest/conservation areas.	Area governance, area surveillance and permitting.	The number of officials/law enforcement/participation	Defining a clear area's boundary and surveillance against the offense.
7. Administrative agencies	Laws enforcement and community coordination.	Area governance, area surveillance, permitting and dispute resolution.	The number of officials/law enforcement/participation.	Defining a clear area's boundary and surveillance against the offense, as well as community coordination.
8. Agricultural agencies	Promotion of economically important crops based on government policies.	The promotion for economic crops based on government policies.	The belief of agriculturists/ number of officials/budget	Promoting knowledge to agriculturists and supplying plant seeds to response the demand.
9. Water resources agencies (DWR), (RID), (DGW)	The development, rehabilitation, conservation of water resources, supporting the role of watershed committee, supplying and developing ground water, drilling, control and protecting groundwater.	The promotion for public participation in the watershed communities, integration for solving flood/drought problems.	The number of officials/law enforcement/ dispute resolution/ participation.	Supplying sufficient water to the needs of agriculturists and other sectors.
10.Environmental agencies	Environmental quality	Supervision, planning and surveillance in	The number of officials/law	Promoting the preparation for

Group of watershed resources users	Forms of exploitation	Relationships of other stakeholders	Conditions of occurred problems	The need for watershed exploitation
	management planning and environmental pollution monitoring (waste/wastewater/solid waste)	the areas and permitting, and encouraging for participation.	enforcement/ dispute resolution/participation.	participative integrated natural resource and environmental management plan.
11. Local government	The local governance and communities' living quality development	Local management, community's living quality development planning.	The number of personnel/ knowledge on management/monitoring and evaluation.	Promoting knowledge for local development, exchanging the roles and missions, as well as budgets for local development.
12.Religious places/monk's accommodations/temples	The performance of religious activities/doctrines propaganda	The use of land, evangelism, and the use/conservation of forest resources.	Invading state land/natural ecosystem disturbance.	Supervising and preventing areas from interference from religious activities, monitoring and surveillance.
13.Local schools	The knowledge sharing places.	Encouraging youth education, academic services in the communities, conservation of natural resources and the environment.	Less personnel/ budget/knowledge in conservation	Promoting access to knowledge on conservation, and preparing local environmental curriculum.
14. Private organizations for various fields of conservation	The support/assistance for community and community development.	The community development, coordination of public and private sectors, and monitoring environmental quality.	Attitude in working with public sectors/ trust/budget/ data and information.	Integrating geospatial work with the collaboration of state, community and private organizations
15.Volunteer network for local resources and environmental protection	The community's support/monitoring/ development for natural resources and the environment.	The development/monitoring/ surveillance/public relation for natural resources and environment.	The support/integration with government agencies/ budget/knowledge.	Integrating local works in the areas together with government agencies.

(Adapted from ONEP, 2013)

4.4.2 Management and Participation problems in the Lam Nam Yang Part1 Watershed

The Lam Nam Yang Part1 is managed by the Yang Sub-basin committee, which is under the Department of Water Resources, Ministry of Natural resources and Environment. The Yang Sub-basin Committee consisted of 44 committee members concluding provincial level agencies, district agencies, water user groups and individuals. This committee has a regulatory body with the task to manage water resources and also to integrate IWRM in the national water management process. The Water Resources Regional office 4 was assigned to serve as secretaries of the Yang Sub-basin which is part of the Chi River Basin Committees.

Information on the problems of management of the yang sub-basin administration was shared by key informant interviews who are the basin official secretary committee and other 2 sub-basin committees. The problems of the management of the watershed can be summarized as follows:

1) Organizational and administrative problems consisting of the lack of unity and organizational integration and associated divisions, unclear job description and responsibility.

2) Issues of compliance with policies and plans such as the past policy of water resource management that had ambiguous numbered goal and did not cover the relevant important factors.

3) Lack of unity and participation from stakeholders at all levels, and also lack of integrated management of natural resources and environmental management

4) Law and regulation problems that had various issues, lacked unity and were outdated such as water resource law, basic water rights, forest related laws and regulations which had to be changed in accordance with the current situations.

5) Lack of information, good data-based, useful information.

6) Insufficient budget problems: there was no insufficient, irrelevant and necessary budget allocation because it was based on the previous pattern of budget allocation that was not necessary, ambiguous, and politic-involved and more distributions in fewer amounts. More importantly, there were various organizations from different ministries managed watershed resource freely causing lack of unity and cooperation or integrated operational plans and budgets.

7) Lack or low level of participation of stakeholders especially the local leader, experts, teachers, and the local wisdom of the community in planning and be partnership of the management in the areas.

4.4.3 Perception of people on Management of the Natural Resources, Environment and Sustainability in the watershed

From the opinion of the people to the management of the natural resources, environment and sustainability in the watershed, it was found that people had different ideas which are:

4.4.3.1 Information sharing

Most people received the information on the watershed management from the village broadcasting tower (59.2 %), the Department of Local Administration (PAO., SAO.) 50.1 %, neighborhood conversation (43.9 %), radio broadcast (39.5%), Regional Administration (District, Province), estimated 20.3 %, local newspaper and periodicals (15.1%) , the Central Authorities (13.9 %), membership in the groups participated in prevention, rehabilitation and estimation of natural resources and environment (13.2 %), educational institutes (12.5%), newspaper (11.2%), nongovernmental organization (7.3 %) and no information receiving (4.4 %).

4.4.3.2 Participation in the watershed management activities.

People received the information on natural resources and environment and watershed activities (75.1%), participated in environment management activities (19.5%), involved in planning at the local, provincial and watershed level (11.4 %), involved in monitoring of natural resources related activities (10.6%), being the advisors, committees, members of the environmental working groups (9.4%), gave an advice and information to various organization (6.8%) and others like being the former environment volunteers and the current members of tree bank (3.6 %).

4.4.3.3 The needs for participation in the watershed management.

Most people had the reasons to participate the activities because they wanted to know about the problem occurred and the work procedures in the watershed (58.4%), wanted to protect the environment for the next generations (35.6 %), wanted to protect the natural resources for sustainable and abundant ecosystem (30.4 %), able

to prepare for the upcoming problems (29.1 %), wanted to protect the resources that might be affected from the various development projects (17.7 %), assigned duty (11.4%), rights and duties under the Constitution (10.6%) and others (0.5%).

4.4.3.4 Roles and responsibilities in the natural resources and environment management the watershed

Most of the people thought that it should be the local people's duty to maintain and manage the natural resources and environment (88.8%) while others thought it should be the Local Administration's duty (PAO, Sub-district Municipality, SAO.), estimated 78.4 %. Some of them thought that the Regional Administration (36.6%) and the Central Authorities (35.6 %) should responsible for the duty, and others thought that NGO (27.8%), private sectors (24.4%), educational institutes (23.4 %) and public media (21.8%) should be in charge of the duty. However, some of the people thought that everyone in the society should have roles and responsibilities in this matter (7 %).

4.4.3.5 Satisfaction of the people on management of natural resources and environment in the watershed

It could be found in overall that the majority of people were greatly satisfied with the local people's natural resources and environment maintenance and management in the watershed. However, people were moderately satisfied with the Local Administration's duty (PAO, Sub-district Municipality, SAO.), the Regional Administration, the Central Authorities, educational institutes, media and private sectors respectively.

4.4.3.6 Suggestions for the Management of Natural Resources in the watershed

People had additional suggestions that everyone had to help maintaining the nature, established the natural resources preservation group in the community, coordinated with government agencies and assessed the past activities for sustainability. There should be promotion of applying Sufficient Economy Philosophy bestowed by His Majesty the King in managing the natural resources. To increase the cost of living of the people and to improve people's health, the community leader must have knowledge on the natural resource and environment solution. The

government agencies had to distribute the knowledge in the local community with more educated staffs so that people in the community could help perverse the forest, streams, river, and the environment to us these resources sustainability. The associated organizations had to be responsible and do the duty with full effort.

4.5 Environmental indicator development Process

The development of environmental indicators for sustainable watershed management of the Lam Nam Yang Part1 Watershed consisted of several steps, including analysis of the key environment issues using DPSIR framework as a determinant for selecting indicators, interviews with relevant experts for indicators development via their opinions, indicators selection by key stakeholders/local experts using criteria for the selection, and weight determining for selected indicators.

4.5.1 DPSIR of key environmental issues

From identification of natural resources and environment situation in 4.2, together with the survey result, it can be that the main problems influencing the sustainability of watershed were in 4 issues namely forest resources (forest depletion, biodiversity (decline of plant and animal species), water resources (water shortages for agricultural and water shortage for consumption) ,and soil resources (soil deterioration). These environmental problems affected the sustainability of watershed and livelihood of the people. From these problems, it could be analyzed to demonstrate the relationship of the various elements in the form of Driver-Pressure-State-Impact-Response framework (DPSIR) by started analyzing from state of the environment in each issues, for example, state or condition of the problems caused by driving force in economy, poverty, human behavior and climate change. In addition, the driving force influenced exploitation activities of human with environment, such as agriculture, use of forest resources, use of chemicals, causing changes in natural conditions and environment. The changes in environmental conditions would impact the performance of the entire watershed as physical or biological changes, as well as utilization and health of people. After that, the researcher analyzed how people or government should propose measures to response the Driver, Pressure, State, and Impact on the watershed and

livelihood. Also, the problems analysis using DPSIR framework would help developing and selecting environmental indicators systematically, and linked to the conditions of occurred problems, causes, effects and solutions clearly. The DPSIR of environmental issues in the watershed areas was presented in Figure 4.43.

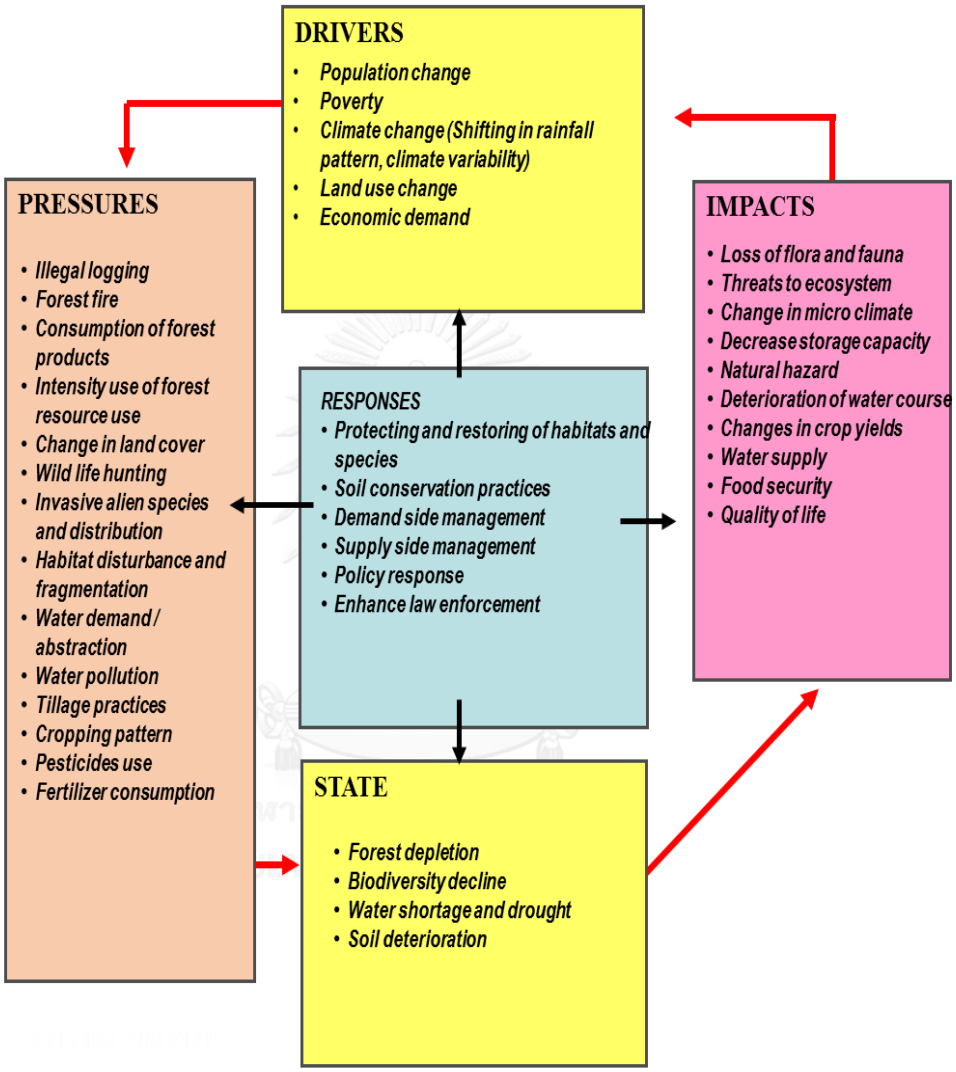

Figure 4. 43 DPSIR of the Lam Nam Yang Watershed Part 1

4.5.2 Experts interviews for indicators preparation

In the process of carrying out this work, the researcher interviewed 9 experts, including 2 experts from academic institutions, and 7 experts from agencies. The topics for interviews included problems and obstacles of previous indicators of Thailand, participation for indicators preparation, and possibilities of applying the

previous indicators in this study, criteria used for indicators selection, priority of the indicators, target configuration, the factors influencing the successful implementation of indicators, and helped in selecting the draft indicators of the Lam Nam Yang Watershed Part1. The details of the interviews were summarized below.

4.5.2.1 Problems and obstacles of indicators preparation and previous monitoring and evaluation of Thailand

1) Data collection of several environmental indicators, which did not collect every year, so there was no continuity. Due to some data required a lot of resources, for example, a lot of budget, need special techniques and large amount of data for data collection, data collected may have different definitions making the data difficult to be compared with each other, or in causes of outdated data (more than 5 years) or there was no update.

2) Technical Analysis or interpretation about the evaluation based on the discretion or expertise of each officer. Therefore, the results of evaluation in each subject that required many officers need to be trained, clarified and reviewed to be able to understood and established a qualified and up to acceptable and reliable standard evaluation system.

3) Monitoring and evaluation of many policies or plans on natural resources and environment applied different methods, indicators and evaluation criteria, and resulted in different or conflict results. For example, monitoring and evaluation of environmental quality management plan, pollution plan, Master Plan for climate change, or plan on biodiversity, etc.

4) The previous data received from monitoring and evaluation was not improved, did not be used for planning or did not be used for any plan review.

4.5.2.2 The importance and participation of various sectors for environmental indicators development

1) Various sectors should be involved in all steps of policies and plans preparation, for example, defining policies should involve the relevant policymakers, agencies, practitioners, and indicators collected agencies. (Jointly consider the suitability of each indicator/define a data collection framework/create up to standard information, etc.)

2) Participation in the indicators development was extremely important because the creators and users had to be coordinated together continuously in order to reduce the risk of producing data that did not meet the requirements and the risk of deviating indicators from reality. As a result, there should be integration of data and opinions on indicators, as well as the results analysis.

3) Encouraging related sectors to participated as much as possible in order to create the acceptance or confidence in the quality and standardization of information. For example, in cases of previous forest information, there were participative processes in gaining opinions on collected information, but there also were doubts and questions about the definition, used scale, used technique for data processing and others. Therefore, the lack of participation at any steps of the procedure might cause errors in the use of indicators or results reporting, so the annotation was needed to enable data users to be aware of using it for communication and transfer.

4.5.2.3 Possibilities and suitability for current indicators usage (from both domestic and international agencies) for application in the study area.

1) Processes of preparing environmental indicators had several limitations, as well as information providers for each indicator from various local or international agencies with different methodologies. Indicator users must consider the quality of the information thoroughly before using.

2) The indicators could be applied with appropriate consideration. Sometimes, the same indicators might have different names and sources. More indicators could be added, but not too much, and must be consistent with the context of the problems, objectives or needs of the area. For international indicators, the users must consider the indicators whether they were consistent with context of the areas or not, due to various factors, including different physical, economic and social conditions.

3) In addition, in the studies of watershed areas, the researchers might consider the qualitative indicators as well, because, sometimes, quantitative indicators could not indicate the performance or effectiveness of some fields of implementations, for example, the awareness of people in the area, the participative behaviors in activities or projects for natural resources and environment conservation, and so on.

4.5.2.4 Criteria and guidelines for environmental indicators selection.

1) It should be the representative offering a clear measurement of environmental condition, environmental pressure and community respond, as well as clear objectives of measurement.

2) It is required to be easy to understand and could demonstrate a trend from the past to the future.

3) It derived from reliable science theory that can be used practically, and be information with stable meaning from the same measuring and analyzing methods that were unchangeable over time. Also, tried to use data from the same data source to minimized data distortion arising from different data measurement and storage processes that could lead to measurement errors.

4) It is required to have flexibility and adaptability by the changing environment and human activities.

5) It should be able to be applied in many ways in national and regional scope to be universal.

The experts suggested that the criteria for using in this study watershed area had no need for too many criteria, and should be focused on understanding of the indicators users and overseers. The existing criteria and various agencies could be applied as used criteria should be consistent with objectives of the study. For example, it should respond to relevance to watershed sustainability, which met the needs of users or stakeholders who could understand and apply the indicators (Relevance to Stakeholders). Also, indicators should be measurable, reliable and did not cost much.

4.5.2.5 The importance priorities and weight of environmental indicators.

1) Environmental monitoring and evaluation was to determine the environmental situation in each year or each time with different problems and urgencies for problem resolution. Therefore, there should be an analysis of environmental importance priorities by defining criteria and evaluation, defining weight of environment and factors for monitoring.

2) Giving different weight did not mean that the indicators with less weight would always be less important, but based on the current factors and circumstances. When circumstances or environmental quality or policies changed, weight of indicators might need to be adjusted as well.

4.5.2.6 Objectives of environmental indicators.

1) The good objective defining should be defined from the analysis of how environmental situation was. At least, the defined objectives should respond and support the objectives of policies and plans at all levels, for example, national plan for economic and social development, government policies, environmental plans, watershed plans, provincial plans, etc.

2) The objectives should meet the environmental standards or be the considered truth with a balance of national prosperity development and environmental sustainability.

4.4.2.7 Factors or measures enhancing the process of environmental monitoring and evaluation and indicators utilization.

1) To define a clear scope of monitoring and evaluation, selecting techniques/methods/tools used in the monitoring and evaluation were the key to get the answer that met the monitoring objectives.

2) The participation of all sectors was a measure to create the monitoring and evaluation with clear agencies responsible for it. Also, all sectors would help watching and monitoring as watch dogs preventing data distortion, as well as creating a network for monitoring and evaluation.

3) Considering and selecting a lot of indicators as representatives that suit for the measurement was not needed. However, they should be qualified indicators with no change in the definition/scope from their original.

4.5.2.8 List of Indicators for the Lam Nam Yang Watershed

To acquire primary list of indicators, the researcher conducted a scoping exercise starting from identified, analyzed, and profiled the environmental indicators regarding the watershed sustainability from review of relevant documents on environmental indicators from various agencies at all levels, from international level, national level, as well as regional, provincial and district levels. The candidate indicators were selected by considering and selecting environmental indicators that were relevant to the analysis of state of environment of the Lam Nam Yang Part1 Watershed. After that, the experts help in selecting the indicators using DPSIR framework. Initially, the selected 101 environmental indicators categorized in the casual chain of Drivers, Pressure, State, Impact and Response, respectively. The

selected indicators consists of 13 Drivers indicator, 24 Pressure indicators, 24 State indicators, 21 Impact indicators, and 19 Response indicators as can be seen in Table 4.4.

Table 4. 4 List of indicators selected by experts

No.	Type	Issue	Indicator name
1	Driver	Population change	Human population
2	Driver	Population change	Population growth
3	Driver	Population change	population density
4	Driver	Poverty	Population living below poverty line,
5	Driver	Poverty	Number of household with the minimum annual income of 30,000 Baht per person
6	Driver	Climate change	Shifting in rainfall pattern
7	Driver	Climate change	Change in mean annual precipitation
8	Driver	Climate change	Greenhouse gas emissions
9	Driver	Climate change	average temperature
10	Driver	Land use change	Proportion of change of each category of land use to another land use per unit of time
11	Driver	Economic demand	Agricultural products needs
12	Driver	Economic demand	market share of agricultural chemicals
13	Driver	Economic demand	wood products
14	Pressure	Illegal logging	Volume of tree fellings
15	Pressure	Illegal logging	Forest area damaged by illegal logging
16	Pressure	Illegal logging	forest crimes
17	Pressure	Forest fire	Area damaged by fire,
18	Pressure	Forest fire	Rate of occurrence of forest fires
19	Pressure	Forest fire	Legal action against people who causes forest fires
20	Pressure	Consumption of forest products	consumption of wood products
21	Pressure	Consumption of forest products	consumption of non-wood products
22	Pressure	Intensity use of forest resource use	Timber harvest
23	Pressure	Change in land cover	distribution of land-cover types across the total watershed area
24	Pressure	Wild life hunting	Species and numbers of wildlife being hunted
25	Pressure	Wild life hunting	Number of wildlife crimes
26	Pressure	Invasive alien species and distribution	abundance and distribution of selected invasive species
27	Pressure	Habitat disturbance and fragmentation	Recreation activities
28	Pressure	Habitat disturbance and fragmentation	infrastructure projects
29	Pressure	Water demand/abstraction	Water use by sectors,
30	Pressure	Water demand/abstraction	annual withdrawals of ground water
31	Pressure	Water demand/abstraction	area under irrigated crops
32	Pressure	Water demand/abstraction	area under irrigated paddy
33	Pressure	Water pollution	Effluent concentration and discharge
34	Pressure	Tillage practices	Arable areas under tillage practices

No.	Type	Issue	Indicator name
35	Pressure	Cropping pattern	Area of mono crops (selected crops)
36	Pressure	Pesticides use	Application rates of different pesticide categories
37	Pressure	Fertilizer consumption	Application rates (kg/rai) of N and P
38	State	Forest resources	Proportion of forest area to watershed's area
39	State	Forest resources	Proportion of remaining head watershed in the forest
40	State	Forest resources	Proportion of the remaining swamp forests and wetland areas
41	State	Forest resources	Reduction of stream and riparian vegetation,
42	State	Forest resources	Volume and structure of forests
43	State	Forest resources	Area of key ecosystems
44	State	Biodiversity	abundance and distribution of selected species
45	State	Biodiversity	Red list index
46	State	Biodiversity	Threatened species as a percent of total species
47	State	Biodiversity	Threatened or extinct as a share of total known species
48	State	Biodiversity	Existence of endangered species in the region
49	State	Water resources	Frequency, duration and extent of water shortages
50	State	Water resources	Overall reservoir stocks
51	State	Water resources	Water levels
52	State	Water resources	Percent of the runoff/rainfall
53	State	Water resources	Water flow duration (months)
54	State	Water resources	Base flow due to groundwater
55	State	Water resources	Proportion of agricultural areas with small-sized reservoir
56	State	Soil resources	Degree of top soil losses
57	State	Soil resources	Soil erosion rates
58	State	Soil resources	area affected by soil erosion
59	State	Soil resources	physical soil structure
60	State	Soil resources	chemical soil composition
61	State	Soil resources	biological soil components
62	Impact	Loss of flora and fauna	Absence of key species,
63	Impact	Loss of flora and fauna	species richness
64	Impact	Threats to ecosystem	concentration of heavy metals and organic compounds in environment and in living species
65	Impact	Change in micro climate	Relative humidity
66	Impact	Change in micro climate	Evapotranspiration
67	Impact	Decrease storage capacity	Total suspended solids concentrations in selected locations (Reservoir, natural storage)
68	Impact	Natural hazard	frequency of flooding
69	Impact	Natural hazard	land slide
70	Impact	Deterioration of water courses	BOD/DO in water
71	Impact	Changes in crop yields	Production of selected crops per rai
72	Impact	Water supply	Groundwater reserves depletion
73	Impact	Food security	Decrease in Medicine
74	Impact	Food security	fishery products
75	Impact	Food security	wild food
76	Impact	Quality of life	Number of households access to clean water for

No.	Type	Issue	Indicator name
			drinking and consuming compared to all households
77	Impact	Quality of life	Number of households with water available for utilization compared to the entire household
78	Impact	Quality of life	Communities that rely on forests for sustenance
79	Impact	Quality of life	Rate of migration
80	Impact	Quality of life	People who affected from natural disasters annually
81	Impact	Quality of life	Number of complaints on resource conflicts
82	Impact	Quality of life	Number of patients due to use of chemical pesticides
83	Response	Protecting and restoring of habitats and species	Protected area as a percent of total watershed area
84	Response	Protecting and restoring of habitats and species	Forest fire monitoring and controlling mechanism
85	Response	Protecting and restoring of habitats and species	Area of protecting stream and riparian buffer
86	Response	Protecting and restoring of habitats and species	Area of forest plantation
87	Response	Protecting and restoring of habitats and species	conservation activities
88	Response	Soil conservation practices	Ratio of land under sustainable agriculture to total agricultural area
89	Response	Soil conservation practices	% of farmers practicing soil and water conservation technologies
90	Response	Soil conservation practices	local agricultural programs to enforce sustainable farming management systems
91	Response	Soil conservation practices	planting cover crops
92	Response	Demand side management (water)	Efficiency of water use
93	Response	Demand side management (water)	water pricing
94	Response	Demand side management (water)	license of users
95	Response	Supply side management	Improve water storage capacity
96	Response	Supply side management	Improve water utility
97	Response	Policy response	Revision of forests policy to enhance the participation of communities and local government
98	Response	Policy response	land use planning
99	Response	Policy response	watershed management
100	Response	Policy response	provide disaster preparedness plan/early warning system
101	Response	Enhance law enforcement	No. lawsuit on forestry and wildlife cases

4.5.3 Selection of Potential Environmental indicators

4.5.3.1 Selection and priority of potential indicators

The researcher interviewed and asked 12 stakeholders and local experts to selected potential environmental indicators by using the prepared indicator sheets as a tool. The indicator sheet consisted of 101 indicators, which stakeholders could add more indicators as appropriate. The stakeholders and local experts used three criteria for selection, including the Relevance to Sustainable of Yang Part1 Watershed; Relevance to stakeholders; and Measurability and understandable by locales. Such criteria were processed and adapted from information collected by Dawson (2011);

Recommendations on the use of selection criteria for local purposes by von Schirnding (2002) together with the recommendations of experts to create a selection criteria for this study.

To define the scores of each criteria the researcher applied the suggested methodologies in the selection of draft sustainability indicators for Fraser Basin (Fraser Basin Counsil, 2000), the score rating for ecological indicators of the Coos watershed (University of Vermont, 2010), and the use of selection criteria for sustainability indicators for Capture Fishery in Songkhla Lake by Doungsuwan (2013). The stakeholders and local experts would score each of the criteria from 1 (low) to 4 (high), then the total scores of 3 criteria together could be used to find the average. Any indicator that received an average score of 3 or above was considered as passed for selection. The indicator sheet of total score is shown in Appendix E. The explanation of weight scoring for selection of potential environmental indicators is as Table 4.5.

Table 4. 5 Scores of each criteria in the selection of potential environmental indicators.

Description Score	**Criteria**			**Average score**
	Relevance to Sustainable of Yang watershed	**Relevance to stakeholders**	**Measurability and understandable by locales**	
1	Minimum relevance to sustainability of watershed.	Stakeholders paid less attentions and less utilization.	It should be measurable and understandable in minimum levels.	
2	Moderate relevance to sustainability of watershed.	Stakeholders paid moderate attentions and moderate utilization.	It should be measurable and understandable in moderate levels.	
3	High relevance to sustainability of watershed.	Stakeholders paid high attentions and high utilization.	It should be measurable and understandable in high levels.	
4	Maximum relevance to sustainability of watershed.	Stakeholders paid highest attentions and highest utilization.	It should be measurable and understandable in highest levels.	

The scores of 101 environmental indicators given by 12 stakeholders and experts was done by using the evaluation criteria is presented in Table 4.6.

Table 4. 6 Average Scores of each environmental indicators.

No.	**Type**	Issue	Indicator name	Critiria1	Critiria2	Critiria3	**Average**
1	Driver	Population change	Human population	2.83	3.00	2.58	2.80
2	Driver	Population change	Population growth	3.08	2.75	2.67	2.83
3	Driver	Population change	population density	3.58	3.42	3.08	3.36
4	Driver	Poverty	Population living below poverty line,	3.08	2.83	2.67	2.86

No.	Type	Issue	Indicator name	Critiria1	Critiria2	Critiria3	Average
5	Driver	Poverty	Number of household with the minimum annual income of 30,000 Baht per person	3.83	3.50	2.50	3.28
6	Driver	Climate change	Shifting in rainfall pattern	3.83	3.08	2.42	3.11
7	Driver	Climate change	Change in mean annual precipitation	3.50	3.42	2.75	3.22
8	Driver	Climate change	Greenhouse gas emissions	3.17	2.75	2.83	2.92
9	Driver	Climate change	average temperature	3.42	3.33	3.00	3.25
10	Driver	Land use change	Proportion of change of each category of land use to another land use per unit of time	3.42	3.42	2.50	3.11
11	Driver	Economic demand	Agricultural products needs	3.08	3.00	2.08	2.72
12	Driver	Economic demand	market share of agricultural chemicals	3.08	2.58	2.33	2.66
13	Driver	Economic demand	wood products	3.17	3.00	2.17	2.78
14	Pressure	Illegal logging	Volume of tree felling	3.08	3.00	2.17	2.75
15	Pressure	Illegal logging	Forest area damaged by illegal logging	3.67	3.50	2.83	3.33
16	Pressure	Illegal logging	forest crimes	3.33	3.00	2.25	2.86
17	Pressure	Forest fire	Area damaged by fire,	3.75	3.50	2.92	3.39
18	Pressure	Forest fire	Rate of occurrence of forest fires	3.08	3.00	2.17	2.75
19	Pressure	Forest fire	Legal action against people who causes forest fires	3.17	3.00	2.17	2.78
20	Pressure	Consumption of forest products	consumption of wood products	3.33	3.00	2.25	2.86
21	Pressure	Consumption of forest products	consumption of non-wood products	3.25	2.75	2.83	2.94
22	Pressure	Intensity use of forest resource use	Timber harvest	3.17	3.00	2.25	2.81
23	Pressure	Change in land cover	distribution of land-cover types across the total watershed area	3.17	3.25	2.58	3.00
24	Pressure	Wild life hunting	Species and numbers of wildlife being hunted	3.17	2.83	2.50	2.83
25	Pressure	Wild life hunting	Number of wildlife crimes	3.17	3.00	2.17	2.78
26	Pressure	Invasive alien species and distribution	abundance and distribution of selected invasive species	3.17	2.83	2.83	2.94
27	Pressure	Habitat disturbance and fragmentation	Recreation activities	3.33	3.00	2.25	2.86
28	Pressure	Habitat disturbance and fragmentation	infrastructure projects	3.17	3.00	2.08	2.75
29	Pressure	Water demand/abstraction	Water use by sectors,	3.50	3.33	2.25	3.03
30	Pressure	Water demand/abstraction	annual withdrawals of ground water	3.17	3.25	2.50	2.97
31	Pressure	Water demand/abstraction	area under irrigated crops	3.17	2.83	2.83	2.94
32	Pressure	Water demand/abstraction	area under irrigated paddy	3.25	3.00	2.25	2.83
33	Pressure	Water pollution	Effluent concentration and discharge	3.17	2.75	2.83	2.92
34	Pressure	Tillage practices	Arable areas under tillage practices	3.33	3.00	2.25	2.86
35	Pressure	Cropping pattern	Area of mono crops (selected crops)	3.25	3.00	2.17	2.81
36	Pressure	Pesticides use	Application rates of different pesticide categories	3.75	3.42	2.83	3.33
37	Pressure	Fertilizer consumption	Application rates (kg/rai) of N and P	3.17	3.00	2.17	2.78

No.	Type	Issue	Indicator name	Critiria1	Critiria2	Critiria3	Average
38	State	Forest resources	Proportion of forest area to watershed's area	3.25	3.25	3.00	3.17
39	State	Forest resources	Proportion of remaining head watershed in the forest	3.58	3.50	2.58	3.22
40	State	Forest resources	Proportion of the remaining swamp forests and wetland areas	3.08	3.00	2.17	2.75
41	State	Forest resources	Reduction of stream and riparian vegetation,	3.17	3.00	2.17	2.78
42	State	Forest resources	Volume and structure of forests	3.33	3.00	2.25	2.86
43	State	Forest resources	Area of key ecosystems	3.08	3.00	2.17	2.75
44	State	Biodiversity	abundance and distribution of selected species	3.58	3.67	2.75	3.33
45	State	Biodiversity	Red list index	3.08	3.00	2.33	2.80
46	State	Biodiversity	Threatened species as a percent of total species	3.92	3.33	3.00	3.42
47	State	Biodiversity	Threatened or extinct as a share of total known species	3.08	3.00	2.42	2.83
48	State	Biodiversity	Existence of endangered species in the region	3.17	3.00	2.25	2.81
49	State	Water resources	Frequency, duration and extent of water shortages	3.67	3.42	2.50	3.20
50	State	Water resources	Overall reservoir stocks	3.83	3.75	3.50	3.69
51	State	Water resources	Water levels	3.92	3.75	3.25	3.64
52	State	Water resources	Percent of the runoff/rainfall	3.08	3.00	2.17	2.75
53	State	Water resources	Water flow duration (months)	3.17	2.75	2.75	2.89
54	State	Water resources	Base flow due to groundwater	3.17	3.00	2.17	2.78
55	State	Water resources	Proportion of agricultural areas with small-sized reservoir	3.17	3.00	2.25	2.81
56	State	Soil resources	Degree of top soil losses	3.92	3.50	3.00	3.47
57	State	Soil resources	Soil erosion rates	3.25	2.75	2.83	2.94
58	State	Soil resources	area affected by soil erosion	3.17	3.00	2.25	2.81
59	State	Soil resources	physical soil structure	3.75	3.58	3.00	3.44
60	State	Soil resources	chemical soil composition	3.25	3.00	2.42	2.89
61	State	Soil resources	biological soil components	3.00	2.67	2.83	2.83
62	Impact	Loss of flora and fauna	Absence of key species,	3.17	3.00	2.25	2.81
63	Impact	Loss of flora and fauna	species richness	3.25	3.00	2.25	2.83
64	Impact	Threats to ecosystem	concentration of heavy metals and organic compounds in environment and in living species	3.17	2.75	2.83	2.92
65	Impact	Change in micro climate	Relative humidity	3.33	3.00	2.25	2.86
66	Impact	Change in micro climate	Evapotranspiration	3.08	3.00	2.25	2.78
67	Impact	Decrease storage capacity	Total suspended solids concentrations in selected locations (Reservoir, natural storage)	3.67	3.50	2.83	3.33
68	Impact	Natural hazard	frequency of flooding	3.25	3.00	2.25	2.83
69	Impact	Natural hazard	land slide	3.17	2.75	2.83	2.92
70	Impact	Deterioration of water courses	BOD/DO in water	3.08	3.00	2.25	2.78
71	Impact	Changes in crop yields	Production of selected crops per rai	3.83	3.42	2.58	3.28
72	Impact	Water supply	Groundwater reserves	3.25	3.00	2.25	2.83

No.	Type	Issue	Indicator name	Critiria1	Critiria2	Critiria3	Average
			depletion				
73	Impact	Food security	Decrease in Medicine	3.08	2.75	2.75	2.86
74	Impact	Food security	fishery products	3.33	3.00	2.25	2.86
75	Impact	Food security	wild food	3.42	3.00	2.33	2.92
76	Impact	Quality of life	Number of households access to clean water for drinking and consuming compared to all households	3.92	3.92	3.25	3.70
77	Impact	Quality of life	Number of households with water available for utilization compared to the entire household	3.50	3.50	2.92	3.31
78	Impact	Quality of life	Communities that rely on forests for sustenance	3.25	3.00	2.25	2.83
79	Impact	Quality of life	Rate of migration	3.17	2.75	2.58	2.83
80	Impact	Quality of life	People who affected from natural disasters annually	3.33	3.00	2.25	2.86
81	Impact	Quality of life	Number of complaints on resource conflicts	3.08	3.00	2.25	2.78
82	Impact	Quality of life	Number of patients due to use of chemical pesticides	3.42	3.33	2.83	3.19
83	Response	Protecting and restoring of habitats and species	Protected area as a percent of total watershed area	3.83	3.42	3.00	3.42
84	Response	Protecting and restoring of habitats and species	Forest fire monitoring and controlling mechanism	3.33	3.00	3.33	3.22
85	Response	Protecting and restoring of habitats and species	Area of protecting stream and riparian buffer	3.42	3.00	2.25	2.89
86	Response	Protecting and restoring of habitats and species	Area of forest plantation	3.50	3.25	2.33	3.03
87	Response	Protecting and restoring of habitats and species	conservation activities	3.25	3.00	2.25	2.83
88	Response	Soil conservation practices	Ratio of land under sustainable agriculture to total agricultural area	3.00	2.75	2.83	2.86
89	Response	Soil conservation practices	% of farmers practicing soil and water conservation technologies	3.50	3.25	2.92	3.22
90	Response	Soil conservation practices	local agricultural programs to enforce sustainable farming management systems	3.50	3.00	2.25	2.92
91	Response	Soil conservation practices	planting cover crops	3.33	3.67	3.08	3.36
92	Response	Demand side management (water)	Efficiency of water use	3.33	3.00	2.25	2.86
93	Response	Demand side management (water)	water pricing	3.25	3.00	2.25	2.83
94	Response	Demand side management (water)	license of users	3.17	3.00	2.25	2.81
95	Response	Supply side management	Improve water storage capacity	3.42	3.58	2.58	3.19
96	Response	Supply side management	Improve water utility	3.17	2.92	2.17	2.75

No.	Type	Issue	Indicator name	Critiria1	Critiria2	Critiria3	Average
97	Response	Policy response	Revision of forests policy to enhance the participation of communities and local government	3.17	2.75	2.83	2.92
98	Response	Policy response	land use planning	3.08	3.00	2.25	2.78
99	Response	Policy response	watershed management	3.00	3.00	2.25	2.75
100	Response	Policy response	provide disaster preparedness plan/early warning system	3.00	2.67	2.75	2.81
101	Response	Enhance law enforcement	No. lawsuit on forestry and wildlife cases	3.00	3.00	2.17	2.72

From the results of selection of potential environmental indicators based on the scores received, it was found that there were 31 indicators with the average over 3, including 6 Drivers indicators, 5 Pressure indicators, 9 State indicators, 5 Impacts and 6 Response indicators, respectively.

4.5.3.3 Weighing of Indicators

In the second interview, the researcher processed 31 selected potential environmental indicators to create additional details of 5 components, including Drivers, Pressure, State, Impact and response, so that all stakeholders and local experts could consider the weight of every indicators by using indicator sheet as a tool with a weighting method called Multi Criteria Analysis (Ratio estimation) following Malczewski (1999) cited in Tantasirin, 2008). The steps on weighting indicators were as follows:

1) Assign ratio scale for each indicators from 1-100
2) Original weight = Ratio scale/ minimum Ratio scale
3) Normalized weight = Original weight / Sum (original weight)

The results of scoring and weighting of 31 potential environmental indicators were shown in Table 4.7.

Table 4. 7 The potential environmental indicators with the weighting score

No.	Type	Issue	Indicator name	Critiria1	Critiria2	Critiria3	Total
1	Driver	Population change	population density	3.58	3.42	3.08	**3.36**
2	Driver	Poverty	Number of household with the minimum annual income of 30,000 Baht per person	3.83	3.50	2.50	**3.28**
3	Driver	Climate change	Shifting in rainfall pattern	3.83	3.08	2.42	**3.11**
4	Driver	Climate change	Change in mean annual precipitation	3.50	3.42	2.75	**3.22**
5	Driver	Climate change	average temperature	3.42	3.33	3.00	**3.25**
6	Driver	Land use change	Proportion of change of each category of land use to another land use per unit of time	3.42	3.42	2.50	**3.11**

No.	Type	Issue	Indicator name	Critiria1	Critiria2	Critiria3	Total
7	Pressure	Illegal logging	Forest area damaged by illegal logging	3.67	3.50	2.83	**3.33**
8	Pressure	Forest fire	Area damaged by fire,	3.75	3.50	2.92	**3.39**
9	Pressure	Change in land cover	distribution of land-cover types across the total watershed area	3.17	3.25	2.58	**3.00**
10	Pressure	Water demand/abstraction	Water use by sectors,	3.50	3.33	2.25	**3.03**
11	Pressure	Pesticides use	Application rates of different pesticide categories	3.75	3.42	2.83	**3.33**
12	State	Forest resources	Proportion of forest area to watershed's area	3.25	3.25	3.00	**3.17**
13	State	Forest resources	Proportion of remaining head watershed in the forest	3.58	3.50	2.58	**3.22**
14	State	Biodiversity	abundance and distribution of selected species	3.58	3.67	2.75	**3.33**
15	State	Biodiversity	Threatened species as a percent of total species	3.92	3.33	3.00	**3.42**
16	State	Water resources	Frequency, duration and extent of water shortages	3.67	3.42	2.50	**3.19**
17	State	Water resources	Overall reservoir stocks	3.83	3.75	3.50	**3.69**
18	State	Water resources	Water levels	3.92	3.75	3.25	**3.64**
19	State	Soil resources	Degree of top soil losses	3.92	3.50	3.00	**3.47**
20	State	Soil resources	physical soil structure	3.75	3.58	3.00	**3.44**
21	Impact	Decrease storage capacity	Total suspended solids concentrations in selected locations (Reservoir, natural storage)	3.67	3.50	2.83	**3.33**
22	Impact	Changes in crop yields	Production of selected crops per rai	3.83	3.42	2.58	**3.28**
23	Impact	Quality of life	Number of households access to clean water for drinking and consuming compared to all households	3.92	3.92	3.25	**3.58**
24	Impact	Quality of life	Number of households with water available for utilization compared to the entire household	3.50	3.50	2.92	**3.17**
25	Impact	Quality of life	Number of patients due to use of chemical pesticides	3.42	3.33	2.83	**3.17**
26	Response	Protecting and restoring of habitats and species	Protected area as a percent of total watershed area	3.83	3.42	3.00	**3.50**
27	Response	Protecting and restoring of habitats and species	Forest fire monitoring and controlling mechanism	3.33	3.00	2.33	**3.00**
28	Response	Protecting and restoring of habitats and species	Area of forest plantation	3.50	3.25	2.33	**3.17**
29	Response	Soil conservation practices	% of farmers practicing soil and water conservation technologies	3.50	3.25	2.92	**3.17**
30	Response	Soil conservation practices	planting cover crops	3.33	3.67	3.08	**3.08**
31	Response	Supply side management	Improve water storage capacity	3.42	3.58	2.58	**3.17**

The weights of each environmental indicators were sorted ranking from the highest to the lowest as shown in Table 4.8.

Table 4. 8 Ranking of potential environmental indicators

No.	Type	Issue	Indicator name	Ratio Scale	Original Weight	Normalized Weight
1	State	Water resources	Overall reservoir stocks	90.83	3.40582	0.04928
2	State	Water resources	Water levels	86.67	3.24959	0.04702
3	State	Water resources	Frequency, duration and extent of water shortages	85.00	3.1871	0.04611
4	Pressure	Water demand/abstraction	Water use by sectors	80.83	3.03087	0.04385
5	Impact	Changes in crop yields	Production of selected crops per rai	72.50	2.71841	0.03933
6	Impact	Decrease storage capacity	Total suspended solids concentrations in selected locations (Reservoir, natural storage)	71.67	2.68716	0.03888
7	Driver	Climate change	Shifting in rainfall pattern	66.67	2.49969	0.03617
8	Pressure	Pesticides use	Application rates of different pesticide categories	65.83	2.46844	0.03571
9	State	Forest resources	Proportion of forest area to watershed's area	65.83	2.46844	0.03571
10	State	Soil resources	physical soil structure	65.83	2.46844	0.03571
11	Pressure	Change in land cover	distribution of land-cover types across the total watershed area	65.00	2.4372	0.03526
12	State	Forest resources	Proportion of remaining head watershed in the forest	65.00	2.4372	0.03526
13	Pressure	Forest fire	Area damaged by fire,	61.67	2.31221	0.03345
14	State	Biodiversity	abundance and distribution of selected species	61.67	2.31221	0.03345
15	Impact	Quality of life	Number of patients due to use of chemical pesticides	59.17	2.21847	0.0321
16	State	Soil resources	Degree of top soil losses	57.50	2.15598	0.03119
17	Impact	Quality of life	Number of households with water available for utilization compared to the entire household	57.50	2.15598	0.03119
18	Driver	Climate change	average temperature	55.83	2.09349	0.03029
19	Driver	Land use change	Proportion of change of each category of land use to another land use per unit of time	55.83	2.09349	0.03029
20	Driver	Population change	population density	55.42	2.07787	0.03006
21	State	Biodiversity	Threatened species as a percent of total species	55.00	2.06224	0.02984
22	Response	Supply side management	Improve water storage capacity	55.00	2.06224	0.02984
23	Response	Protecting and restoring of habitats and species	Protected area as a percent of total watershed area	52.50	1.9685	0.02848
24	Pressure	Illegal logging	Forest area damaged by illegal logging	48.33	1.81227	0.02622
25	Response	Protecting and restoring of habitats and species	Area of forest plantation	48.33	1.81227	0.02622
26	Response	Protecting and restoring of habitats and species	Forest fire monitoring and controlling mechanism	45.83	1.71854	0.02486
27	Impact	Quality of life	Number of households access to clean water for drinking and consuming compared to all households	42.50	1.59355	0.02306
28	Driver	Climate change	Change in mean annual precipitation	41.67	1.5623	0.0226
29	Response	Soil conservation practices	% of farmers practicing soil and water conservation technologies	41.67	1.5623	0.0226

No.	Type	Issue	Indicator name	Ratio Scale	Original Weight	Normalized Weight
30	Driver	Poverty	Number of household with the minimum annual income of 30,000 Baht per person	39.58	1.48419	0.02147
31	Response	Soil conservation practices	planting cover crops	26.67	0.99988	0.01447
				TOTAL	69.1164	1

From the Table 4.8 , it could be seen that environmental indicators related to water resources received the highest weight (No. 1-4) included overall reservoir stocks, water levels, frequency, duration and extent of water shortages, and water use by sectors, These four indicators were indicators that showed the state of water resources of the Lam Nam Yang Part1 watershed. The environmental indicators No. 5 (Changes in crop yields) and 6 (decrease storage capacity) were the impacts that associated with water problems that received high score of indicators as well. Driver indicator (shifting in rainfall pattern) got highest weight was also related to water available. The seven environmental indicators related to water resources that got high scores by stakeholders and local experts were in the same direction of the survey result that people saw the most important problem was on water resources.

The pressure indicators that got second highest score was application rates of different pesticide categories, followed by distribution of land-cover types across the total watershed area, and area damaged by fire, forest area damaged by illegal logging, respectively.

The Response indicators that got highest weight was improve water storage capacity, followed by protected area as a percent of total watershed area, area of forest plantation, forest fire monitoring and controlling mechanism, % of farmers practicing soil and water conservation technologies, and planting cover crops, respectively.

In conclusion, potential environmental indicators that stakeholders and local experts selected based on 3 criteria and level of importance consisted of 31 indicators. Details of unit of measurement and possible source of each indicator is summarized in Appendix F.

4.5.3.4 Opinions of stakeholders and local experts on a set of environmental indicators

1) In terms of potential environmental indicators selected, all stakeholders and local experts agreed that it could be applied to measure the sustainability of watershed. However, 5 stakeholders and local experts thought that the indicators selected by experts (101 indicators) should be concerned to be sufficient to capture overall aspects of the watershed situation. The indicators with more weight or more readiness might be used as priority depended on the users.

2) In this study, indicators of the Lam Nam Yang Part1 Watershed still lacked the aspects of watershed management with local knowledge and local responses. Thus, the indicators set should be given to communities or the relevant authorities, so that they could consider and study the suitability, limitations and possibilities for additional indicators on such aspects.

3) Many stakeholders and local experts commented that the major problems and obstacles of using a set of indicators from this study were how to apply these indicators practically and strengthen the understanding of indicators users, particularly all levels of executives. Stakeholders and local experts, as the watershed committee of Yang Sub-basin, recommended that there should be the study presentation to the watershed committee, so that they could consider them, or at least they would be acknowledged and developed these indicators further, more or less.

4) Stakeholders and local experts agreed that another important problem was unsystematic data collection scattering of each agencies, so there should be an agency acting as a central agency to coordinate for systematic management and indicators storage. Some stakeholders and local experts suggested that the secretary of the Yang-sub basin Committee or Provincial Environment and Natural Resources agency should probably be the central authority.

CHAPTER V
CONCLUSIONS AND RECOMMENDATIONS

This study aims to identify the state of watershed management of the Lam Nam Yang Part1 and to develop a set of watershed indicators specifically the environmental aspect with the involvement of stakeholders at a watershed level. The DPSIR framework was applied to identify key environmental issues and use to frame the environmental indicators of the Lam Nam Yang Part1 watershed. A set of environmental indicators selected to monitor the sustainable of the watershed totaled 101 indicators including 13 Drivers indicators, 24 Pressure indicators, 24 State indicators, 21 Impact, and 19 Response indicators. Out of 101 indicators, 31 indicators considered as the potential environmental indicators. It is expected that a set of indicators proposed are beneficial to relevant stakeholders in the Lam Nam Yang Part1 watershed in order to develop, extend, and adapt to specific contextual area for achieving sustainable watershed management.

Although this study has experienced that there are some limitations and difficulties in the construction of environmental indicators in development process, it is also clear that this is a worthwhile exercise and that the benefit of developing a set of environmental indicators creates the knowledge sharing among stakeholders and local experts in the watershed level. In particular, all stakeholders and local experts agree that there is a need to relate more communities, local business, and agencies to involve in refining and applying the environmental indicators.

Followings are the findings of the research.

5.1 Conclusion of the study

5.1.1 From the results of the study, it was found that the Lam Nam Yang Part1 watershed is facing environmental and management problems in many aspects. The natural resources such as forest, plants, animals, soil, and water are deteriorated, for example; water shortage, loss of soil fertility, forest area depletion, and decline of plant and animal species. These environmental issues affected the sustainability and functions of the watershed, and the impacts can be observed by local people and key

informants. The important driving forces as problems catalysts in the Lam Nam Yang Part1 Watershed included climate variability (shifting in rainfall pattern, rainfall intensity), land use change due to agricultural area expansion, economic or market demand, poverty, and population change. The exploitation of natural resources, farming, use of chemicals, changes in land use, all of these were the pressure causing the changes in natural conditions and environmental quality. As a result, the changes would affect the physical and biological conditions, utilization and health of people, which changed the functions of watershed.

Some of the major problems and constraints in watershed management of the Lam Nam Yang Part1 are lack of unity and organizational integration among agencies, lack of unity and participation from stakeholders, many laws and regulations are outdated, lack of good database, and insufficient budget allocation to solve natural resources and environmental problems.

5.1.2 The development of environmental indicators for sustainable watershed management of the Lam Nam Yang Part1 watershed consisted of various steps including identification of key environment issues using DPSIR as a framework for indicators selection, the interviews with experts to form environmental indicator set, the indicators selection by key stakeholders and local experts. The results showed that the experts selected 101 indicators for monitoring the sustainability of the Lam Nam Yang Part1 watershed, and the key stakeholders and local experts' emphasized the 31 potential indicators as the priority. A set of 101 environmental indicators can be summarized in Figure 5.1 with the 31 potential indicators in red bold letter.

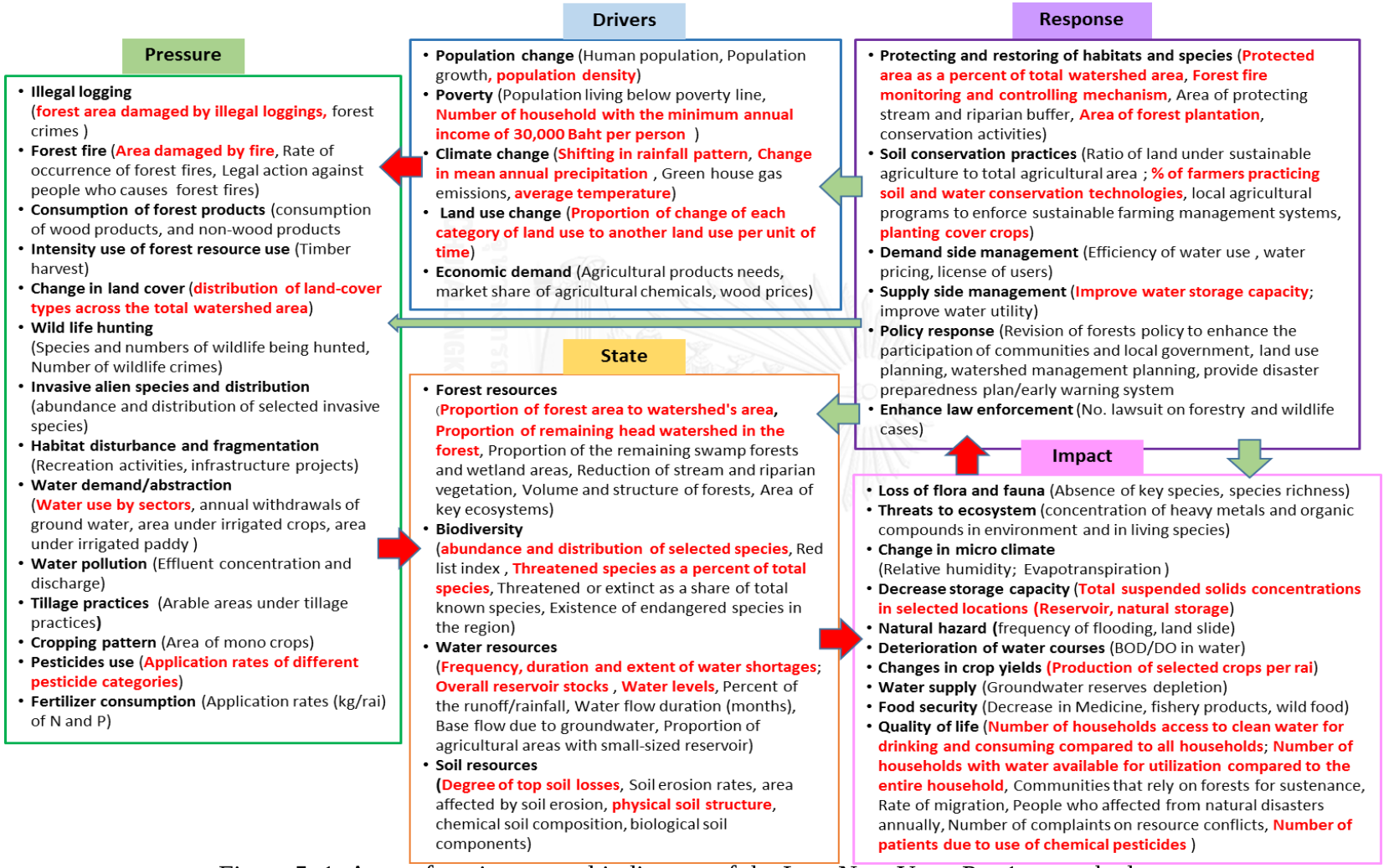

Figure 5. 1 A set of environmental indicators of the Lam Nam Yang Part1 watershed

5.2 Discussion

It was found that the key issues related to the result of the study could be discussed as followings.

5.2.1 Consistency of Policy and plans

Environmental indicators of Lam Nam Yang Part1 Watershed selected by key stakeholders and local experts supported organizational goals in various levels such as list of proposed preliminary indicators compiled by National Statistical Office (2016) in Goal 2 “End hunger, achieve food security and improved nutrition and promote sustainable agriculture”; Goal 6 “Ensure availability and sustainable management of water and sanitation for all”; and Goal 15 “Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss” such as number of households access to clean water for drinking and consuming compared to all households, Protected area as a percent of total watershed area, and % of farmers practicing soil and water conservation technologies. Also some indicators selected are indicators listed in the OECD core set of environmental indicators (2008) such as freshwaters resources (intensity of use of water resources), forest resources (intensity of use of forest resources), and biodiversity (threatened species), respectively. Although, there were similar names of indicators, but the measurements and the goals might be different. Furthermore, the developed indicators supported the goal of Thailand specified in the draft Natural resources and Environment Strategic plan on many topics, and in the sustainable development in indicators of the NESDB (2007), for example, number of household with the minimum annual income of 30,000 Baht per person and proportion of water supply retained in storage. For the provincial level, the selected indicators were indicators already collected directly by the Kalasin province, including people who affected from natural disasters annually, number of households with water available for utilization compared to the entire household, and number of households access to clean water for drinking and consuming compared to all households. In addition, the selected indicators could be applied for moving towards goal of the Yang Sub-basin prescribed that conserving water, soil and forest,

preserving local wisdom with civil and public, eliminating poverty, encouraging sufficient economy.

5.2.2 DPSIR Framework

A set of indicators of Lam Nam Yang Part1 Watershed were developed by using the Driver–Pressure–State–Impact Response (DPSIR) framework. This framework has been widely adopted in the study of environmental problems and has proven to have useful in understanding the beginning and persistence of environmental problems at scales ranging from the global to the sub-catchment (Carr, *et.al*., 2007). The DPSIR framework contains advantages: such framework, through a clearly structured organization of the indicators, enable clear and concise communication to decision-makers (Niemeijer and de Groot, 2008). It helped expose how the information provided by the indicators was related to various processes and how specific policy or management actions could be addressed human-induced environmental problems. However, DPSIR through its emphasis on causal chains tend to induce a somewhat narrow that might lead to ignorance of dealing with the multiple attitudes and definitions of issues by stakeholders and the general public (Svarstad *et al*, 2006).

5.3 Indicators application

Environmental indicators developed from this study were the created indicators that reflected the sustainability of Lam Nam Yang Part1 watershed. The indicators were the first set that relevant stakeholders and related agencies might applied them in the actual areas, which the set of indicators was associated with several agencies. The intention of creating environmental indicators was to integrated monitor and evaluate environmental situation for the sustainable watershed management. The set of indicators from this study and other results of the study would allow several agencies to understand the causes, effects and solutions of environmental issues more clearly. Therefore, if various agencies and sectors could apply the developed indicators to related monitoring and evaluation plans at a watershed-scale, this would allow all stakeholders to work together as an integrated

management because different agencies were unable to solve the complex problems with continue effects separately (Blomquist and Schlager, 2005).

Another important role of developed indicators was the related people, agencies and network, which could apply these indicators for further development for environmental quality monitoring and evaluation in actual areas by consider using indicators that were not very complex, easy to understand and required less cost.

5.4 Limitations of the study

5.4.1 The process of environmental indicators development depended on the importance of the experts and stakeholders involvement, which the selection of experts and stakeholders directly affected the selection of indicators. Also, the selection of indicators was up to the discretion of each individual stakeholder. In this study, there were 9 experts and 12 stakeholders and local experts, and each of them had different expertise and interest in environmental issues. As a result, the selection of environmental indicators might be different if there were more experts and stakeholders with diverse expertise.

5.4.2 The criteria used in the selection and weighting was important for the selection of potential environmental indicators. In this study, the main criteria for selection and weighting were from the review of documents and expert's opinions, so the criteria or weight might cause different results of selection. This study gave the equal weight to individual components (DPSIR), so that the results could be easily understood. However, each indicator might be different and also level of importance, thus, weighting the indicators and components or criteria were much depending on stakeholders' views.

5.4.3 For this development of environmental indicators, although, it was the operation in the watershed level, but the involvement of local people in developing indicators was quite low, because the selection of stakeholders was very specific for those who were familiar with the preparation and use of indicators only, which mostly were agency representatives. Therefore, the selected indicators might not cover or be indicators that local people interested.

5.5 Recommendations

5.5.1 There should be the application of a set of environmental indicators by preparing additional data, so that they could be used to measure practically, and be accepted to all parties. Also, the continuous improvement of indicators was needed to allow them to suit the changing circumstances. When new problems occurred, new pressures would arise, and the existing indicators might not reflect the changes clearly.

5.5.2 To increase the quality and reliability of environmental indicators to be accepted and meet the standards, it should involve more stakeholders and focus on the balance of stakeholders on each aspect. Moreover, there should be a process of encouraging understanding and mutual recognition in the preparation of indicators, so that the stakeholders would agree on the selected indicators appropriately. A set of indicators should meet the requirements of stakeholders in the watershed, so it should be made to include local people to participate more.

5.5.3 Due to the scattering of information stored at the local authorities, it is difficult to collect and utilize data systematically. In many cases, data was available at the central government agencies which might limited the accessibility to local people and local organizations. As a result, there should be a systematic data collection unit and management at the watershed level that act as the central unit to coordinate between central, regional, local government agencies, and all stakeholders' group.

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APPENDICES

APENDIX A Examples of Environmental Indicators from Organizations

Table A UNCSD Environmental Indicators

Issues	Driving forces	States	Responses
Protection of the quality and supply of freshwater resources	Annual withdrawals of ground and surface water	Groundwater reserves	Waste-water treatment coverage
	Domestic consumption of water per capita	Concentration of faecal coliform in freshwater	Density of hydrological networks
		Biochemical oxygen demand in water bodies	
Protection of the oceans, all kinds of seas and coastal areas	Population growth in coastal areas	Maximum sustained yield for fisheries	
	Discharges of oil into coastal waters	Algae index	
	Releases of nitrogen and phosphorus to coastal waters		
Integrated approach to the planning and management of land resources	Land use change	Changes in land condition	Decentralized local-level natural resource management
Managing fragile ecosystems: combating desertification and drought	Population living below poverty line in dryland areas	National monthly rainfall index	
		Satelite derived vegetation index	
		Land affected by desertification	
Managing fragile ecosystems: sustainable mountain development	Population change in mountain areas	Sustainable use of natural resources in mountain areas	
		Welfare of mountain populations	
Promoting sustainable agriculture and rural development	Use of agricultural pesticides	Arable land per capita	Agricultural education
	Use of fertilizers	Area affected by salinization and waterlogging	
	Irrigation percent of arable land		
	Energy use in agriculture		
Combating deforestation	Wood harvesting intensity	Forest area change	Managed forest area ratio
			Protected forest area as a percent of total forest area
Conservation of biological diversity		Threatened species as a percent of total native species	Protected area as a percent of total area
Environmentally sound management of biotechnology			R & D expenditure for biotechnology
			Existence of national biosafety regulations or guidelines
Protection of the atmosphere	Emissions of greenhouse gasses	Ambient concentrations of pollutants in urban areas	Expenditure on air pollution abatement
Issues	Driving forces	States	Responses
	Emissions of sulphur oxides		
	Emissions of nitrogen oxides		

Issues	Driving forces	States	Responses
	Emissions of sulphur oxides		
	Emissions of nitrogen oxides		
	Consumption of ozone depleting substances		
Environmentally sound management of solid waste and sewage-related issues	Generation of industrial and municipal solid waste		Expenditure on waste management
	Household waste disposed per capita		Waste recycling and reuse
			Municipal waste disposal
Environmentally sound management of toxic chemicals		Chemically induced acute poisonings	Number of chemicals banned or severely restricted
Environmentally sound management of hazardous wastes	Generation of hazardous wastes	Area of land contaminated by hazardous wastes	Expenditure on hazardous waste treatment
	Imports and exports of hazardous wastes		
Safe and environmentally sound management of radioactive wastes	Generation of radioactive wastes		

(Source: DPCSD, 1996)

Table B OECD Core Environmental Indicators

Issue	Core indicators		
	Pressures	States	Responses
Climate change	Index of greenhouse gas emissions: CO2 emissions, CH4 emissions, N2O emissions, CFC emissions	Atmospheric concentrations of greenhouse gases; Global mean temperature: Energy intensity, Economic and fiscal instruments	Energy efficiency
Ozone layer depletion	Index of apparent consumption of ozone depleting substances (ODP): Apparent consumption of CFCs/ and halons	Atmospheric concentrations of ODP Ground level UV-B radiation: Stratospheric ozone levels	CFC recovery rate
Eutrophication	Emissions of N and P in water and soil: N and P from fertilizer use and from livestock	BOD/DO in inland waters, in marine waters	Population connected to biological and/or chemical sewage treatment plants: Population connected to sewage treatment plants, User charges for waste water treatment, Market share of phosphate-free detergents
Acidification	Index of acidifying substances: Emissions of NOx and SOx	Exceedance of critical loads of pH in water & soil: Concentrations in acid precipitation	% of car fleet equipped with catalytic converters Capacity of SOx and NOx abatement equipment of stationary sources
Toxic contamination	Emissions of heavy metals, Emissions of organic compounds: Consumption of pesticides	Concentration of heavy metals & organic compounds in env. media & in living species: Concentration of heavy metals in rivers	Changes of toxic contents in products and production processes: Market share of unleaded petrol

Issue	Core indicators		
Urban environmental quality	Urban air emissions (SOx, NOx, VOC): Urban traffic density, Urban car ownership, Degree of urbanisation (urban population growth rates, urban land)	Population exposure to air pollution, to noise: Concentrations of air pollutants Ambient water conditions in urban areas	Green space (Areas protected from urban development) Economic, fiscal and regulatory instruments: Water treatment and noise abatement expenditure
Biodiversity	Habitat alteration and land conversion from natural state: road network density, change in land cover, etc.	Threatened or extinct species as a share of total species known Area of key ecosystems	Protected areas as % of national territory and by type of ecosystem: Protected species
Cultural landscapes	Presence of artificial elements		Sites protected for historical, cultural or aesthetic reasons
Waste	Generation of waste (municipal, industrial, hazardous, nuclear): Movements of hazardous waste		Waste minimization: Recycling rates, Economic and fiscal instruments, expenditures
Water resources	Intensity of use of water resources	Frequency, duration and extent of water shortages	Water prices and user charges for sewage treatment
Forest resources	Intensity of forest resource use	Area, volume and structure of forests	Forest area management and protection (e.g. % of protected forest area in total forest area; % of harvest area successfully regenerated of afforested)
Fish resources	Fish catches	Size of spawning stocks	Fishing quotas
Soil degradation (desertification & erosion)	Erosion risks: potential and actual use of land for agriculture: Change in land use	Degree of top soil losses	Rehabilitated areas
Material resources	Intensity of use of material resources		
Socio-economic, sectoral and general indicators	Population growth & density, Growth and structure of GDP, Private & government final consumption expenditure, Industrial production, Structure of energy supply, Road traffic volumes, Stock of road vehicles, Agricultural production		Environmental expenditure: Pollution abatement and control expenditure, Official Development Assistance Public opinion

Table C European Core Set of environmental indicators

Issue	Core Indicators	DPSIR
Air Pollution	Emissions acidifying pollutants	P
	Emissions ozone precursors	P
	Urban emissions NOx, VOC, PM, SO2, NO2	P
	Emissions SO2 APE5a Emissions SO2	P
	Emissions NOx APE6a Emissions NOx (total & by sector)	P
	Emissions NH3 APE7a Emissions NH3 (total & by sector)	P
	Emissions NMVOC APE8a Emissions NMVOC (total & by sector)	P
	Emission of particulates APE9a Emissions primary and secondary PM10 (total & by sector) Emissions secondary+primary PM2.5	P
	Emissions Heavy metals and POPs (total & by sector)	P

Issue	Core Indicators	DPSIR
	Exceedance days of air quality target in urban areas: SO2 NO2 PM10 O3 CO benzene	S/I
	Ecosystem exposure to exceedance of critical levels and loads	S/I
	Human health exposure and risk by air pollutants	I
	Exposure of ozone to crops/forests	I
	Effect of measures on past trends	R
Ozone layer depletion	Production of ODP	D
	Sales/Consumption of ODP	P
	Trend in global tropospheric potential chlorine and bromide	S
	Average ozone column	S
Climate change	Greenhouse Gas Emissions vs. targets (by country)	P
	Projected GHG emission in 2010 vs Targets (by country)	P/R
	Temperature world/Europe (annual mean deviations)	S
	Atmospheric GHGconcentration levels	S
	Emissions of carbon dioxide (CO2) and non-CO2 (N2O, CH4, fluorinated gases)	P
	Emissions of key source sectors (energy, transport, industry, agriculture, waste) by country	P
	CC6 State of climate and atmosphere	S
	State of cryosphere	S
	Impacts on soils, land resources, forestry	I
	Impacts on ecosystems and biodiversity	I
	Impacts on hydrology and water resources	I
	Impacts on marine environment and coastal zones	I
	Impacts on human health	I
	Effectiveness of policies and measures (ex-post)	R
	Projected emissions of key source sectors (energy, transport, industry, agriculture, waste)	R
biodiversity	Habitat diversity	S
	Species diversity	S
	Threatened species	I
	Genetic diversity	S
	Threats to ecosystems	I
	Landscape changes	I
	Introduced and invasive species	I
	Protection of threatened species	R
	Restoration	R
	Designated areas	R
	Species diversity in designated areas	R
	Habitat diversity in designated areas	R
	Human impacts on designated areas	I
Water Quantity	Water exploitation index	P
	Water use by sectors	P
	Water use by agriculture	P
	Water use by industry	P
	Water use by households	P
	Water use by tourism	P
	Groundwater levels	I
	Overall reservoir stocks	S
	Saltwater intrusion	S
	Water prices	R
	Efficiency of water use	R
	Water Leakage	R
Nutrients and organic matter pollution	Nitrate in groundwater	S
	Nutrients in rivers	S
	Phosphorus in lake	S

Issue	Core Indicators	DPSIR
	Nutrients in coastal waters	S
	BOD and Ammonium in rivers	S
	Sources of nitrogen and phosphorus	P
	Loads (riverine and direct) of nutrients to coastal waters	P
	Emissions of organic matter	P
	Drinking water quality	I
	Bathing water quality	I
	Eutrophication indicators (chlorophyll, Secchi depth) in lakes	S
	Chlorophyll in transitional, coastal and marine waters	S
	Phytoplankton algae in transitional and coastal waters	I
	Frequency of low bottom oxygen in coastal and marine waters	I
	Urban waste water treatment	R
Hazardous substances	Hazardous substances in groundwater	S
	Hazardous substances in rivers	S
	Hazardous substances in lakes	S
	Hazardous substances in transitional, coastal and marine waters	S
	Hazardous substances in marine sediment	S
	Hazardous substances in marine organisms	S
	Loads of hazardous substances to coastal waters	P
	Emissions to water of hazardous substances from industry	P
	Emissions to water of hazardous substances from urban waste water treatment plants	P
	Discharge of oil from refineries and offshore installations	P
	Accidental oil spills from marine shipping	P
	Illegal discharges of oil at sea	S
	Non-compliance with EU Environmental Quality Standards	I
	Biological effects of hazardous substances on organisms	I
	Oiled seabirds	I
	Indicators on Loads of hazardous substances into waters do also include policy evaluation	R
Ecological quality	Biological quality of transitional waters	S
	Biological quality in coastal waters	S
	Aquatic habitat quality	S
	Biological quality in rivers	S
	Biological quality in lakes	S
	Biological quality of marine waters	S
	Introduced and invasive aquatic species	I
	Implementation of EU Water Policies	R
Material Flow and Waste generation	Total Material Requirement (TMR) by main resource categories	
	Resource productivity	
	Waste generation from total resource extraction	
	Indicator of "shifting environmental burden"	
	Municipal waste	
	Generation of industrial waste	
	Generation of construction and demolition waste	
	Generation of packaging waste	
	Generation of waste from electrical and electronic equipment	
	Generation of waste from end-of-life vehicles	
	Generation of waste oils and tyres	
	Generation of hazardous waste	
	Waste intensity (total waste generated per unit of GDP)	
	Content of dangerous substances in products which end up in priority waste streams(ratio to total material content)	

Issue	Core Indicators	DPSIR
	Waste recovery by operation categories and waste stream: Sewage sludge, waste tyres, paper and cardboard, glass, municipal waste and packaging waste	
	Waste disposal	
	Land use associated with waste recovery and disposal Land use for landfills	
	Leachate formation from landfills	
	Total amount of waste transported for disposal (tonne km)	
	Transboundary movements of waste	
	Treatment capacity	
	Waste management costs per ton by treatment category	

(Source: European Environmental Agency, 2003)

Table D State of the Great Lakes Indicator Reporting Framework (Source: SOLEC, 2011)

DPSIR Framework Reporting Areas	Driving Forces	Pressures			State			Impacts		Responses
Top Level Categories	**Economic/ Social**	**Pollution & Nutrients**	**Invasive Species**	**Invasive Species**	**Invasive Species**	**Aquatic-Dependent Life**	**Aquatic-Dependent Life**	**Aquatic-Dependent Life**	**Aquatic-Dependent Life**	**Aquatic-Dependent Life**
Reporting Indicators	*Human population* *Economic prosperity* *Energy consumption* *Value of Great Lakes* *Greenhouse gas emissions*	*Contamination in sediment* *Atmospheric deposition* *Inland water quality index* *Nutrients in tributaries* *Pesticides in tributaries* *Bacterial loadings from tributaries* *Municipal wastewater loadings* *Industrial loadings*	*Aquatic non-native species including a watch list of high risk species* *Terrestrial non-native species* *sea lamprey* *Dreissenid mussels*	*Watershed stressor Index* *Forest disturbance* *Artificial coastal Structures* *Hardened shorelines* *Surface water temperature* *Air temperature* *Extreme precipitation events*	*Toxic chemicals in offshore waters* *Contaminants in whole fish* *Contaminants in waterbirds* *Groundwater quality* *Nutrients in lakes* *Major ions* *Water clarity* *Water chemistry*	*Wetland fish Wetland plants* *Wetland birds* *Wetland invertebrates* *Wetland amphibians* *Walleye Lake Trout* *Preyfish* *Benthos* *Diporeia* *Zooplankton Health* *Zooplankton Biomass* *Phytoplankton* *Threatened species* *Bald eagle* *Lake Sturgeon* *Piping Plover*	*Land cover* *Aquatic habitat connectivity* *Fish habitat* *Base flow due to groundwater* *Water levels* *Ice duration* *Forest cover* *Sediment coastal nourishment* *Tributary flashiness* *Wetland landscape extent and composition*	*Drinking water* *Beach advisories* *Fish consumption restrictions* *Harmful Algal Blooms* *Cladophora*	*Botulism outbreaks* *Fish disease occurrences* *Endocrine disruption*	*Withdrawing water sustainably* *Conserving and protecting forest land* *Managing contaminated sediment* *Treating wastewater* *Protecting and restoring of habitats and species* *Enhancing wildlife and conserving soil and water on agricultural lands* *Stocking native fish* *Protecting special lakeshore areas Implementing industrial efficiency measures* *Educating Great Lakes basin residents*

APPENDIX B

QUESTIONAIRE SURVEY

No. of Questionnaire……..

Title Questionnaire survey of people on the natural resources and environment and participation in management of Lam Nam Yang Part 1 Watershed, Kalasin Province

Notes :

1. This questionnaire survey is prepared by Mrs. Warintorn Khunanake, Doctoral Degree Student of the Environment Development and Sustainability, Chulalongkorn University.
2. The objective of the survey is to collect the opinion of local people on the condition of natural resources and environment and participation in management of Lam Nam Yang Part 1 Watershed, Kalasin Province. The survey is partial of the Dissertation on the topic of "Development of environmental indicators relevant stakeholders' involvement for sustainable watershed management: a case study of the Lam Nam Yang Part 1 watershed in the northeastern Thailand".
3. There are 5 parts of the questionnaire in total 14 pages. (Please answer all questions)

The data provided by each informant both personal information and opinion will be kept and used only to analyze and process on in the study.

I would like to thank all the correspondents for your kind cooperation.

Your sincerely,
Mrs. Warintorn Khunanake

Informant Data
Name.....Surname.....Address.....
Amphoe.....Province.....Phone No. (If any).....Watershed you are living in……

Part 1: Baseline information of the informant

1. **Gender** o Male o Female
2. **Age**……**years**
3. **Religion** o Budism o Christ o Islam o Others.....
4. **Family Status** o Father o Mother o Children o Cousins/ others.....
5. **How long have you reside in the community?**
   o Born and lived here for .....years
   o Moved from .....and stay here more than.....years Why moving and stay here?.....
6. **Family members** (No.).....persons (including the informant)
7. **Family members that have income** ……. persons (including the informant)
8. **Level of Education**
   o Not enter school o Primary level o secondary level
   o Vocational degree o Bachelor degree o Master or higher
   o Others (Please specify).....

Part 2: Socio-economic information of the informant

9. **What is your main occupation (please answer only 1)**
   o Farmers o Labors o Trade/private business
   o Fisherman o Company employee o Government officers
   o Student o Unemployed o Others (please specify).....
10. **What is your supplementary occupation**
    o Labors o Farmers o Fisherman
    oTrade/private business o Company employee o None
    o Others (please specify).....
11. **Total income from main occupation of households** .....Baht/Year
12. **Total income from supplementary occupation of households**..... Baht/Year
13. **Does the total household income sufficient or not?**
    o Not sufficient o Sufficient but no savings o Sufficient and some savings
14. **Land Tenure**
    o How many lands do you own? .....Plots
    o Total area.....Rai
15. **Land Utilization**
    o Residential area o Paddy fields o Farm crops (Pls. specify.....)
    o Garden crops (Pls. specify.....) o Trees (Pls. specify.....)
    o Vegetables (Pls. specify.....) o Flowers o Pasture land
    o Aquaculture เพาะเลี้ยงสัตว์น้ำ o Wasted land o Livestock
    o Others (Pls. specify.....)

16. Land holdings

o Self own/spouse o Father and Mother's o Cousins'
o Rented lands o Others (Pls. specify.....)

17. Land holding types

o Title Deeds o Certificate of utilization (NS.3K)
o Claim certificate (Sor Tor Kor)
o None o Others (Pls. specify.....)

18. Sources of drinking and domestic use

Drinking water

o Rain o Shallow Water / Groundwater o Bottled water
o Pipe water o Others (Pls. specify.....)

Water use

o Rain o Shallow Water / Groundwater o Irrigation
o Pipe water o Natural water sources o Others (Pls. specify.....)

19. Sufficient of Water for drinking and domestic use

Drinking water o Sufficient o Not sufficient (How you solve the problem?.....

Water use o Sufficient o Not sufficient (How you solve the problem?.....

20. Do you or your family members participate in community economic groups?
(Ex. Saving groups, Village fund, professional groups)

o No
o Yes, Group name.....Years of membership……..
position.....

21. Do you or your family members participate in community social groups?
(Ex. Elderly care group, funeral assistance association, conservation groups)

o No
o Yes, Group name.....Years of membership…….. Position.....

Part 3: Health and sanitation

22. Did you or your family members have illness in the past year?

o No o Yes

23. If so, what are the illness?

o Respiratory system o Digestive system o Skin
o Blood system o Muscular system o Ear, Nose, Throat
o Others (Pls. specify.....)

24. What were the causes of illness?

o Occupation o Accident from works
o Accident from traffic o Environment (climate, smoke, dust)
o Others (Pls. specify.....)

25. How did you treat the illness?

o Self remedy o Buy medicine from drugs store
o Community health center
o Hospital o Herbs/local wisdom o Others (Pls. specify.....)

26. How do you treat you wastewater from household?

o Direct discharged into soil o Discharged into natural water bodies
o Discharged into public drainage o Others (Pls. specify.....)

27. How do you disposal household waste?

o Piling o Open burning o Open dumping
o Garbage bag for collecting o Others (Pls. specify.....)

Part 4: Opinion on Natural resources and environment in the watershed

28. In your opinion, do you think your watershed is facing these problems?

28.1 Forest area depletion (If yes, you can answer more than one items)

o No
o Yes caused by
- ❑ Illegal logging
- ❑ Forest fire
- ❑ Forest conservation zone is unclear
- ❑ Human settlement in forest areas
- ❑ Agriculture expansion into forest areas
- ❑ Development projects (roads/dam/reservoir)
- ❑ Overexploitation of forest products
- ❑ Others (Pls. specify.....)

o What are the impacts of the above consequences?
- ❑ Soil erosion and soil loss
- ❑ Habitats destruction and loss of biodiversities
- ❑ drought /Changes in air and soil moisture
- ❑ flashflood/ High speed water runoff and severe bank erosion
- ❑ Sources for carbon sink decline
- ❑ Others (Pls. specify.....)

o What are your suggestions to solve this problems? .....

28.2 Biodiversity Decline (terrestrial and aquatic animal and plants) (If yes, you can answer more than one items)

o No
o Yes, caused by
- ❑ climate change
- ❑ Habitats destruction
- ❑ Over exploitation
- ❑ Alien species invasion
- ❑ Wildlife hunting
- ❑ Illegal trading of forest products and wildlife
- ❑ Others (Pls. specify.....)

o What are the impacts of the above consequences?
- ❑ Food security
- ❑ Plants and animals are at risk of extinction.
- ❑ Ecological imbalance/instability
- ❑ Livelihood of local communities
- ❑ Productivity of ecosystem decreased
- ❑ Others (Pls. specify.....)

o What are your suggestions to solve this problems? .....

28.3 Soil erosion and soil loss (If yes, you can answer more than one items)

o No
o Yes, caused by
- ❑ Natural setting of the area
- ❑ Deforestation and riparian destruction
- ❑ Agricultural activities

- ❑ Excavated of top soil / road constructions / soil filling
- ❑ Sand Minings
- ❑ Others (Pls. specify.....)

o What are the impacts of the above consequences?

- ❑ Shallow water (Retention and drainage performance decrease)
- ❑ Contamination in water sources and water quality degradation
- ❑ Impacts on aquatic lives
- ❑ Changes in crop yields
- ❑ Affect quality of life and property
- ❑ Others (Pls. specify.....)

o What are your suggestions to solve this problems? .....

28.4 Soil deterioration (If yes, you can answer more than one items)

o No

o Yes, caused by

- ❑ Natural settings (Poor soil structure)
- ❑ Bare soil
- ❑ Rice stalks and agricultural waste burning
- ❑ Monocropping for long period
- ❑ Excessive use of chemical fertilizers
- ❑ Lack of conservative measures and poor management
- ❑ Others (Pls. specify.....)

o What are the impacts of the above consequences?

- ❑ Changes in crop yields
- ❑ Forest area encroachment from agriculture expansion
- ❑ More expenditures for land improvement
- ❑ Lead to more chemicals and pesticide use
- ❑ Soil contamination
- ❑ Easily eroded by rainfall and wind
- ❑ Others (Pls. specify.....)

o What are your suggestions to solve this problems? .....

28.5 Drought and water shortage for agriculture (If yes, you can answer more than one items)

o No

o Yes, caused by

- ❑ Agricultural area expansion and intensification
- ❑ Deterioration of natural storage
- ❑ Insufficient storage
- ❑ Insufficient irrigation area
- ❑ Sandy soil (low water retention)
- ❑ Water demand for development
- ❑ Climate variation (shifting in rainfall patterns)
- ❑ Others (Pls. specify.....)

o What are the impacts of the above consequences?

- ❑ Insufficient water for cropping
- ❑ Decreasing in agriculture yields
- ❑ Socio-economic damage
- ❑ Water use conflict
- ❑ Drought and unhealthy land for utilization

❑ Others (Pls. specify.....)

o What are your suggestions to solve this problems? .....

28.6 Water shortage for consumption (If yes, you can answer more than one items)

o No

o Yes, caused by
- ❑ Sitation in water courses/ water courses deterioration
- ❑ Insufficient water supply system
- ❑ Insufficient storage
- ❑ Quality of groundwater and surface water
- ❑ Climate variation (shifting in rainfall patterns)
- ❑ Others (Pls. specify.....)

o What are the impacts of the above consequences?
- ❑ Health impacts
- ❑ Impact on availability of water for raising animals
- ❑ More expense to buy water for drinking and household use
- ❑ Livelihood and wellbeing
- ❑ Community conflict
- ❑ Others (Pls. specify.....)

o What are your suggestions to solve this problems? .....

28.7 Flooding (If yes, you can answer more than one items)

o No

o Yes, caused by
- ❑ Natural setting (topography) (Flood plain)
- ❑ Deforestation (No natural cover for water retention)
- ❑ Road /water blockage constructions
- ❑ Shallow water (Siltation in water ways)
- ❑ Natural water sources encroachment (swamp, wetland, reservoir, ponds)
- ❑ Poor management
- ❑ Others (Pls. specify.....)

o What are the impacts of the above consequences?
- ❑ Health impact from waterborne disease
- ❑ Impact on transportation and communication
- ❑ Impact on housing and property
- ❑ Impact on agriculture production
- ❑ Mentally stress
- ❑ Others (Pls. specify.....)

o What are your suggestions to solve this problems? .....

28.8 Wastewater (If yes, you can answer more than one items)

o No

o Yes, caused by
- ❑ Natural occurrence
- ❑ Wastewater from households
- ❑ Wastewater from industries
- ❑ Wastewater from agriculture
- ❑ Wastewater from restaurants/hotels/establishments
- ❑ Others (Pls. specify.....)

o What are the impacts of the above consequences?
- ❑ Quality of water and soil
- ❑ Impacts on aquatic life
- ❑ Increase in disease
- ❑ Visual pollution

❑ Long term changes in ecosystem
❑ Others (Pls. specify.....)

o What are your suggestions to solve this problems? .....

28.9 Air Pollution (If yes, you can answer more than one items)

o No
o Yes, caused by
❑ Natural occurrence
❑ Smoke from forest/forest burning
❑ Burning of agricultural residues
❑ Smoke from the workplaces/industries
❑ Dust from traffic
❑ Others (Pls. specify.....)

o What are the impacts of the above consequences?
❑ Health of the people
❑ Scenery and seeing
❑ Minor nuisance suffered
❑ Visual on transportation
❑ Others (Pls. specify.....)

o What are your suggestions to solve this problems? .....

28.10 Smell (If yes, you can answer more than one items)

o No
o Yes, caused by
❑ Natural occurrence
❑ Smell of wastewater
❑ Smell of garbage
❑ Smell from agriculture and livestock
❑ Smell from industries
❑ Others (Pls. specify.....)

o What are the impacts of the above consequences?
❑ Health
❑ Annoying and disturbances
❑ Risk of getting disease from the carrier animals, such as rats, flies and cockroaches
❑ Scenery problems
❑ Conflicts in the community
❑ Others (Pls. specify.....)

o What are your suggestions to solve this problems? .....

28.11 Solid waste (If yes, you can answer more than one items)

o No
o Yes, caused by
❑ Agricultural waste
❑ Waste from establishments/ industrial factories
❑ Waste from households
❑ Residual waste/no waste storage
❑ Inadequate waste disposal areas
❑ Others (Pls. specify.....)

o What are the impacts of the above consequences?
❑ Impact on health
❑ Increase in disease
❑ Smell bothering
❑ Scenery issues
❑ Conflicts in the community
❑ Others (Pls. specify.....)

o What are your suggestions to solve this problems? .....

28.12 Natural and cultural heritages deterioration (If yes, you can answer more than one items)

o No

o Yes, caused by
- ❑ Natural degradation
- ❑ Lack of knowledge and understanding of the importance
- ❑ Building that against nature and the surrounding
- ❑ Intrusion for benefits
- ❑ Illegal excavation, demolition, relocation, and constructing various utility services
- ❑ Others (Pls. specify.....)

o What are the impacts of the above consequences?
- ❑ National heritage being destroyed
- ❑ Lessen community pride and solidarity
- ❑ No recreational areas
- ❑ Lack of income from tourism
- ❑ Scenic and aesthetic issues
- ❑ Conflicts in the community
- ❑ Others (Pls. specify.....)

o What are your suggestions to solve this problems? .....

29. In your opinion, what is the trend of each environmental issue in the past 10-20 years?

	Worse	Same	better	No problems	Don't no
	1	2	3	4	0
1.Forest area depletion	❑	❑	❑	❑	❑
2.Biodiversity decline	❑	❑	❑	❑	❑
3.Soil erosion and soil loss	❑	❑	❑	❑	❑
4.Soil deterioration	❑	❑	❑	❑	❑
5.Drought and water shortage for agriculture	❑	❑	❑	❑	❑
6.Water shortage for consumption	❑	❑	❑	❑	❑
7.Flood	❑	❑	❑	❑	❑
8.Wastewater	❑	❑	❑	❑	❑
9.Air pollution	❑	❑	❑	❑	❑
10.Smell	❑	❑	❑	❑	❑
11.Solid waste	❑	❑	❑	❑	❑
12.Natural and cultural heritage deterioration	❑	❑	❑	❑	❑

30. In your opinion, what are the main drivers of the environment problems in the watershed?

	No problem	Not much	Moderate	high	highest
	1	2	3	4	5
1. Human population	❑	❑	❑	❑	❑
2. Poverty and economic difficulties	❑	❑	❑	❑	❑
3. Lack of knowledge and awareness	❑	❑	❑	❑	❑
4. Local government and authorities did not take serious actions.	❑	❑	❑	❑	❑
5. Central government and authorities take serious actions.	❑	❑	❑	❑	❑
6. Limited allocation of financial resources	❑	❑	❑	❑	❑
7. Problems solving did not meet local needs.	❑	❑	❑	❑	❑
8. Outdated laws	❑	❑	❑	❑	❑
9. Inappropriate policies.	❑	❑	❑	❑	❑
10. No effective mechanism for coordination among government agencies / local authorities/ community organization	❑	❑	❑	❑	❑

31. In your opinion, how do you prioritize these environmental issues?

	No problem	low	Moderate	high	highest
	1	2	3	4	5
1.Forest area depletion	❑	❑	❑	❑	❑
2.Biodiversity decline	❑	❑	❑	❑	❑
3.Soil erosion and soil loss	❑	❑	❑	❑	❑
4.Soil deterioration	❑	❑	❑	❑	❑
5.Drought and water shortage for agriculture	❑	❑	❑	❑	❑
6.Water shortage for consumption	❑	❑	❑	❑	❑
7.Flood	❑	❑	❑	❑	❑
8.Wastewater	❑	❑	❑	❑	❑
9.Air pollution	❑	❑	❑	❑	❑
10.Smell	❑	❑	❑	❑	❑
11.Solid waste	❑	❑	❑	❑	❑
12.Natural and cultural heritage deterioration	❑	❑	❑	❑	❑

32. In your opinion, how do you rank the impacts of environmental problems on watershed ecosystem and livelihood?

	No impact	low	Moderate	high	highest
	1	2	3	4	5
1. Health	❑	❑	❑	❑	❑
2. Wellbeing and security	❑	❑	❑	❑	❑
3. Lessen opportunity to access and utilization of natural resource	❑	❑	❑	❑	❑
4. Changes in agriculture yield	❑	❑	❑	❑	❑
5. Jobless and migration	❑	❑	❑	❑	❑
6. Impacts on land and property	❑	❑	❑	❑	❑
7. Impacts on wildlife and aquatic animals	❑	❑	❑	❑	❑
8. Conflict and competition over resources	❑	❑	❑	❑	❑
9. Become insecure place to live					
10. Not suitable for recreation	❑	❑	❑	❑	❑
11. Changes in ecological system	❑	❑	❑	❑	❑
12. More disaster and extreme events	❑	❑	❑	❑	❑
13. Climate variation (Rainfall pattern)	❑	❑	❑	❑	❑

33. In your opinion, how do you rank the importance of watershed functions?

	Not important	low	Moderate	high	highest
	1	2	3	4	5
1.Habitat of people and social	❑	❑	❑	❑	❑
2.Habitat of plants, animals, and biodiversity	❑	❑	❑	❑	❑
3.Recreational places	❑	❑	❑	❑	❑
4.Sources of surface and groundwater	❑	❑	❑	❑	❑
5.Sources of natural resources such as minerals, woods, herbs	❑	❑	❑	❑	❑
6.Be the place for people ways of living	❑	❑	❑	❑	❑
7.Soil erosion control	❑	❑	❑	❑	❑
8.Control and release water flow	❑	❑	❑	❑	❑
9.Circulation of nutrients and energy					
10.Sources of food and drugs	❑	❑	❑	❑	❑
11.Circulation of clean air	❑	❑	❑	❑	❑
12.Be the learning places	❑	❑	❑	❑	❑
13.Provide scenic and aesthetic value of natural sites	❑	❑	❑	❑	❑
14.Be the place for cultural and tradition merits	❑	❑	❑	❑	❑

Part 5 : Opinion on natural resources and environmental management in the watershed

34. How do you perceive watershed management information?

o Never

o Yes, from

- ❑ Talking to family members, neighbor
- ❑ Village broadcasting tower
- ❑ Local newspapers/magazine
- ❑ Community radio.
- ❑ Regional government agencies
- ❑ Central Government agencies.
- ❑ Local governments
- ❑ Newspapers
- ❑ Educational institutes
- ❑ NGOs
- ❑ Environmental Networks /groups
- ❑ Others (Pls. specify.....)

35. What types of watershed management activities did you participate in?

o No, just wanted to be informed of environment/watershed information

o Involved in consultation process

o Involved in environmental management planning process (provincial/local/Basin plans)

o Participated in various environmental management activities.

o Monitoring and evaluation of community and agency operations.

o Advisory to the various agencies and committees

o Member of environmental surveillance network

o Others (Pls. specify.....)

36. In the future, do you want to participate in watershed management and why?

o No

o Yes, because

- ❑ To know about environmental related problems
- ❑ To prepare for coping with environmental problems and disasters
- ❑ To protect private property that may be affected by various projects.
- ❑ To protect the common property of the community.
- ❑ To protect natural resources to maintain ecosystem integrity.
- ❑ To protect natural resources for future generations
- ❑ Being assigned from community or organization
- ❑ Right and duty underlying in Constitution Law
- ❑ Others (Pls. specify.....)

37. In your opinion, who do you think should be the main actor in conserve, restore, and manage natural resources and environment in the watershed? (you can answer more than one items)

o Local people and communities

o NGOs

o Regional government agencies
o Central government agencies
o Local government organizations
o Private sector
o Educational institutions
o The media
o Others (Pls. specify.....)

38. In the past few years, which groups impressed you most for their roles in management of the watershed?

	Not impressed	Low	Moderest	More	Most
	1	2	3	4	5
1. Local people and communities	❑	❑	❑	❑	❑
2. NGOs	❑	❑	❑	❑	❑
3. Regional government agencies	❑	❑	❑	❑	❑
4. Central government agencies	❑	❑	❑	❑	❑
5. Local government organizations	❑	❑	❑	❑	❑
6. Private sector	❑	❑	❑	❑	❑
7. Educational institutions	❑	❑	❑	❑	❑
8. The media	❑	❑	❑	❑	❑

39. Other suggestions

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APPENDIX C

Guiding Question for the key informant interview

1. Baseline information of the informant
   1.1 Name, occupation and organization
   1.2 Role of your organization or group and your responsibility related to watershed management.
   1.3 Are you representation of any groups or community networks?
   1.4 What reasons do you participate in watershed management?
2. Understanding of your watershed
   2.1 How is your watershed? What are the components and functions of the watershed?
   2.2 Do you think your watershed is important to human, animals, plants, and ecosystem?
3. Opinion on natural resources and environment situation in the watershed
   3.1 Do you think your watershed is deteriorated by environmental problems? If yes, where are they? What are the causes of each problem? How you tackle or solve each environmental problem?
   3.2 What is the trend of each environmental issue in the past 10-20 years? Any clear evidences?
   3.3 What are the main driving forces of the environmental problems?
   3.4 What are the environmental problems do you think have great impacts on watershed health?
4. Opinion on natural resources and environmental management and the sustainability of watershed
   4.1 How do you perceive and exchange watershed management information?
   4.2 Have you ever been involved in watershed management activities? What activities?
   4.3 In the future, do you want to participate in the watershed management process?
   4.4 In your opinion, who do you think should be the main actor in conserve, restore, and manage natural resources and environment in the watershed?
   4.5 In the past few years, which groups impressed you most for their roles in management of the watershed?
   4.6 What are the threats and obstacles in watershed management? How to enhance the management capability?
   4.7 Do you think participation of stakeholders is the key factor to the success or failure of watershed management? Why? How do we strengthen and create more involvement?
5. Other comments and suggestions

APPENDIX D

Guiding question for expert consultation

1. Overview of the research objectives, what are the preliminary finding from literature review, methods used in development of indicators.
2. Consults and exchange views on the followings:
   - 2.1 Problems and obstacles of indicators preparation and previous monitoring and evaluation of Thailand
   - 2.2 The importance and participation of various sectors for environmental indicators development
   - 2.3 Possibilities and suitability for current indicators usage (from both domestic and international agencies) for application in the study area.
   - 2.4 Criteria and guidelines for environmental indicators selection.
   - 2.5 The importance priorities and weight of environmental indicators.
   - 2.6 Objectives of environmental indicators.
   - 2.7 Factors or measures enhancing the process of environmental monitoring and evaluation and indicators utilization.
3. Select and recommend indicators that suitable for the Lam Nam Yang Watershed from the long list of Indicators.

APPENDIX E Indicator sheet for total score of environmental indicator selection

	Type	Issue	Indicator name	Related to sustainable of watershed management	Socially relevance/understandable	Operational Feasible (Practically)/Availability	Total	Stakeholder 1			Stakeholder 2			Stakeholder 3			Stakeholder 4			Stakeholder 5			Stakeholder 6			Stakeholder 7			Stakeholder 8			Stakeholder 9			Stakeholder 10			Stakeholder 11			Stakeholder 12		
								Related to sustainable of watershed management	Socially relevance	Operational Feasible	Related to sustainable of watershed management	Socially relevance	Operational Feasible	Related to sustainable of watershed management	Socially relevance	Operational Feasible	Related to sustainable of watershed management	Socially relevance	Operational Feasible	Related to sustainable of watershed management	Socially relevance	Operational Feasible	Related to sustainable of watershed management	Socially relevance	Operational Feasible	Related to sustainable of watershed management	Socially relevance	Operational Feasible	Related to sustainable of watershed management	Socially relevance	Operational Feasible	Related to sustainable of watershed management	Socially relevance	Operational Feasible	Related to sustainable of watershed management	Socially relevance	Operational Feasible	Related to sustainable of watershed management	Socially relevance	Operational Feasible	Related to sustainable of watershed management	Socially relevance	Operational Feasible
1	Driver	Population change	population density	3.58	3.42	3.08	**3.36**	4	3	3	4	4	3	3	4	3	4	3	3	4	3	3	3	4	3	3	3	3	4	3	4	3	4	3	4	3	3	3	4	3	4	3	3
2	Driver	Poverty	Number of household with the minimum	3.83	3.50	2.50	**3.28**	4	4	2	4	4	3	4	4	2	4	3	3	4	4	2	3	4	3	3	3	3	4	3	2	4	4	2	4	3	3	4	3	3	4	3	2
3	Driver	Climate change	Shifting in rainfall pattern	3.83	3.08	2.42	**3.11**	4	4	2	4	4	3	4	3	3	4	3	3	4	3	2	3	3	3	4	3	2	4	3	3	4	3	2	4	2	2	3	3	2	4	3	2
4	Driver	Climate change	Change in mean annual precipitation	3.50	3.42	2.75	**3.22**	4	3	3	4	4	3	4	4	2	4	3	3	3	4	3	3	3	3	3	4	3	3	4	2	3	3	3	4	3	3	4	3	2	3	3	3
5	Driver	Climate change	average temperature	3.42	3.33	3.00	**3.25**	4	3	3	3	4	3	3	3	3	4	4	3	4	4	3	3	4	3	3	3	3	4	3	3	3	3	3	4	3	3	3	3	3	3	3	3
6	Driver	Land use change	Proportion of change of each category of land	3.42	3.42	2.50	**3.11**	4	3	2	3	4	3	4	3	3	3	3	3	4	3	2	4	4	2	4	3	2	3	4	3	3	4	2	3	3	2	3	3	3	3	4	3
7	Pressu	Illegal logging	Forest area damaged by illegal logging	3.67	3.58	2.83	**3.36**	4	4	3	4	4	3	3	3	3	4	3	3	4	4	3	4	3	3	3	4	3	3	3	3	4	3	3	4	4	2	4	4	2	3	4	3
8	Pressu	Forest fire	Area damaged by fire,	3.75	3.50	2.92	**3.39**	4	4	3	4	4	3	4	3	3	3	4	3	4	4	2	4	3	3	3	3	3	4	3	3	4	4	3	4	3	3	3	4	3	4	3	3
9	Pressu	Change in land cover	distribution of land-cover types across the total	3.17	3.25	2.58	**3.00**	4	3	2	4	4	3	3	4	3	2	3	3	3	3	3	2	4	3	2	3	3	3	3	3	4	2	2	4	3	2	4	4	2	3	3	2
10	Pressu	Water demand/abstra	Water use by sectors,	3.50	3.33	2.25	**3.03**	3	4	2	3	3	2	3	3	3	4	4	2	4	4	2	3	3	3	4	3	2	4	4	3	4	3	2	3	3	2	4	3	2	3	3	2
11	Pressu	Pesticides use	Application rates of different pesticide	3.75	3.42	2.83	**3.33**	4	4	2	4	4	3	4	3	3	4	4	2	3	3	3	4	3	3	4	3	3	4	3	3	4	4	3	4	3	3	3	4	3	3	3	3
12	State	Forest resources	Proportion of forest area to watershed's area	3.25	3.25	3.00	**3.17**	3	3	3	4	3	3	3	4	3	3	3	3	4	3	3	3	4	3	3	3	3	3	3	3	4	4	3	3	3	3	3	3	3	3	3	3
13	State	Forest resources	Proportion of remaining head watershed in the	3.58	3.50	2.58	**3.22**	4	4	3	4	4	3	3	4	3	3	3	3	4	3	3	4	3	2	3	4	2	3	3	3	4	3	2	4	4	3	4	3	2	3	4	2
14	State	Biodiversity	abundance and distribution of selected	3.58	3.67	2.75	**3.33**	4	4	3	4	3	3	3	4	3	3	3	3	4	3	2	3	4	3	4	4	3	4	4	3	3	4	3	4	3	3	4	4	2	3	4	2
15	State	Biodiversity	Threatened species as a percent of total species	3.92	3.33	3.00	**3.42**	4	3	3	4	4	3	4	3	3	4	3	3	4	4	3	4	3	3	3	4	3	4	3	3	4	3	3	4	3	3	4	4	3	4	3	3
16	State	Water resources	Frequency, duration and e	3.67	3.42	2.50	**3.19**	4	4	2	4	3	3	4	4	2	3	4	3	4	4	3	3	3	3	4	3	3	4	4	2	3	3	2	3	3	3	4	3	2	4	3	2
17	State	Water resources	Overall reservoir stocks	3.83	3.75	3.50	**3.69**	4	4	4	4	4	3	4	4	4	3	4	3	4	4	3	4	4	4	4	4	3	3	4	3	4	4	4	4	3	4	4	3	4	4	3	3
18	State	Water resources	Water levels	3.92	3.75	3.25	**3.64**	4	4	4	4	4	3	3	4	3	4	4	4	4	4	3	4	4	4	4	4	3	4	4	3	4	3	3	4	3	3	4	4	3	4	3	3
19	State	Soil resources	Degree of top soil losses	3.92	3.50	3.00	**3.47**	4	4	3	4	3	3	4	4	3	4	4	3	4	3	3	4	4	3	4	3	3	4	3	3	4	4	3	4	3	3	4	4	3	3	3	3
20	State	Soil resources	physical soil structure	3.75	3.58	3.00	**3.44**	4	4	3	4	4	3	3	4	3	4	4	3	3	3	3	4	3	3	4	4	3	4	4	3	4	4	3	4	3	3	3	3	3	4	3	3
21	Impact	Decrease storage cap	Total suspended solids concentrations in	3.67	3.50	2.83	**3.33**	4	4	3	4	4	3	4	4	3	3	4	3	4	3	2	4	3	3	4	3	3	3	3	3	4	3	3	3	4	3	3	4	3	4	3	2
22	Impact	Changes in crop yield	Production of selected crops per rai	3.92	3.42	2.58	**3.31**	4	4	2	4	4	3	4	4	3	3	3	3	4	3	3	4	3	3	4	4	3	4	4	2	4	3	2	4	3	3	4	3	2	4	3	2
23	Impact	Quality of life	Number of households access to clean water for	3.92	3.92	3.25	**3.58**	4	4	3	4	4	4	4	4	4	3	4	3	4	3	3	4	4	3	4	4	3	4	4	3	4	4	4	4	4	3	4	4	3	4	4	3
24	Impact	Quality of life	Number of households with water available for	3.50	3.50	2.92	**3.17**	4	4	3	3	4	3	4	4	3	3	4	3	3	4	3	3	3	3	4	3	3	4	4	3	3	3	3	4	3	3	3	3	3	4	3	2
25	Impact	Quality of life	Number of patients due to use of chemical	3.42	3.33	2.83	**3.17**	3	4	3	4	4	3	3	3	3	4	3	3	3	4	3	3	3	2	4	3	2	3	4	3	3	3	3	4	3	3	3	3	3	4	3	3
26	Respor	Protecting and restor	Protected area as a percent of total	3.83	3.42	3.00	**3.50**	4	4	3	4	3	3	4	4	3	3	3	3	4	3	3	4	4	3	4	4	3	3	4	4	3	3	3	3	4	3	3	4	4	3	4	3	3
27	Respor	Protecting and restor	Forest fire monitoring and controlling	3.33	3.00	2.33	**3.00**	4	3	2	3	3	3	4	3	2	3	3	3	3	3	2	3	3	3	3	3	2	3	3	2	4	3	2	3	3	3	3	3	2	4	3	2
28	Respor	Protecting and restor	Area of forest plantation	3.50	3.25	2.33	**3.17**	4	3	2	4	4	2	3	3	2	4	3	2	4	4	2	3	3	3	4	3	2	3	3	3	3	4	3	3	3	3	4	3	2	3	3	2
29	Respor	Soil conservation pra	% of farmers practicing soil and water	3.50	3.25	2.92	**3.17**	4	3	3	3	3	3	4	3	2	3	3	3	4	3	3	4	4	3	3	3	3	4	4	3	3	3	3	4	3	3	3	4	3	3	3	3
30	Respor	Soil conservation pra	planting cover crops	3.33	3.67	3.08	**3.08**	3	4	3	4	3	3	3	4	3	4	3	3	4	4	3	4	4	3	3	4	3	3	4	4	3	4	3	3	4	3	3	3	3	3	3	3
31	Respor	Supply side management	Improve water storage capacity	3.42	3.58	2.58	**3.17**	3	4	2	4	4	2	3	3	3	3	4	2	3	3	3	4	4	3	4	3	3	3	4	2	3	4	3	4	4	3	4	2	3	3	4	2

Appendix F Unit of measurement and possible sources of 31 potential indicators

No.	Type	Issue	Indicator name	Unit of measurement	Possible sources
1	Driver	Population change	population density (ความหนาแน่นของประชากร)	จำนวนประชาการต่อตารางกิโลเมตร ในพื้นที่ลุ่มน้ำ	Department of Provincial Administration กรมการปกครอง
2	Driver	Poverty	Number of household with the minimum annual income of 30,000 Baht per person (ครัวเรือนมีรายได้เฉลี่ยไม่น้อยกว่าคนละ 30,000 บาทต่อคนต่อปี)	รายได้ทั้งหมดในรอบปีของทุกคนในครัวเรือนรวมกันแล้วหารด้วยจำนวนสมาชิกทั้งหมดในครัวเรือน	กรมพัฒนาชุมชน (ข้อมูล จปฐ.), (Basic Minimum Needs : BMN)
3	Driver	Climate change	Shifting in rainfall pattern (การเปลี่ยนแปลงช่วงเวลาของฝนตก)	จำนวนวันฝนตกในแต่ละเดือนเทียบกับค่าเฉลี่ยในอดีตของแต่ละสถานีตรวจวัด หรือพื้นที่ total annual precipitation in centimeters and at each weather station,	สถานีตรวจวัดอุตุนิยมวิทยาอำเภอกมลาไสย จังหวัดกาฬสินธุ์ Meteorological station, Kamalasai District, Kalasin
4	Driver	Climate change	Change in mean annual precipitation (การเปลี่ยนแปลงของค่าเฉลี่ยปริมาณน้ำฝนในแต่ละปี)	ปริมาณน้ำฝนตกเฉลี่ยรายปีเทียบกับค่าเฉลี่ยในอดีตของแต่ละสถานีตรวจวัด หรือในพื้นที่ลุ่มน้ำ total annual precipitation in centimeters at each weather station	สถานีตรวจวัดอุตุนิยมวิทยาอำเภอกมลาไสย จังหวัดกาฬสินธุ์ Meteorological station, Kamalasai District, Kalasin
5	Driver	Climate change	average temperature (อุณหภูมิเฉลี่ย)	ค่าเฉลี่ยของอุณหภูมิรายเดือนหรือรายปีจากสถานีตรวจวัดที่มีอยู่ในพื้นที่ลุ่มน้ำ	สถานีตรวจวัดอุตุนิยมวิทยาอำเภอกมลาไสย จังหวัดกาฬสินธุ์ Meteorological station, Kamalasai District, Kalasin
6	Driver	Land use change	Proportion of change of each category of land use to another land use per unit of time (สัดส่วนการเปลี่ยนแปลงการใช้ที่ดินแต่ละประเภทในแต่ละช่วงเวลา)	เปรียบเทียบสัดส่วนการเปลี่ยนแปลงการใช้ที่ดินแต่ละประเภทในแต่ละช่วงเวลาโดยใช้ระบบสารสนเทศทางภูมิศาสตร์	กรมพัฒนาที่ดิน Land Development Department
7	Pressure	Illegal logging	Forest area damaged by illegal logging (พื้นป่าที่เสียหายจากการลักลอบตัดไม้)	ขนาดของพื้นที่ป่า (ไร่) ที่ถูกลักลอบตัดในพื้นที่ลุ่มน้ำ	Department of National Parks, Wildlife and Plant Conservation, Royal Forest Department
8	Pressure	Forest fire	Area damaged by fire (พื้นที่ที่เสียหายจากการเกิดไฟป่า)	ขนาดของพื้นที่ป่า (ไร่) ที่ถูกทำลายโดยไฟป่าในแต่ละปีในพื้นที่ลุ่มน้ำ	Department of National Parks, Wildlife and Plant Conservation, Royal Forest Department
9	Pressure	Change in land cover	distribution of land-cover types across the total watershed area	สัดส่วนของสิ่งปกคลุมดินแต่ละประเภทในพื้นที่ลุ่มน้ำ	กรมพัฒนาที่ดิน Land Development Department

No.	Type	Issue	Indicator name	Unit of measurement	Possible sources
			(การกระจายตัวของสิ่งปกคลุมดินในพื้นที่ลุ่มน้ำ)	(ร้อยละ)	
10	Pressure	Water demand/abstraction	Water use by sectors (ปริมาณการใช้น้ำของแต่ละกิจกรรม)	ปริมาณการใช้น้ำของแต่ละกิจกรรม เช่น การเกษตร อุตสาหกรรม ครัวเรือน (ล้านลบม. /ปี)	กรมทรัพยากรน้ำ; กรมชลประทาน
11	Pressure	Pesticides use	Application rates of different pesticide categories (อัตราการใช้สารศัตรูพืชแต่ละประเภท)	สัดส่วนการใช้สารศัตรูพืชแต่ละประเภท (กิโลกรัมต่อไร่)	Kalasin Provincial Agricultural Extension Office
12	State	Forest resources	Proportion of forest area to watershed's area (สัดส่วนพื้นที่ป่าต่อพื้นที่ลุ่มน้ำทั้งหมด)	ร้อยละของพื้นที่ป่าไม้เทียบกับพื้นที่ลุ่มน้ำทั้งหมด	Department of National Parks, Wildlife and Plant Conservation, Royal Forest Department
13	State	Forest resources	Proportion of remaining head watershed in the forest (สัดส่วนของป่าต้นน้ำเทียบกับพื้นที่ป่าทั้งหมด)	ร้อยละของพื้นที่ป่าต้นน้ำ เมื่อเทียบกับพื้นที่ป่าทั้งหมด	Department of National Parks, Wildlife and Plant Conservation, Royal Forest Department
14	State	Biodiversity	abundance and distribution of selected species (ความอุดมสมบูรณ์และการแพร่กระจายของชนิดพันธุ์ที่ถูกคัดเลือก)	จำนวนของชนิดพันธุ์ที่คัดเลือกและการแพร่กระจายในพื้นที่ลุ่มน้ำ	Department of National Parks, Wildlife and Plant Conservation, Royal Forest Department
15	State	Biodiversity	Threatened species as a percent of total species	จำนวนชนิดพันธุ์ที่ถูกคุกคามเทียบกับจำนวนชนิดพันธุ์ทั้งหมดในพื้นที่ลุ่มน้ำ	Department of National Parks, Wildlife and Plant Conservation, Royal Forest Department
16	State	Water resources	Frequency, duration and extent of water shortages (ความถี่, ช่วงเวลา และปริมาณการขาดแคลนน้ำ)	จำนวนวัน, ช่วงเวลา และปริมาณน้ำที่ขาดแคลนใน 1 ปี	Department of Water Resources
17	State	Water resources	Overall reservoir stocks (ปริมาณน้ำในอ่างเก็บน้ำ)	ร้อยละของปริมาตรน้ำทั้งหมดในอ่างเก็บน้ำที่สามารถนำมาใช้ประโยชน์ได้ ในพื้นที่ลุ่มน้ำ	Department of Water Resources, Royal Irrigation Department
18	State	Water resources	Water levels (ระดับน้ำบาดาล)	ระดับความลึกของน้ำบาดาล (เมตร)	Department of Groundwater Resources
19	State	Soil resources	Degree of top soil losses	ระดับการการสูญเสียหน้าดิน (ตัน/ปี)	กรมพัฒนาที่ดินLand Development Department
20	State	Soil resources	physical soil structure (โครงสร้างของดิน)	สมบัติทางกายภาพของดิน ได้แก่ เนื้อดิน โครงสร้างของดิน ความหนาแน่น ความพรุน อุณหภูมิ และสีของดิน	กรมพัฒนาที่ดินLand Development Department
21	Impact	Decrease storage capacity	Total suspended solids concentrations in selected locations (Reservoir, natural	ปริมาณของแข็งที่ไม่ละลายน้ำและสามารถแขวนลอยอยู่ในน้ำได้ (mg/L)	Department of Water Resources, Royal Irrigation Department

No.	Type	Issue	Indicator name	Unit of measurement	Possible sources
			storage) ปริมาณสารแขวนลอยทั้งหมดจากอ่างเก็บน้ำ/แหล่งน้ำธรรมชาติ		
22	Impact	Changes in crop yields	Production of selected crops per rai ผลผลิตทางการเกษตร (พืชแต่ละชนิด)	ปริมาณผลผลิตทางการเกษตรของพืชแต่ละชนิด (ตัน/ไร่)	เกษตรจังหวัดกาฬสินธุ์ Kalasin Provincial Agricultural Extension Office
23	Impact	Quality of life	Number of households access to clean water for drinking and consuming compared to all households (จำนวนครัวเรือนมีน้ำสะอาดสำหรับดื่มและบริโภคเทียบกับครัวเรือนทั้งหมด)	ร้อยละของครัวเรือนมีน้ำสะอาดดื่มและบริโภคพอตลอดปีเทียบกับครัวเรือนทั้งหมดในพื้นที่ลุ่มน้ำ	กรมพัฒนาชุมชน (ข้อมูล จปฐ.), (Basic Minimum Needs : BMN)
24	Impact	Quality of life	Number of households with water available for utilization compared to the entire household (จำนวนครัวเรือนมีน้ำใช้พอเพียงเทียบกับครัวเรือนทั้งหมด)	ร้อยละของครัวเรือนที่มีน้ำใช้พอเพียงตลอดปีเทียบกับครัวเรือนทั้งหมด	กรมพัฒนาชุมชน (ข้อมูล จปฐ.), (Basic Minimum Needs : BMN)
25	Impact	Quality of life	Number of patients due to use of chemical pesticides (จำนวนผู้ป่วยที่ได้รับพิษจากสารกำจัดศัตรูพืช)	จำนวนผู้ป่วยที่ได้รับพิษจากสารกำจัดศัตรูพืชต่อปี	Kalasin Provincial Health Office
26	Response	Protecting and restoring of habitats and species	Protected area as a percent of total watershed area (ร้อยละของพื้นที่คุ้มครองในพื้นที่ลุ่มน้ำ)	สัดส่วนของพื้นที่คุ้มครองต่อพื้นที่ลุ่มน้ำทั้งหมด (ร้อยละ)	Department of National Parks, Wildlife and Plant Conservation
27	Response	Protecting and restoring of habitats and species	Forest fire monitoring and controlling mechanism (การติดตามตรวจสอบ และมาตรการควบคุมไฟป่า)	จำนวนแผนป้องกันและมาตรการควบคุมไฟป่า	Department of National Parks, Wildlife and Plant Conservation, Royal Forest Department
28	Response	Protecting and restoring of habitats and species	Area of forest plantation (พื้นที่ป่าปลูก)	พื้นที่ปลูกป่า (ไร่/ปี); สัดส่วนของพื้นที่ปลูกป่าต่อพื้นที่เป้าหมาย	Department of National Parks, Wildlife and Plant Conservation, Royal Forest Department
29	Response	Soil conservation practices	% of farmers practicing soil and water conservation technologies (ร้อยละของเกษตรกรที่ใช้มาตรการการอนุรักษ์ดินและน้ำ)	จำนวนครัวเรือนที่เข้าร่วมและใช้เกษตรทฤษฎีใหม่; จำนวนครัวเรือนที่ใช้ปุ๋ยธรรมชาติอย่างเดียวในการเพาะปลูก; จำนวนครัวเรือนที่นำศาสตร์พระราชามาใช้	Kalasin Land Development Station; Kalasin Provincial Agricultural Extension Office
30	Response	Soil conservation practices	planting cover crops (การปลูกพืชคลุมดิน)		Kalasin Land Development Station; Kalasin

No.	Type	Issue	Indicator name	Unit of measurement	Possible sources
					Provincial Agricultural Extension Office
31	Response	Supply side management	Improve water storage capacity (การเพิ่มความจุการกักเก็บน้ำ)	จำนวนแหล่งน้ำที่มีการปรับปรุงประสิทธิภาพต่อปี; จำนวนของแหล่งน้ำที่สร้างเพื่อการชลประทานในลุ่มน้ำต่อปี; จำนวนบ่อน้ำในไร่นาต่อปี	Kalasin Irrigation Office, Department of water resources Kalasin Land Development Station

VITA

Waintorn Khunanake was born in Roi-Et, Thailand on 18th December 1970. She graduated from Kasetsart University with the Bachelor's degree in Fisheries (Marine Science) in 1993, and graduated from Chulalongkorn University with the Master of Science (Environmental Science) in 1997. She enrolled in the Environment, Development, and Sustainability (EDS) program, the Graduate School, Chulalongkorn University in 2010.