Czech University of Life Sciences Prague

Faculty of Tropical AgriSciences

Master's thesis

Farmer's perception of ecosystem services for lowland rice cropping systems in Battambang province, northwest of Cambodia

Supervisor
Vladimir Verner

Author
Raksmey Phoeurk

Prague-Suchdol, 2017

Assignment

Declaration

I hereby declare that this diploma thesis “Farmer’s perception of ecosystem services for lowland rice cropping systems in Battambang province, northwest of Cambodia” is a part of my own research under a coordination of my supervisor. Where any part of the whole work has previously been submitted for a degree or any other qualification at this university or any other institution and the information derived from the published and unpublished reports or documents of others has been acknowledged in the text and references.

…………………………

Prague – Suchdol, 27th of April, 2017 Raksmey Phoeurk

Acknowledgment

I sincerely and gratefully would like to thank my supervisor, Dr. Vladimir Verner, who kindly supervised and guided me with valuable comments until the end of my succeed today. His dedication is really appreciated.

Also, my special thanks go to Dr. Sok Kimchhin and Dr. Neang Malyne, the secretary and rector of Ecoland Research Centre in Cambodia, who dedicated their valuable times to guide me and provided me with crucial comments. Without both of them I would not be able to achieve my work smoothly and fruitfully.

Grateful thanks go to the ALFABET program and its committee who kindly supported me for the whole 2-year-scholarship as well as assisting me for some administrative tasks.

My thesis was also elaborated within the team of Internal Grant Agency of the Faculty of Tropical AgriSciences number 20165011.

I also would like express my gratefulness to the local farmers and authority in my study area who kindly and friendly participated in my research.

Last but not least, I would like to express my special thanks to my future wife, Miss. Nou Sreyoun, who supported, encouraged and inspired me to achieve reach my dream.

Finally, I am highly thankful to my relatives, friends and assistants who always kindly help and support me.

Abstract

Rice cropping system has significantly played role in food security and poverty alleviation in Cambodia. The main cultivated areas are located in rainfed lowlands around Tonle Sap Lake relying mainly on natural resources provisioning. However, due to serious changes in water flow of Mekong River and continuous climate dynamics, several changes of rice cropping systems are observed recently. This thesis focused particularly on the farmer's perceptions of ecosystem services in rice cropping systems around Tonle Sap Lake in Battambang province, northwest of Cambodia. The main aim was to carry out ex-post analysis and understanding of land-use changes and economic profitability of rice cropping systems with respect to recent dynamics in Tonle Sap Lake floodplain ecosystem. 120 rice farmers randomly selected in two different agro-ecosystems that are low-water land and middle-water land in Sangkae district. Agrarian system analysis and diagnosis method was applied to deeply analyse the changes in rice cropping systems, socio-economic interaction with resources use and land intensification at household level. Results showed that farmers changed their traditional rice cropping systems to modern systems by adopting new innovations, inputs and technology. Nevertheless, new cropping systems seem to be less sustainable, usually because of inadequate use of new technologies or inputs. Furthermore, rice cropping systems in middle-water land were profitable compared to low-water land. For economic performances, long-term rice (354 USD/ha), early season rice (81 USD/ha), and double rice (310 USD/ha) in Middle-water land were higher than long-term rice (182 USD/ha), early season rice (76 USD/ha) and double rice (258 USD/ha) Low-water land. Farmers in both study sites were aware of the ecosystem services provided by Tonle Sap Lake, but not all of them perceived same importance among the cropping systems. Thus, changes in ecosystem services posed rather negative impacts on smallholder livelihood in floodplain areas. The poorest households, who mainly relied on traditional rice cropping system, were highly vulnerable to food insecurity and insufficient household's income due to changes of the ecosystem services in their location, particularly decreasing water level.

Keywords: rice cropping system, traditional rice system, agrarian system, process analysis, Tonle Sap Lake, Cambodia

Table of Contents

List of Tables

List of Figures

Abbreviations

ASDP	Agricultural sector strategic development
AS	Agrarian system
CI	Conservation International
DR	Dry season rice
ES	Ecosystem services
ESR	Early season rice
FL	Floating rice
FS	Farming system
GO	Gross output
GVA	Gross value-added
GDP	Gross domestic product
IRRI	International Rice Research Institute
IR	International Rice
NTFPs	Non-Timber Forest Products
RGC	Royal Government of Cambodia
MoE	Ministry of Environment
PES	Payment for environmental services
MRC	Mekong River Commission
MAFF	Ministry of Agriculture, Forestry and Fishery
MEA	Millennium Ecosystem Assessment
RR	Receding rice
SPSS	Social Package for Social Sciences
TSL	Tonle Sap Lake
UNEP	United Nation Environment Programme
WCS	Wildlife Conservation Society
WWF	World Wildlife Fund

1 Introduction

Agriculture contributes to Cambodian economy by 29% and it is based particularly on crop production, which creates around 60% of Cambodian agrarian gross domestic product. Paddy rice represents a major crop playing crucial role in ensuring food security and income generation for the rural population. The majority of rainfed lowland areas are cultivated in floodplain of Tonle Sap Lake (TSL) which accounts for almost 90% of the total rice cultivation fields in Cambodia as well as for 77% of total rice production (Chea, 2015; MAFF, 2016). Particularly rice-based cropping systems are enormously dependent on the natural resources provisioning. Tonle Sap Lake is known as a complex ecosystem which provides a substantial hydrological, biological, nutritional, cultural value and the productive operations as natural floodwater reservoir in the lower Mekong region offering flood protection and assuring dry season flow to the Mekong Delta (Arias et al., 2014; Kummu et al., 2014). More than half of water in Tonle Sap lake comes from the Mekong river (>50%), 34% from 11 tributaries in the Tonle Sap lake catchment, and 12.5% directly from rainfalls (Arias at al., 2014). The floodplain system of TSL plays a critical role not only in providing necessary water resources and other environmental services for the entire country, but it also represents a global biodiversity hotspot supporting the remarkable production of fish, agriculture, mainly rice, and wetland products (Keskinen et al., 2013).

However, the hydrological alterations, hydropower development, building dams in the upstream countries, in the lower Mekong tributaries brought to Tonle Sap Lake have changed the flood pulse in TSL that would have negative impacts on ecosystems and agriculture in the floodplain area (Keskinen et al., 2013; Arias et al., 2014; Kamoshita & Ouk, 2015). The majority of the households in floodplain (60%) is involved in agriculture for their subsistence or cash generation and rice (*Oryza sativa* L.) cultivation is a key component of the TSL ecosystem, which is highly synchronized with the flood pulse (Keskinen et al., 2013). Thus, any changes would have significant interaction with rice-based cropping systems in the floodplain areas.

Battambang province is the major producer of rice called “rice bowl” in Cambodia, where more than 70% of the population depend on agriculture as their main job and almost half of them cultivate rice (provincial department of planning, 2016). Kamoshita & Ouk (2015) found that extreme flooding damaged more than one tenth of rice cultivated area in 2011 in the country, but the total areas of rice affected by these floods reached more than 30% in Battambang province, while damages in Sangkae district itself represented 70% of the total cultivated area. Moreover, even in following years, the rice production continued to decline, for example by twenty per cent in 2014 comparing to 2013, and increased by almost 20 per cent in 2015 (provincial department of planning, 2016). With these changes of TSL, farmers have changed their rice cropping systems by adapting new innovations and technologies in the purpose of increasing their rice production. Cultivated area for rice cropping systems in floodplain areas of TSL have been changed from floating rice or long-term rice cultivation to high-yield rice growing, particularly early season rice and/or receding rice cultivation (Keskinen et al., 2013).

Based on the interactions of these changes of TSL ecosystems, especially flood pulse, and rice cropping systems, the study discusses advantages and disadvantages of the changes in rice cropping systems as well as documents the perception of Ecosystem services of TSL affecting the livelihood of households living in different agro-ecosystems. Moreover, there are still lack of scientific studies on such topic from Cambodia which would deeply analysed the changes of agricultural land-use systems of rice cropping systems in the floodplains in/around TSL whereas the Ecosystem services of TSL altered by the changes of its flood pulse. The study proposes to conduct a research on these interactions between Ecosystem services of TSL and rice cropping system in lowland area in Battambang province in northwest of Cambodia.

2 Literature review

2.1 Ecosystem services concept

The concept of ecosystem services (ES) has been considered and used as a significant model for linking beneficial environmental services with human well-being in order to appropriately make natural conservation decision (Fisher et al., 2009; TEEB, 2010; Lamargue et al., 2011; Hauck et al., 2013). During the 1970s and 1980s, the number of publications stressing the role of natural ecosystems in human activities as well as setting the prioritised ecological-economic term for policy makers extended scientific and public attention on biological conservation (Braat & de Groot, 2012). The main purpose of adapting Ecosystem services concept is to explicitly reveal the linkages between functions of ecosystems as economic dimensions and human society, especially clearly show the negative effects of ecosystem decline and pollution to human well-being. Hence, it can increase the public focuses on environmental conservation as well as encourage decision makers to implement conservation policy effectively (Braat & de Groot, 2012; de Groot, 2010). Term ES was firstly used in the publication written by Ehrlich and Ehrlich in 1981, entitled “The cause and consequences of the disappearance of species”. During 2001 and 2005, in its historical development was clearly noticeable as a major milestone by the publication of UNEP’s Millennium Ecosystem Assessment. This concept started to be well known because of Millennium Ecosystem Assessment classification this ES into 4 groups which is detail in figure 1 as below.

It sought a strong scientific evidence to understand how ecosystems affect human welfare and has to be sustainably managed (de Groot, 2010). There are several literature sources that provide the definitions of ES. Daily (1997) has provided this definition of ES as the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life. Anyways, these definitions are still aligning with Millennium Ecosystem Assessment while it provides as the benefits to people obtaining from ecosystems. On the other hand, there are three following has defined after MEA (2005) such as Boyd & Banzhaf (2007) offered ES are the components of nature, directly enjoyed, consumed, or used to yield human well-being; Fisher et al. (2009) set as the aspects of ecosystem utilized (activity or passively) to produce human well-being; the latest on provided by TEEB Foundations (2010) ES are the direct and indirect contributions of ES to human well-being.

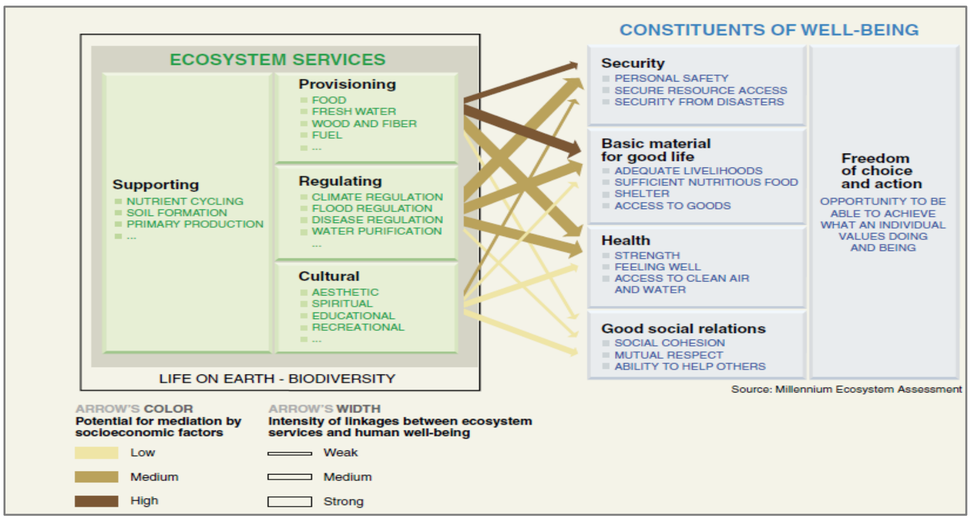


Fig. 1 Linkages between Ecosystem services and human well-being
Source: Millennium Ecosystem Assessment (2005)

To be more efficient for this concept implementation, at the beginning is important to have a consistent and ecologically-based approach. It is because of the concept of ES has become a major topic, which is needed to take into account critical criterion for conservation assessments (Egoh et al., 2007; Fisher, 2009). Regarding to de Groot et al. (2010) has drawn a similar conclusion on ES concept that the ES approach and ES valuation efforts have changed the terms of discussion on environmental conservation, natural resource management, and other areas of public policy. Recently, it is widely recognised that ecosystem conservation and conservation management strategies do not essentially pose a trade-off between the ‘‘environment’’ and ‘‘development’’. He also suggested that investments in conservation, restoration, and sustainable ecosystem use are increasingly seen as a ‘‘win-win situation’’ which creates extensively ecological, social and economic benefits between stakeholders.

2.2 Ecosystem services and agriculture land-use systems

In agricultural, natural resources provide massive ecosystem services such as regulating ecosystem services including pollination, biological pest control, shade, and shelter, and provisioning services including food, fibre, water quality protection and climate regulation. This provisioning service leads to the increase of production and productivity of agriculture (Zhang et al., 2007; Stallman, 2011). In turn, agricultural productions also get other environmental dis-services which declining the productivity and increasing production inputs or cost, and competition for water and nutrients by undesired species (Zhang et al., 2007). There are three critical ways of interaction between ES and agriculture (Dale & Polasky, 2007). Firstly, a lot of ES provided by agro-ecosystems such as provisioning services includes food and fibres, regulating services including soil retention and pest control, supporting services such as nutrient cycle and water filtration, and cultural services, e.g. spiritual well-being and rural lifestyles. Secondly, agriculture also receives many ES from natural resources as important inputs in production such as soil fertility, pollination and pest control (Zhang et al., 2007). Third, agriculture can reduce the quality and quantity of ecosystems in terms of both goods and services (Tilman et al., 2002; Dale & Polasky, 2007). Regarding to these interactions, suitable agricultural land management is necessary and required in order to increase sustainable agriculture and natural resources management (Tilman et al., 2002; MEA, 2005). Due to the sustainable agricultural intensification and environmental conservation, incentive tool in agriculture ecosystems is the most appropriate encouragement to farmers to strongly involve in their suitable production practices of food, fibre and fuel as well as providing many ES in their agricultural land use (Tilman et al., 2002; Swinton et al., 2007).

2.3 Ecosystem services and paddy rice interaction

Regarding to Dale & Polasky (2007), three ways of interaction between agriculture and ES can be recognized. Paddy rice has important role in providing goods and services of ecosystems such as food production, nutrient cycling, soil protection, flood control, gas regulation, pollination, aesthetic scenery, habitat for birds, insects and soil organisms (Xiao et al., 2005; Pan et al., 2009; Kogel-Knabner et al., 2010; Dan et al., 2010). However, it conversely provides negative effects on environmental functions due to overuse of inputs especially chemical fertilizers and pesticides (Itoh et al., 2011; Knoblauch et al., 2011). There are several studies which adapted this ES concept concerning to rice ecosystems such as in China, Japan, Vietnam, Philippines, West Africa, and Cambodia. The authors have used different methodologies with this concept to provide the evidences of benefits and economic value of the environmental services obtain from rice ecosystems.

The studies of Dan (2010), Yu et al. (2011), and Shams (2007) have applied the ES concept in order to investigate the value of the goods and services of ecosystems in the paddy rice. Based on the result, Dan (2010) who focused on ES between organic and conventional rice paddies reported that the monetary value of ES in the organic rice field was provided approximately 30 thousand yuan RMB per hectare and year comparing to conventional rice paddies was more than 22,700 yuan RMB per hectare and year. Similar study, but using different evaluation model, Yu et al. (2011) indicated that the integrated economic value per unit area of ecosystem services of the ten rice paddies ranged annually from USD 8,605-21,405 per hectare. The economic value per unit area of ecosystem services, not including the value of primary production, accounted for 74-89% of the integrated value per unit area.

Aside from these studies, there are three authors have adapted the ES concept link to rice cropping system in order to investigate the value of ES in rice cropping system in monetary value as well as considering the suitable rice production for sustainable practices including both economic benefits and environmental conservation. Shame (2007) showed the quantities of fish and other aquatic animals collected, between 111 kg and 267 kg per family based on ecosystems, from rice field ecosystems have constituted as an important source of food and income for the rural households in Cambodia. On the other hand, Akara (2010) focused on the contribution of organic rice in environment conservation and poverty reduction in Kampong Thom province. He found that the rice cropping system between rainy season rice and organic rice, without hand tractors, have provided a high value of economic efficiency than the other rice cropping systems. On the other hand, he suggested that organic rice cropping system has strongly support the environment conservation. Similarly, Malyne (2015) conducted a study on maintaining ecosystem services provided by rice production system specifically in flood plain areas of Tonle Sap Lake. She has identified nine rice cropping systems and found that rainy season rice and floating rice provide high value of ES. Hence, she concluded that the combination of rice cropping system between short-term rice with rainy season rice benefits both the most economically efficient as well as environmental services provisioning especially floating rice.

2.4 Awareness and perceptions of ecosystem services by farmers

Integrating farmer's awareness and perceptions of ES into their assessment for environmental policy and decision-making is very important, through the value of ES they have placed on (Nkonya et al., 2016; Zhang et al., 2016). Relevant studies have adapted ES concept from Millennium Ecosystem Assessment (2005) in order to investigate the awareness and perception of ES. Smith & Sullivan (2014) and Zhang et al. (2016) have categorized ES into following groups: provisioning service, regulating service, cultural services and supporting services, based on their pre-survey and used Likert scale method for each of ES which were already listed in the questionnaires. Zhang et al. (2016) indicated that almost 90 per cent of the villages were aware of such provisioning ES including crops, biofuel or fuel wood, freshwater, natural and plant-derived medicine, and wildlife, considering as very important ES to the rural communities in Nigeria. Meanwhile, Smith & Sullivan (2014) indicated that farmer provided a high value of ecosystem services as important services as well as identified the threats towards ES whilst were mostly in their agriculture. Moreover, they perceived themselves to be relatively vulnerable to the loss of services. Anyways, Lithourgidis et al. (2016) documented attitudes of the farmers and awareness on their rice farming practices. The results suggested that high level of awareness of potential impacts of farming practices on the environment showed by farmers to who may be influenced by their high experiences in farming, adequate formal education and valid source of information on environment. In addition, Lamargue et al. (2011) conducted a survey on stakeholder perceptions of ecosystem services in three European grassland regions. He illustrated that farmer did not perceive all the listed ecosystem services in questionnaire as important to them depending on their region. However, they considered those ecosystem services existing in their grassland area are important. A similar study of Lasco et al. (2016) sought to understand the perceptions of Filipino smallholder farmers regarding climate change and the roles of trees in coping with such changes. The results showed that the importance of tree roles in building resilience to climate risks was probably less among respondents with higher levels of education and who derived income from tree products. In contrast, it positively perceived of the value of trees with whom having trees on their farms planted by household members, observed an increase in temperature and decline in yield as well as the climate information provided by the government. Farmer's perception investigation is to understand the value of ES in their agriculture and land use. However, there have been a limitation of researches which focus on famer's awareness and perception of ES in agriculture in Cambodia.

2.5 Payment for environmental services

Payment for environmental services is rather a marketing-based tool for supporting ES concept contributing in sustainable environmental conservation. PES represents a mechanism for promoting sustainable management of ecosystem services and can be useful for supporting rural development (Ingram et al., 2014).

In a context of increasing attention about forest and biodiversity conservation, ecosystem services preservation by local communities is now put forward by policy-makers and scientists worldwide (Millet & Peresse, 2014). In case of Cambodia, the ecosystem service concept was already existed through PES projects were implemented since the beginning of 2000s in order to attribute the economic value to ecosystems due to continuously degradation of forest as well as dramatically depleted of the natural resources (Millet & Peresse, 2014; Milne & Chevier, 2014). Anyways, it is being supported by international donors and non-governmental organisations (NGOs) including substantial finance, intellectual and politic enhancement in advance to these policy ideas over the last decade (Milne & Chevier, 2014). More details about PES projects are shown in table.1 below.

Table 1 Summary of PES projects in Cambodia

ES type	Project	Implementer	Payee	Payer
Biodiversity PES	Community-based Ecotourism	WCS	Village fund	Tourists
	Agri-environment Payments	WCS	Individual farmers	Urban consumers hotels and restaurants
	Direct Contracts schemes for bird nest protection,	WCS, WWF, Birdlife	Individual villagers	NGO
	Direct Contracts for Turtle Net Protection	CI	Individual villagers	NGO
	Conservation incentive agreements	CI, Poh Kao	Commune fund and individual villages	NGO
Watershed PES NB. not yet operational	Payments for fresh water provision	Wildlife Alliance / MoE	Not determined	Not determined
	Watershed protection for hydro-power in Cardamom Mountain	FFI / MoE & FA	Not determined	Not determined
REDD pilots NB. not yet operational	Oddar Meanchey Community Forestry REDD+ Project	PACT / FA	Stopped	Voluntary Carbon market (certified)
	Seima Protection Forest REDD+ Pilot	WCS / FA	CF and the RGC	Voluntary Carbon market (certified)
	REDD+ Community Carbon Program	FFI / FA	Not determined	Not determined

Source: adapted from Milne and Chervier (2014)

There are few researches focusing on PES feature and its impacts assessment conducted in Cambodia. Regarding to the evaluation report of Millet & Peresse (2014) found that the concept remains unclear by stakeholders, political and financial issues, lack of PES assessment system.

2.6 Tonle Sap Lake characteristics and overview

Tonle Sap Lake (TSL), one of the largest freshwater lake in Southeast Asia and the heart of Mekong River system in Cambodia, covers an area of 250,000 to 300,000 ha (2,500 to 3,000 km^2) in the dry season and 1,000,000 to 1,600,000 ha (10,000 to 16,000 km^2) in the wet season where providing socio-economics for Cambodian people and had been founded about 500 years ago (MRC, 2010). Regarding to Cabbonel (1963) it was showed that TSL is located in the centre of the Cambodian central plain, which has an elevation of 10-30 m above sea level and covers 75 per cent of the country. A huge amount of the water in TSL is always fulfilled by the annual inflow of the Mekong water via TSL's rivers, during every wet season while the water level in the Mekong rise and changed to be empty again when the water flow goes backwards at the end of wet season. More than half of annual water flow into the TSL comes directly from the Mekong via the Tonle Sap Rivers (>50%), 34% from 11 tributaries of TSL's catchment, and 12.5% from rainfall precipitation (MRC, 2010; Arias et al., 2014). This flood pattern noticed as a unique hydrological cycle of TSL (MRC, 2010). Figure 3 visualised the layout and location of TSL in Cambodia. The hydrological regime supports an unnoticeable supports to national economic development contribution of Cambodia by providing a wide range of ecosystems such as high biodiversity and productivity, mainly fish, plant communities, and wildlife. For example, almost half of the Cambodian population uses resources of TSL.

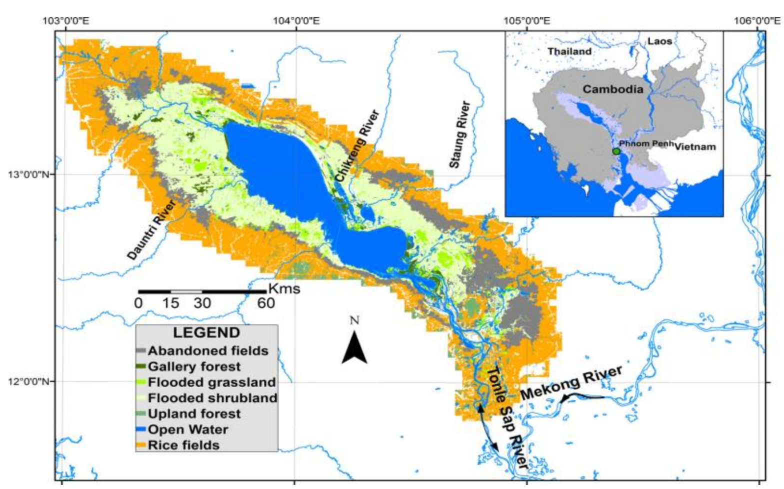


Fig. 2 Overview map of the Tonle Sap
Source: Arias et al. (2014)

Aside from provisioning services, it also provides another Ecosystem services so called cultural service and regulating services, which reflected Khmer cultural identity including traditions, livelihood, festivals, and taste. In addition, its floodplain areas have provided highly potential for agriculture cultivation where is most favourable for agriculture in Cambodia, mainly rice (Liese, 2014).

TSL is classified in three different zones called zone 1, 2 and 3. Each distinct zone provides local households with different ES based on the location in floodplain and major livelihood activities. All zones were classified so-called lower floodplain zone or fishing zone (zone 1) where 5% of population are living closely with the lack and mainly depend on fishing as their major source of income, upper floodplain zone or agricultural zone (zone 2) where 60% of population live in the floodplain area and engaged mainly in agriculture, and urban zone (zone 3) where 35% of population live along the national road (Keskinen et al., 2013). This classification was originally based on topographic location and urbanization (Keskinen, 2003 and 2006). On the other hand, the authority of Tonle Sap has divided these zones into three distinct zones so-called protection zone such as protection zone 1 where villages and farmland located along the national road 5 and 6, protection zone 2 where buffer area between zone 1 and 3, including farmland and shrub land where farmers used to grow floating rice, but now becoming receding rice fields.

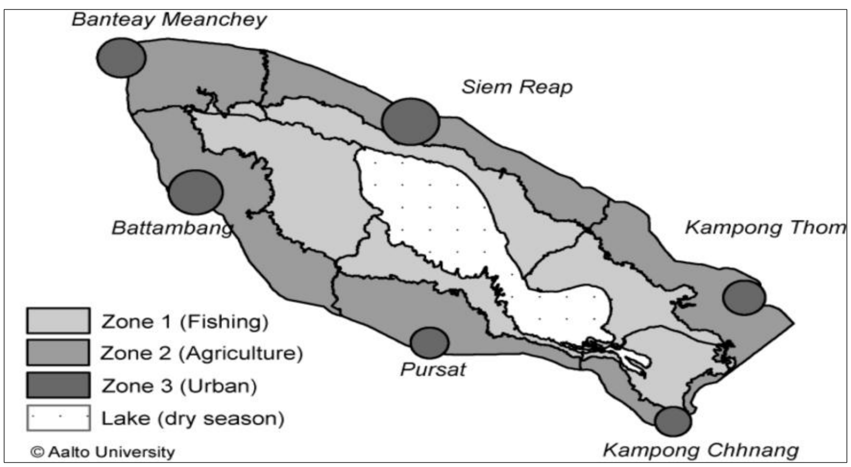


Fig. 3 The zones classification of the Tonle Sap Lake
Source: Keskinen et al., (2013)

2.6.1 Ecological resources and livelihood in Tonle Sap Lake

Ecosystem services play significant roles in providing necessary advantages for human well-being world-wide (Millennium Ecosystem Assessment, 2005). One of the most special world ecosystems is Tonle Sap Lake (TSL) located in central Cambodia. The TSL has at least eight sub-ecosystem services such as permanent water body or the Great Lake itself, rivers and streams, seasonally inundated forests, shrub lands, grasslands, receding and floating rice fields, seasonally flooded crop fields, and marshes and swarms (MRC, 2010). In TSL, the natural floodplain vegetation, wood, flooded forest, aquatic plants, microscopic aquatic animals, and floodwater are used for wide range of purposes of people (Lamberts, 2001). Flooding water is one of the most important ecosystem service bringing a huge nutrient from the Mekong to the lake and mainly useful for irrigation and cultivation of flood-recession rice, which also a major driving force for households' livelihood (Lamberts, 2001; Keskinen et al., 2013). The floodplain vegetation in TSL has supported necessary ecosystem productivity by providing habitats, substrate area, and food for aquatic organisms. Obviously, fish species have commercial value, and more than 100 species caught regularly as well as more than eight hundred species of floodplain plants and animals recorded for recent inventory. The value of fishery production has contributed to annual GDP up to 10 to 12 per cent, which the amount of fish catch up to 120 kilogrammes produced by one hectare of the floodplain, and annually fish catch estimated at least around 400,000 tonnes (MRC, 2010). In addition, this unique ecosystem provides critical spawning and rearing habitat for one of the largest and productive freshwater fisheries in the world (Lamberts, 2001; Baran & Myschowoda, 2009; RGC, 2010; Cooperman et al., 2012). Moreover, fish is one of the main resources in TSL substantially providing protein up to 80% to approximately 1 million or beyond of Cambodian people in the surrounding provinces of TSL (Hortle, 2007; MRC, 2010).

Agricultural productivity, rice cultivation, and agricultural activities are the major sources of income for households' livelihood. Rice is the main crop in the area as 68% of the households plant it. The second most important crop is maize and cereal with just only 0.6% share and vegetable with only 0.1%. Besides crop production, local households practice also off-farm activities in order to maintain their economic security. Similarly, rice cultivation is the main occupations in Tole Sap Basin with 73.2% while the followed by cash crop farming and the other non-farm occupation. However, the flooding pattern was hydrological unique and having vast influences on the natural ecosystem as well as rice ecosystems in/around the floodplains (MRC, 2010).

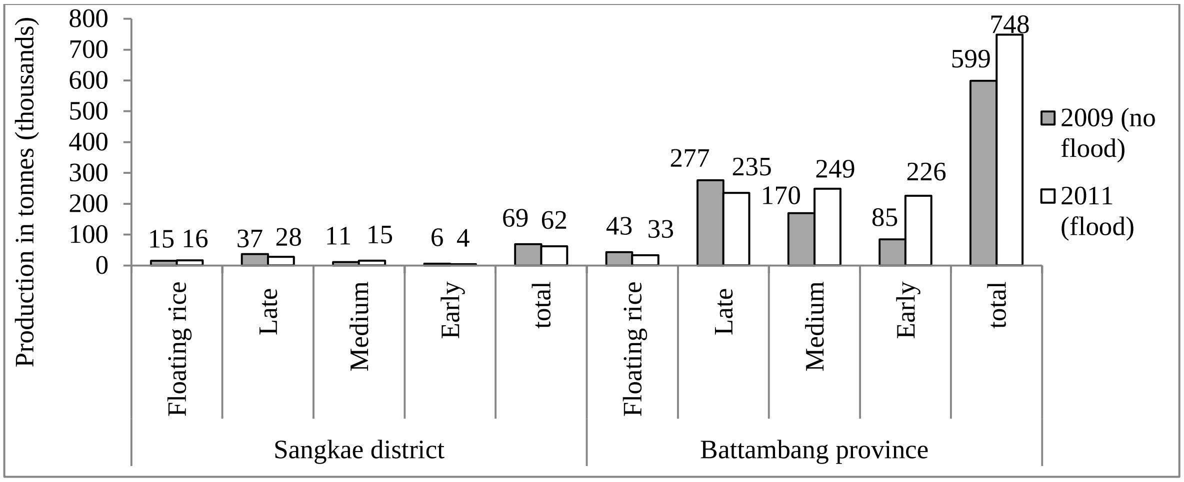


Fig. 4 Grain yield and production of each rice during the non-flood season in 2010 compared with the flood damage years 2009 and 2011
Source: Kamoshita & Ouk (2015)

2.6.2 Ecological changes and its impacts of Tonle Sap Lake

There are two main significant drivers that have led to changing of the hydrological and ecological system of Tonle Sap Lake in Cambodia: hydropower development on Mekong River and global climate change (Keskinen et al., 2013; Arias et al., 2014). These drivers of changes have led to alteration of floodplain habitats and negatively influenced the ecosystem productivity in the area. Particularly hydropower dams, which have been constructed at the upstream areas along Mekong, excessively effected flood pulse of TSL where can survive several kinds of habitats and biodiversity. Arias et al. (2014) suggested that hydropower development in the lower Mekong could bring the hydrological alterations to TSL. Those hydrological alterations are changes in seasonality reducing wet season water level and increasing dry season water level and rate of water rise/drop in which are crucial hydrological parameters for biological factors such as tree seeds germination and fish migration, and therefore major ecological distributions are likely to follow. On the other hand, Arias et al. (2014) have concluded that Tonle Sap's drivers of ecological productivity, habitat cover, sedimentation, and NPP, will face a significant change, and a decline of its ecosystem services in the future if there is no any intervention such as mitigation and adaptation strategies implemented. Similarly, Keskinen et al. (2013) also found that there are two main categories can be divided the impact of hydropower development to aquatic production, mainly fish, which are 1) so-called barrier effect of dams to fish migration; and 2) the impact of hydropower development has on water flow (quality and quantity).

Water flow alteration, both quality, and quantity, has negative impacts on households' livelihood who are living in the floodplain area of TSL, where is predominantly agricultural area, and mainly rely on agriculture as their main source of livelihood in zone 2 (Arias et al., 2014; Masumoto et al., 2004). To show the evidence, paddy rice is the main crop in the environs of TSL which grown in the annual stage relied on the availability of water and the height of flood level. However, recently in which years, paddy rice has been damaged seriously by the flood which reported that 6,200 km^2 of rice field were flooded and 3,700 km^2 of rice field were destroyed (Masumoto et al., 2004). Kamoshita & Ouk (2015) documented that flood in 2011 damaged 11-12% of rice fields in the entire country however, the damaged proportion reached more than 30% in Sangkae district, located in floodplain area of TSL. This area is situated in Battambang province, where is the rice bowl of Cambodia. Table 3 shows the statistics of damaged area of rice field in Battambang province in 2011.

Table 2 Rice planting and damaged areas in 2011 rainy season for 14 districts in Battambang province

N^0	Districts	Planting area (ha)	Damaged area (ha)	Per centage (%)	Replanted area (ha)
1	Banan	28,824	0		0
2	Thmor Koul	64,503	9,456	14.66	2,217
3	Battambang	6,294	0		0
4	Borvil	29,850	0		0
5	Ek Phnom	11,067	5,180	53.19	1,260
6	Moung Russey	52,500	10,282	80.41	1,600
7	Ratanak Mondul	4,423	0		0
8	Sangkae	32,980	10,082	69.43	700
9	Samlaut	2,921	0		0
10	Sampao Loun	3,288	0		0
11	Phnom Preik	2,500	0		0
12	Kamreang	4,652	0		0
13	Keas Kralar	20,544	0		0
14	Rukhakiri	21,861	0		0
Total		286,207	35,000	87.77	5,777

Source: Battambang provincial department of agriculture (2015)

2.7 Small-holder farming systems in South-East Asia

Out of world's 500 million small farmers (those with farm size less than 2 ha), more than 80 per cent are based in Asia. The largest number of small-holders is in China (193 million) and India (93 million) followed by another three Asian countries, i.e. Indonesia (17 million), Bangladesh (17million), and Vietnam (10 million). Small-holders in Asia cultivate small size of actual land, in average 0.5 ha in Bangladesh, 0.8 ha in Nepal or Sri Lanka, 1.4 ha in India and 3 ha in Pakistan (Ganesh & Raghav, 2011).

Rice and wheat are considered as intensive crop productions among the other systems such as maize, cassava, trees and a range of secondary crops in Asia. Farmers generally practice two cropping systems both monoculture and multiple systems for two main purposes, i.e. subsistence and cash. Due to the maximisation of the production, the arable lands are used excessively which reduces the land fertility. Even though those agricultural land areas are being advanced with new technology for irrigation system development, the majority of the countries still practice rain-fed production systems , which is a major contributor to agricultural production in South-East Asia as the irrigation is impossible in an extensive land-use systems in in South-East Asia (Devendra & Thomas, 2002; Devendra, 2016). In Cambodia, area of rain-fed agricultural land accounts for 97%, which is the largest portion in the whole region if it is compared to 68.5% in Malaysia or 63% in Indonesia (Devendra, 2016). Rice based cropping systems are of a high significance for ensuring the food security and as a result, 88% of the total cropped land is used for rice mainly in Cambodia while in Laos accounts for 80% and 60% in Myanmar. Aside from this system, maize, cassava, and perennial tree crop systems are significantly in specifics areas in South-East Asia such as Malaysia's total land area occupied perennial tree crops around 60%. From the other sides, the recognised biggest areas of coconut in the world are the Philippines which is more than 3 million ha and 3 million ha in Indonesia (Devendra & Thomas, 2002).

2.8 Small-holder rice farming systems in Cambodia

Rice-based farming system cultivation is the main source of income as well as insuring the food security for rural poor's households in Cambodia. Furthermore, Rice farming system has played a crucial role as main crop production which importantly contributed of the agricultural gross domestic product (60%) in 2015. For the farm size throughout the country, farmers hold from 0.5 to 3 ha in average per household. Recently, Cambodian farmers have slightly improved their rice production due to increasing yield in average of 0.22% comparing between 3.079 tonne/ha in 2014 and 3.085 tonne/ha in 2015. However, this average yield is lower than the other neighbouring countries such as Vietnam and Thailand respectively (Sophea, 2012; Chea, 2015; MAFF, 2016). Agricultural land is used for rice and it accounted for 84.4% of cultivated land, 9.3% to food crops such as maize, vegetable, mungbeans, cassava, and sweet potato, and 6.3% to industrial crops including oil crops (soybean), sesame, groundnuts, tobacco, sugar cane and jute in 2004. Rice farming system practised with traditional technique by 80% of farmers (Yu & Fan, 2011). Recently, its national average yield is 2.41tonne/ha which is lower than the other neighbouring countries such as Thailand (2.86 tonne/ha), Vietnam (5.6 tonne/ha) and Laos (2.67

tonne/ha) (Sophea, 2012; IRRI, 2013). Smallholder rice farmers in Cambodia are more likely high risk to be affected by natural hazards such as flood, drought, insects, pests and climate variability (MAFF, 2013 and 2016).

2.8.1 Rice cropping system

Rice is considered plays a significant role as a stable crop in Cambodia which extensively cultivated in a rainfed lowland area, covered around 90% of total cultivated land area of the country. Moreover, it has contributed 77% in total rice production. Regarding rice ecosystem classification in Cambodia, there are four rice ecosystems categorised such as (1) Rainfed lowland rice, (2) Deepwater or floating rice system; (3) Rainfed upland rice, and (4) Irrigated dry season rice (Sarom et al., 2001; Sophea, 2012; Chea 2015).

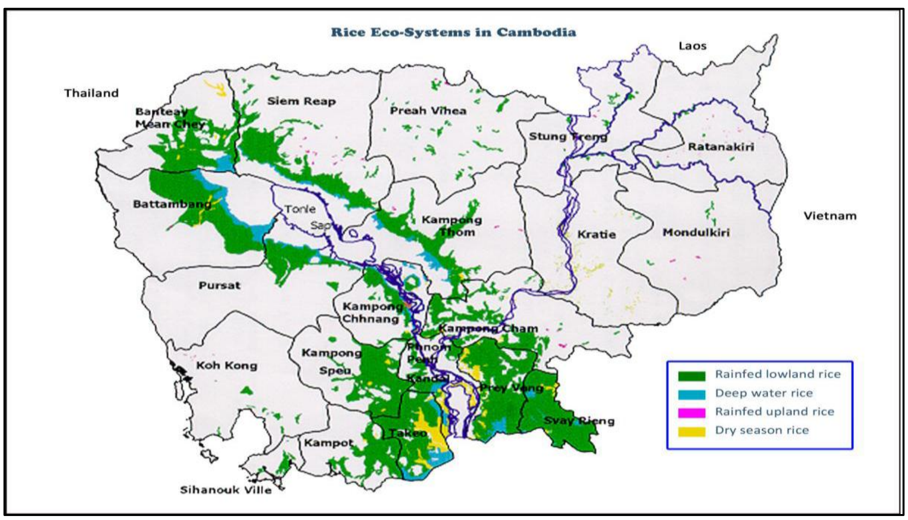


Fig. 5 Rice ecosystems in Cambodia
Source: Sarom et al. (2001), Sophea (2012); Chea (2015)

Rainfed lowland rice mostly exists in the areas around the Tonle Sap, Mekong and Bassac Rivers, beyond the wet season flood zone, which estimated to be around 2.5 million ha in the whole of the country, and seven million tonnes produced annually accounting for 77% of total rice production of the country Chea (2015). Comparing with soil with a medium high clay content, rainfed lowland area is more drought-prone than in the same rainfall environment (Tsubo et al., 2009). Chea (2015) again shows that rainfall is the necessary source for 90% of rainfed lowland rice areas while the soil is also poor. Moreover, he found that irrigation-based agricultural adaptation can improve the supply of rice production for farmer's livelihood in the lowland area. On the other hand, Chea & Yasunobu (2006) cited by Chea (2015) found that due to the lack of irrigation and drainage systems, the harvested area of lowland rice in the wet season is, on average, reduced by between five and twenty per cent because of the frequent occurrence of floods and drought. Similarly, a research of Meertens et al. (1999) and Seng et al. (2004) have found that the general views of growing crops in lowland areas depend on the amounts and reliability of early wet season rainfall or amounts of stored water after harvesting rice. In addition, Fukai et al. (1998) have determined four major constraints of rice cultivations in rainfed lowland area in Thailand and Laos as (1) the lack of standing water at the appropriate time for transplanting, (2) water stress that often develops at the end of the growing season (3) low yield potential of the present cultivars, particularly in Thailand; and (4) adverse soil condition including low pH and soil fertility. In addition, low productivity and response of traditional rice varieties to fertilisers is well known but it was rarely analysis which is causing the production low efficiency (Naklang et al., 2006). Comparing the rainfed lowland condition, Cambodia has a higher prevalence of seasonally flooded and alluvial soil than North-east Thailand and Laos (Seng et al., 2004).

Deepwater rice was one type of flood-prone rice ecosystem where submergence in-depth usually exceeds 100 cm and continues for durations ranging from more than 10 days to 5 months. Moreover, this kind of rice ecosystem easily affected by unpredictable environmental changes, drought, and flood, as well as soil condition which leads to low yield (Maclean, 2002). Deepwater rice was particularly grown in the floodplains and deltas of rivers such as the Ganges and Brahmaputra of India and Bangladesh, the Irrawaddy of Myanmar, the Mekong of Vietnam and Cambodia, the Chao Phraya of Thailand, and the Niger of West Africa (Bouman et al., 2007). In Cambodia, deep-water rice was mostly cultivated in the floodplain of TSL, which dramatically seasonally changes water depth as the flooding water of Mekong River intrudes into the TSL via Tonle Sap River (Kamoshita & Ouk, 2015). Deepwater rice is high productivity than floating rice, which sometimes higher than 4tonne/ha and generates a high profit because of low cost as well as labours requirement (Maclean, 2002). Sarkkula et al. (2003) who stated that floating rice is significant for the poorest households on floodplain area due to its cost-efficiency.

Rainfed upland rice is cultivated in Asia, Africa and Latin America (Maclean, 2002). In Cambodia, small area of rainfed upland rice is mostly located in the north or northeastern of Prah Vihea, Stungtreng, Kratei, Ratanakiri and Mondul Kiri province where represents less than 2% of total wet season rice cultivation area and it was indicated as the small area for rice production among the other agro-ecosystems of rice in Cambodia (Chea, 2015; Sarom et al., 2001).

Dry season rice is mainly found in some provinces such as Takeo, Prey Veng, Kandal, and Kampong Cham. It can be cultivated with modern and traditional varieties, which recently about 70 to 80% of the dry season rice cultivated areas are under modern varieties like IR66, Kru and IR Kesar. Some traditional photoperiod insensitive varieties are still grown like Lum-and Keach and Neang Sar Pragnap. The rice grown areas in Cambodia, approximately 13%, are irrigated or supplemented during the dry season (Sarom et al., 2001). The first dry-season rice is cultivated from the beginning of January when the floodwaters of the Tonle Sap Lake recede from the fields. During the three-month cultivation period until April, this crop may be additionally irrigated (Kleinhenz et al., 2013; Sarom et al., 2001). Based on Kleinhenz et al. (2013) suggests that irrigation system is the most significant prerequisite for cultivating the second dry-season rice crop. As the result, farmers indicate that appropriate irrigation pumps cost around US$250 and require about 120 L/ha of fuel. While this is a significant investment for many or most farmers in the study area, however, farmers spent less than 75 US$/ha for harvesting the first directly-sown crop by the combine. On the other hand, farmers get a higher return for their production which is 637 US$/ha or US$ 828 for the average farm size of 1.3 ha, yield of 3.2 tonne/ha. In addition, farmers practice and use over recommended rate for their wet season cropping system. Seed rates for directly-sown dry-season rice exceed twice of the recommended rates, while 60-70 kg/ha are recommended, farmers on average use 122 kg/ha, with 195 kg/ha in Kampong Hau and 180 kg/ha in April Tuek communes.

2.8.2 Development and constraints of rice-based cropping system in lowland area

The majority of Cambodian farmers have challenged a lot of problems and difficulties in their rice production, which led to reducing the yield in every year. Climate change poses risks and opportunities to the sustained productivity of rice-based farming systems in Cambodia (Poulton et al., 2016). Regarding Panith & Malyne (2012) cited a conclusion of MoE (2002) that farmer's rice outputs are strongly connected with the climate change which led their rice production to highly affected by the occurrence of floods and droughts. Moreover, Cambodian rice producers face several constraints in their productivity improvement such as lack of purified seeds, lack of access to commercial credit with high-interest rate, limited irrigation system, the high cost of inputs like fertilisers, pesticides, and energy (Sophea, 2012). On the other hand, they, who are highly vulnerable from climate change, have a low level of awareness, education, and adaptation. However, farmers in Battambang, Kampong Thom, Takeo and Prey Veng provinces still lack of awareness of climate change adaptation although there are some occasional training programmes provided from stakeholders (Phnom Penh Post, 2014).

Table 3 Rice varieties released during 1990 – 2000 of Cambodia

Agro- ecosystems	Sub-divided groups	Type of rice varieties
Rain-fed upland rice		1. Rimke
		2. Sita
		3. IR66
		4. IR72
		5. KRU
	Early maturity (Dry season/irrigated/receding)	6. IR Kesar
		7. Baray
		8. Chul'sa
		9. Rohat
		10. Rumpe
		11. Santepheap1
		12. Santepheap2
		13. Santepheap3
		14. Popoul
		15. Sarika
		16. Rangchey
		17. CAR1
Rain-fed lowland rice	Medium Maturity	18. CAR2
		19. CAR3
		20. CAR11
		21. Phka Rumchek
		22. Phka Rumchang
		23. Phka Rumduol
		Note: these three varieties are premium and aromatic
		24. CAR4
		25. CAR5
		26. CAR6
		27. CAR7
	Late Maturity	28. CAR8
		29. CAR9
		30. CAR12
		31. CAR13
		32. Don
Deepwater rice/floating rice		33. Khao Ta Pech
		34. Tewada

Source: (Sarom et al., 2001)

To overcome these constraints especially resilience to climate change, the royal government of Cambodia has adopted Agricultural Sector Strategic Development Plan (ASDP) 2009-2013 followed the RGC's National Strategy Development Plan 2009-2013 and Rectangular Strategy Phase-II. As the results, the agricultural sector has been supported by the improvement of the irrigation system, dissemination of new technology and other endeavours, especially agricultural research and development to climate change adaptation. Continuously, RGC has adopted ASDP 2014-2018 in order to promote the enhancement of agricultural productivity, diversification and commercialization, promotion of livestock farming and aquaculture, land reform and sustainable management of natural resources (MAFF, 2015). For rice sector, The RGC set Policy paper on the "Promotion of Paddy Production and Rice Export" which officially announced in 2010.

During 1975-1995, rice varieties significantly considered as an important contribution to economic growth and food security in Cambodia. In between 1995-2000 there were different 34 rice varieties successfully released in distinct agro-ecosystems. There were eight varieties released for irrigated dry and early/late wet seasons. Meanwhile, other ten varieties for medium, eight for late rain-fed lowland condition, three varieties for deepwater rice environments where water depth reaches up to 1.50 m, two for rain-fed upland rice, and other three aromatic premium rice varieties were released for commercial purpose (Sarom et al., 2001).

Hence, Sou (2014) suggested that in order to cope with climate change effectively, the government should not continuously implement the projects just only at the national and provincial level, however, goes directly to the commune level. Meanwhile, Ministry of Water Resource and Meteorology has a crucial role in climate change intervention by providing explicit information regularly to farmers to be well prepared in their rice cultivation. Yet, it still has limited capacity to provide clear broadcasting of meteorology and reach the farmers who are vulnerable to drought and flood (Panith & Malyne, 2012). In rainfed lowland areas, Sarom (2007) and Chea (2015) have similarly outlined some major constraints which farmers faced in their rice productions including water availability (unreliable rainfall), poor soil fertility, pests and disease, insect and weed, and practices with traditional varieties. Regarding Mainuddin et al. (2011) also showed that the appropriated adaptation methods to climate change (uncertain rainfall, drought and increased temperature) such as changing planting date, supplementary irrigation and increase fertiliser inputs should be widely applied in the study areas. Similarly study on the impacts of climate change in Cambodia, Keo. (2015) found that more than 50% of interviewed farmers have changed their rice varieties, and some of them dig small ditches in order to adapt to current climate change. Moreover, the main source of capital is from migration by letting their family members migrate to find a job for money in order to start up agricultural production in next season. Chea et al. (2004) who compared the economics of rice single and double-cropping system by supplementary irrigation in rainfed lowland has suggested that rice double-cropping system is higher profitability than rice sing-cropping system. As a result, it showed that 75% of food supply increased in Takeo and 22% in Kampot while family income increased by 37% in Takeo and 25% in Kampot over a full farm-year. Additionally, he has drawn a conclusion that using wells and pumps for supplementary irrigation improved return as well as expanding the rice double-cropping area.

3 Aims of the thesis

3.1 Aims of the thesis

The overall goal of this study aims at ex-post analysis and understanding of land-use changes and economic profitability of rice cropping systems in Battambang province with respect to recent dynamics in Tonle Sap Lake floodplain ecosystem. The study proposed five specific objectives to document:

(i) household resources and use in study area
(ii) land-use changes in study area
(iii) changes in rice cropping systems in study area
(iv) profitability of different rice cropping systems in study area;
(v) farmer's awareness and perception of ecosystem services in study area.

3.2 Research questions

This study was implemented with a combination of questions which lead to achieve overall goal as well as objectives including what is the context of rice cropping systems in the study area? How the household resources and land are used? How the rice cropping systems are changed by farmers in the area? How farmers obtained the profitability of their rice cropping systems? How farmers are aware and perceive the ecosystem services provided by Tonle Sap Lake in their rice cropping systems?

4 Methodology of research

4.1 Study site description

Sangkae district was chosen as our study site, as the main leading rice producing zone in Battambang province. Battambang province covers 11,702 km^2 with 1,173,414 populations in 2014 (Department of planning, 2015) and its bordering provinces are Bantheay Meanchey to the north, Pursat to the east and south, Siem Reap to the east south and Pailin to the west. It is located in the tropical climate area with average temperature 27.5°C and annual rainfall is 1,306 mm. The warmest month of the year is April with average temperature 29.6°C and the lowest temperature of the year is 24.8°C in December.

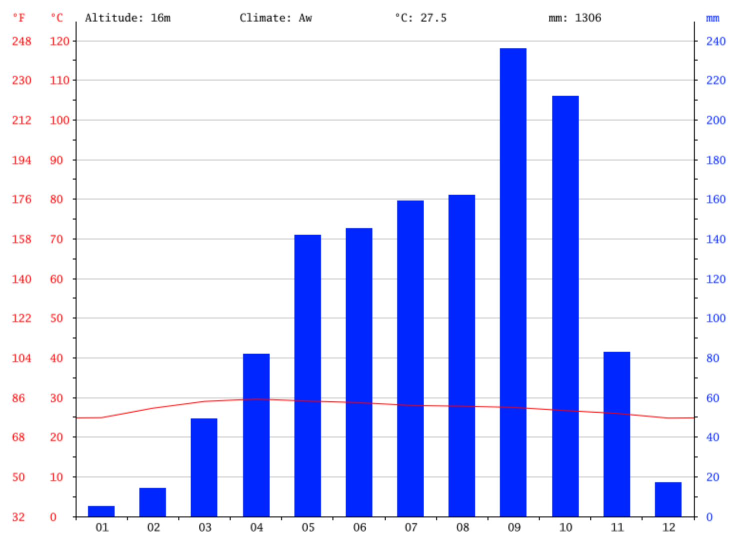


Fig. 6 Temperature in battambong province
Source: Climate Data, 2017

Regarding to department of agriculture, Battambang province has played a crucial role in rice producing area including late maturing and floating rice, and also considered as a rice bowl of Cambodia. It is originally located in the highly fertile on the floodplain area of Tonle Sap Lake (TSL) where the majority of the areas for rice cropping systems existed. Among the 14 districts in Battambang province, Sangkae district was the most popular for growing deep-water rice in TSL, together with the other three districts including Thmor Koul, Moung Russey, Ek Phnom districts (Kamoshita & Ouk, 2015). Sangkae is located near to the Tonle Sap Lake with 127,134 population including 63,429 women. There are more than 80% of total population cultivates agriculture as the main job and more than 60% do rice farming. There were 37,951 hectares of the areas for rice land cultivated in 2014 (Provincial Department of Planning, 2015).

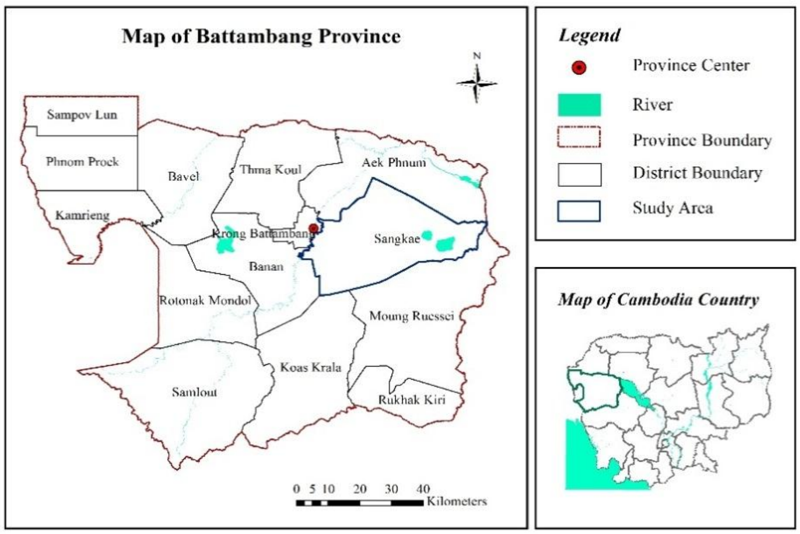


Fig. 7 Map of the study area
Source: author

Within Sangkae district, two different areas were chosen for data collection. First, Middle-water land was situated in the middle zone and located between upper zone and lower zone. Second one, Low-water land was located in low zone and near to the lake (Nguyen et al., 2013; Keskinen et al., 2013).

4.2 Agrarian system analysis and diagnosis

4.2.1 Agrarian system overview

The study was adopted agrarian system concept in order to achieve Aim #1. This is an all-encompassing concept, capable of making sense of agricultural and livelihood activities at a regional scale in a way that accounts for both ecological and socio-economic dimensions (Cochet, 2012).

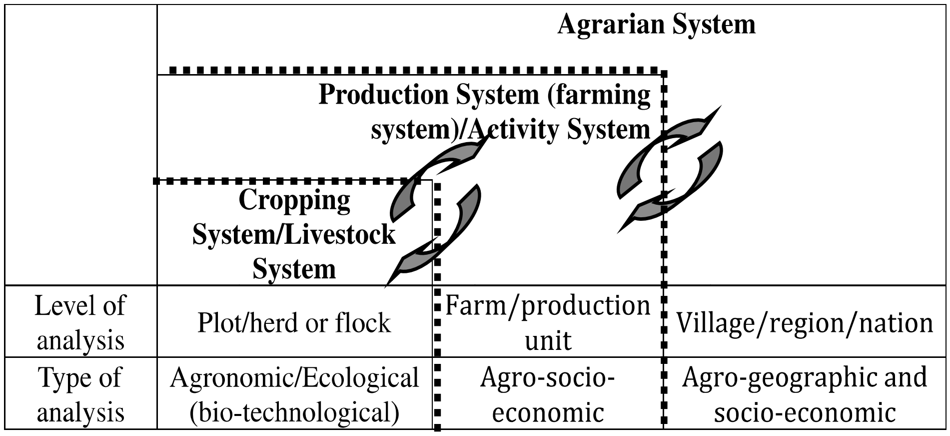


Fig. 8 Nested scales of analysis
Adopted from (Cochet, 2012), p. 133

The typology of the production system is to create the model type of agricultural exploitation by grouping the farms with the same resources, e.g. land, the level of mechanisation and labour force, in similar socio-economic contexts, with a similar combination of cropping systems (Cochet, 2006).

4.2.2 Agrarian system and farming system concept justification

Agrarian System (AS) was initially created during the 1970-1980s by a French-speaking agronomist in France as the English concept about Farming System Research (FSR) promoted by the association for farming system research and extension. AS concept is used as systematic and holistic approach leads to understanding not only the agricultural changes at the regional scale but also includes the understanding of land policy, land planning, social science, history, and anthropology which includes all the functional factors that influences farmers' decision and practices with great ability to analyses agricultural revolution (Cochet, 2012). Basically, historical changes help to identify and understand the main dynamics of differentiation among farming families and thus help define current farming systems (Barral et al., 2012). Similarly, the Farming System (FS) is like AS's production system framework which can be used to determine how capable individual farmers were to recognise their own farms. FS concept is generally relevant for farm holdings or enterprise, large and medium scale, with basic production unit and production processes are recognised (Cochet, 2012). In another word, FS concept is applied at the scale of one production unit. It is defined as the way the available resources, such as land, labour, and capital, are combined to obtain various products (Barral et al., 2012).

However, recently relating to production factors, e.g. land, labour and capital, issues were increasingly disconnected causing constraints for researchers trying to understand the production process (Cochet, 2012). Furthermore, not all farmers had the same access to resources, particularly land, which varied in quantity or quality due to the location within different parts of the ecosystem, ownership and accessibility. Also labour force use differed according to ownership as both household members and external labour was used. and the capital (tools, inputs, cash) is different from one farm to another (Barral et al., 2012). Thus, FS concept is still limited technical and economic analysis of the farm and rarely takes into account the farm environment and historical change, which leads to inexplicit information possible combination of production systems (Cochet, 2012; Barral et al., 2012). Finally, Agrarian System concept is properly adopted for this study due to rice producing farmers is still in a regional and small scale as well as production factors especially labours use is likely disconnected in the context of Cambodia. Moreover, this study is focused only rice cropping system but also link with ecosystem services which lead to sustainable development, both socio-economic and environment.

4.2.3 Landscape reading

This is a stage of understanding the agro-ecosystem and zoning but not the administrative zone(s). It was initiated by personal observation of the agro-ecosystem and vegetation, with the question “why and how?” guides us to meet the elderly and local people for a better understanding of land use change in study zone, which is very similar to transect walk (Barral et al., 2012; Malyne, 2015). Why are different ones located in different places? Two to four elder people in the village were interviewed on rice cropping system in order to understand the rice agro-ecosystem as well as the practices in each system.

4.2.4 Historical study

The current agricultural situation is the fruit of a long or medium term evolution. This study is trying to identify the key factors of change, which create the actual agricultural practices. In this stage, the study was precisely conducted focus group discussions (Malyne, 2015; Barral et al., 2012) on the extreme event which caused rice cropping systems change. The process proposed with the question: "What events and processes have created new forms of agriculture and new landscapes throughout history?" Three group discussions were carried out located in different agro-ecosystem, i.e. Boeng Tuem, Borset, and Ormuni village. Five to six villagers who are elder or more experiences with rice production as well as high knowledge were invited in each village to participate in this group discussion.

4.2.5 Economic calculation

Analysing a cropping system and its profitability results are necessary to understand the reasons behind the farmers' practices. Thus, this study adapted formulas for calculating inputs and outputs as economic value of rice cropping system comparing its profitability as well as sensitivity index value for farmers' decision making in practising proper rice cropping systems. Following indicators were employed in the study (Barral et al., 2012).

- **Gross output**

The gross output (GO) of a cropping system is the value of the total annual production obtained from this cropping system. Thus, it is the sum of the quantity of each product obtained in one year multiplied by the unit price for each product.

$GOi/ha = Qi/ha \times Pi$ where: Qi: rice production (auto consumption pluse sold production); Pi: average selling price on the local market.

- **Intermediate inputs**

The intermediate inputs are defined as the monetary value of the goods and services that are used in one production cycle of cropping system. Thus, the goods are included seeds, seedlings, or plants (if purchased), fertilisers, pesticides, fuel, electricity, water, etc. The services refer to the outside or external providers are hired to work in the production. This might because of farmer does not have the necessary skills, know-how, or equipment. These inputs do not include labour, whether by the family or direct employees (World Bank, 2015).

IIi /ha= *Σ (quantity of inputs used/ha × price) + Σ (service used /ha × price)* where II: monetary value inputs such as seeds, chemical inputs and services used (ploughing, transplanting, weeding, harvest, transports) during one year of production for each cropping system (i) in one unit of land (ha).

- **Gross value-added**

It measures the additional wealth created in one year by each cropping system (i) in one unit of land (ha). That can explain the economic reason for its adoption. This is the difference between the cost of the goods and services that farmers requires, called intermediate inputs, and the value of the products obtained, called the gross output. This difference is gross value-added (GVA). The value added is gross as it does not include the wear on equipment.

$GVA_i/ha = GO_i/ha - II_i/ha$ where GVA_i/ha allows comparisons wealth created from different cropping systems (i=1…9) in one unit of land (ha), which gives an economic-technical reason for the adoption of each cropping system (i). Further more, these study was adapted the value of value 1USD = 4,030 Riel

4.3 Sensitivity analysis of rice cropping system

Sensitivity analysis is used to analysis the linkages between inputs and outputs in term of agricultural productions. It show the degree of the agriculture which affected by stresses and shocks, such as climate change; flood, drought and diseases (Pishgar et al., 2011; Murthy et al., 2014). Particularly, climatic and ecosystem services variation represent the main factors which effect on the cropping systems. The study used this method in order to analyse the linkage between variability of rice cropping systems affected by uncertainty of ecosystem services, mainly floodwater, and climate variation. Rice productivity was based on the three factors such as the year of best condition, normal condition, and worse condition. The study selected four key variables representing the inputs and outputs of rice cropping systems such as capital, income, labour and yield which explicitly indicate how farmers used their inputs and received profitability. This index can show how farmer's decision making on their adoption the actual rice cropping systems. Furthermore, this information has influence on their perceptions of ecosystem services provided by TSL for their rice cropping systems. Anyway, this study was not comparing any statistical correlation of the selected parameters by any simulation or model. Basically, the study documented the data obtained from farmers regarding to their memorisation.

4.4 Data collection

Data collecting process took place from July to August 2016 among 120 rice producing farmers randomly selected in both different agro-ecological systems in Sangkae district. Baset, Oumuni and Rorkar from Middle-water land, Samdach, Svay Sar, and Boeng Tuem from Low-water land. To obtain this random sampling as possible, the study was conducted by selecting few households at the beginning of the main road of the village proceeding across the village lands to both sides of the road toward the village's boundaries (Chea, 2004). PRA (Participatory Rural Appraisal) was applied as it represents the significant method for qualitative data collection, especially for landscape reading and historical changes study (Barral et al., 2011; Malyne, 2015). Representatives of farmers, elder people who were well familiar with the village's situation and village chiefs, were invited to join group discussions which mainly focused on agro-ecosystem administration, agricultural and land-use changes in the following period (see Table 5 and 6 in chapter 5) also including agricultural technique changes and other information related to agricultural and environmental services problems mainly floodwater in the villages. Three group discussions were completely done in three villages such as Borset, Oumuni and Boeng Tuem. The proposed method aims at gaining general pictures of villages. Moreover, during conducting PRA, participants were asked to draw both villages' agro-ecological map. After that, transit walk was conducted based on village's geography. Consequently, semi-structured and structured questionnaires which cover all objectives of this study were used during key informant interview, who are involved in the agricultural sector such as representatives from provincial department of agriculture and department of water resources and meteorology, and individual farmer interview. For key informant interview, it was held a deep discussion on current issues as well as their own institution's intervention and policies. Last but not least, in-depth interview was carried out with five to six farmers whom already done in the questionnaires in order to understand more information and do information verification. It was an opened discussion on their rice based cropping system issues, which provided comprehensive understanding. Finally, additional data and document were collect from relevant institutions such as annual report, and intervention and strategic planning (Sok, 2013; Chea, 2015).

4.5 Data analyses

Microsoft Excel version 2010 was employed for statistical and economic analysis. SPSS version 20 (Social Package for Social Sciences) was performed by specific tools basically descriptive statistic, such as frequencies, means and standard deviations. Independent Sample t-test and Mann-Whitney U-test were applied in order to compare mean and mean rank difference of the group of rice cropping: early season rice, long-term rice and double rice. Likert scale, a psychometric response scale primarily used in questionnaires to obtain participant's preferences or degree of agreement with a statement or set of statements, was also used. Likert scales represent a non-comparative scaling technique (only measure a single trait) in nature. Respondents are asked to indicate their level of agreement with a given statement by way of an ordinal scale (Likert, 1932). This method was applied in order to analyse farmers' awareness and perception of Ecosystem services for their rice cropping systems. The order scaling was set as 4 levels scoring from 1 to 4 which represents from "Strongly agree" to "Disagree" (1=strongly agree, 2=agree, 3= somewhat disagree, 4= disagree). The other scoring level from 1 to 5 representing from "Strongly decrease" to "Don't know" (1=strongly decrease, 2=somewhat decrease, 3=the same, 4=strongly increase, 5=somewhat increase and 6=don't know).

5 Results

5.1 Household characteristics overview and land-use

Table 1 provides basic overview of household human resources in both study sites showing only household size to be the significant difference between them. Households in Low-water land were larger, but having less male labour force compare to those in Middle-water land. Households in both study areas were headed by men, over 50 years old with more than three decades experience with farming.

Table 4 Household's human resources

Variables	Unit of measure	Low-water land (n=68)		Middle-water land (n=52)		p-value	
		Mean	SD	Mean	SD		
Age of household head(1)	years	52.60	12.69	52.53	14.267	0.978	
Farm experience of household head(1)	years	31.62	13.61	32.42	13.14	0.792	
Education of household head(1)	years	4.98	2.10	5.10	2.84	0.821	
Household size(1)	number	5.24	1.76	4.68	1.73	0.094	*
Labour force(2)	number	3.37	1.53	3.21	1.41	0.613	
Male labour force(2)	number	1.77	0.83	1.89	1.04	0.786	
Female labour force(2)	number	1.81	1.03	1.68	0.96	0.563	
Dependent members(2)	number	2.13	1.12	1.95	0.91	0.602	

Note: (1) T-test, (2) Mann-Whitney U-test
*Significant at 10%

Additionally, years of school attendance of household heads in both study areas were not higher than primary school. Anyway, head of households in Middle-water land attended the school more than head of households in Low-water land. For internal labour force, female labour force, and independent members of households in Middle-water land were lower than households in Low-water land.

As stated in the introduction part, rice is the most important crop in both study sites. There was no significant difference observed between the farmland devoted to rice planting among Low-water land and Middle-water land.

a) Low-water land b) Middle-water land

Fig. 9 Typical households in both study sites

However, households in Low-water land have rice field equal to 3.76 (±3.22), and thus larger compare to those from Middle-water land 2.90 (±2.36) in average. Nevertheless, standard deviation values indicate large diversity in sizes of individual fields, so we can state that fields in the Middle-water land were smaller in average.

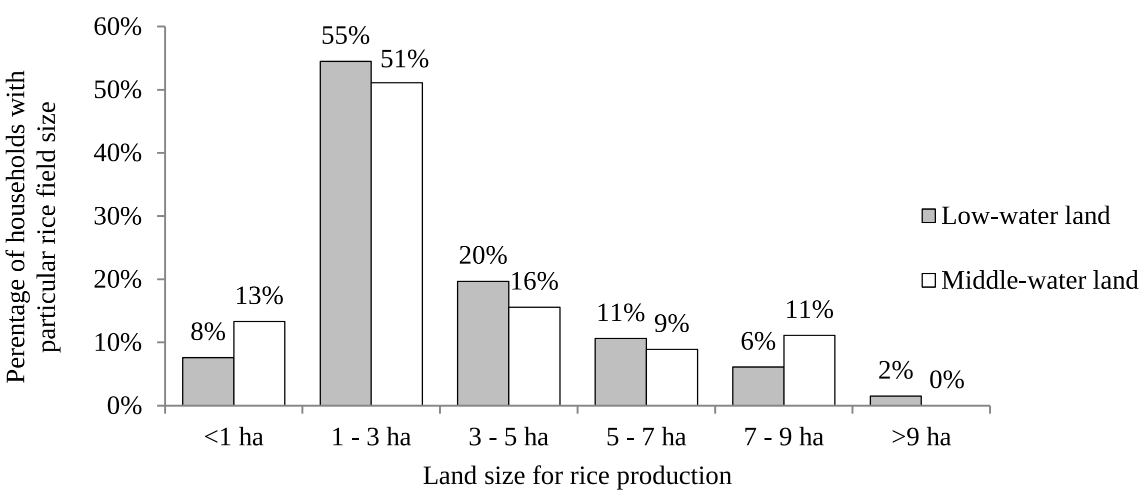


Fig.10 Comparison of land size for rice production in Low-water land and Middle-water land

Table 4 helps us to understand why the difference in rice field size was not significantly different. More than 50% of interviewed households from both study sites had average rice field between one and three hectares.

5.2 Historical changes in land use systems

5.2.1 Land use systems in Middle-water land

Borset is one of the three selected villages located in the Middle-water land, where more changes in the land-use systems could be documented compare to other two ones. The results indicated that the land use systems in this village has been developed and changed by four specific periods.

First period (1971-1994)

The first period started in 1971 and lasted until 1994. The Borset village already existed in the area with an initial number of the population around 230 households with 30 hectares of residential land. In that time, the area of agricultural land was equal to 1,808 hectares. Due to the floodwater sufficiency, farmers were able to cultivate three kinds of rice cropping systems, i.e. floating rice, long-term rice, and medium rice. Besides that, cash crops such as cucumbers (*Cucumis* spp.), pumpkin (*Cucurbita* spp.), chilli (*Capsicum annum*) and eggplants (*Solanum melongena*) were planted as well. Farmers were practising traditional techniques of farming and maintained simple equipment. They used their cattle or buffaloes as the main draught power for agricultural activities including ploughing, raking or transportation. They strongly relied on the ecosystem services provisioning by Tonle Sap lake especially floodwater and rainfall that sufficiently supplied their irrigation systems. Due to the very poor infrastructure, local farmers were not able to access better markets that could offer them a higher price for their products. Particularly natural inputs which were available in their location were used for the rice cultivation, including animal dung as a fertilizer. Farmers had never received any agricultural technical training from government officers or non-governmental organisation (NGO) at regional or national level.

Second period (1995-2006)

During the second period (1995-2006), the number of population more than doubled reaching 530 households and residential land 42 hectares the land for agriculture increase by 38.7% to 2,508 hectares. Such extension of the agricultural area led to declining of forest land. In 2000, local households started to practice high-yield rice cropping systems, such as early season rice and receding rice, on the total area of 40 or 50 hectares. As a result, there were three main rice cropping systems in the village as well however with certain changes. Floating rice was still in practice and long-term and medium rice almost together. During that time, farmers were able to access better infrastructure and market. High-yield rice was a new farming system that appeared in the study area. Approximately 20% of rice producers have adopted this new technique which launched using of chemical inputs and modern machinery mainly tractors, hand tractors, pesticide/herbicide hand sprayers and spraying machines. Due to the availability of the market, they were able to sell their agricultural products with reasonable price and buying agricultural inputs for their agricultural intensification. They were closely connected between officers of provincial department of agriculture and local non-governmental organisation (NGO). Thus, local farmers had received technical training on agricultural practices provided by those stakeholders focused on how to appropriately use the chemical fertilisers, pesticides and prepare land for broadcasting rice seedling. Furthermore, they were provided training on technique of feeding animals such as chickens, ducks, pigs, buffaloes and cattle to improve their livelihood.

Third period (2007-2010)

The third period was shorter compare to previous one (2007-2010), but with very dynamic development. During that time population grew by more than 56% to 800 households that led to the enlargement of the residential area to 56 hectares, compare to 30 and 42 hectares in previous periods. The area of agricultural land did not change, and the development was based on technology adoption and use, as well as on improved, particularly chemical, inputs. Farmers began to apply high amounts of these chemical fertilisers, pesticides, and herbicides in their high-yield rice cropping systems due to decreasing land fertility and increasing abundance of pests (rats) and diseases. In term of agricultural machinery, the number of households using hand tractors and tractors increased while threshing machines were available for hiring in the village. They still continuously received agricultural training as the same as the previous period which provided by stakeholders. Moreover, farmers faced serious drought during this period which led to reducing the yield of their rice cropping systems due to insufficient rainfall and floodwater from Tonle Sap Lake. Flood pulse started to change significantly and flood water did not reach the fields anymore comparing to the first or second period.

Table 5 Land use system in Borset village in the Middle-water land

Indicators	Duration of changes			
	1971-1994	1995-2006	2007-2010	2011-present
Population (household)	230	530	800	968
Residential land (ha)	30	42	56	56
Agricultural land (ha)	1,808	2,508	2,508	2,508
Forest land (ha)	700	0	0	0
Fertiliser use	own (dung)	own (dung) and artificial	artificial only	overuseof fertiliser
Technology advance	simple equipment	simple equipment+ modern machineries	modern machineries	modern machineries
Land intensification	the same	change	change	change
Floodwater	sufficient	sufficient	insufficient	insufficient
Market	no access to better markets	able to access to better market	able to access to better market	able to access to better market
Constraints	no	no	pest, diseases, and drought	pest,diseases, flood, and drought

Fourth period (2011-present)

Last period started in the year of 2011. The number of population continuously increased by 21% and reached 968 households. The land used for both residential and agricultural land was the same, but the rice cropping systems have been radically changed. There were probably 90% of farmers cultivated high-yield rice, such as early season rice and dry season rice. Additionally, 60% of them have changed from floating rice to grow long-term or medium rice cropping systems because of the floodwater condition in Tonle Sap lake have been recently reaching lower and lower levels. Farmer used more and more quantity of inputs in their rice cropping systems such as chemical fertilisers, pesticides and herbicides since the land fertility was degraded as well as facing with diseases and pests. The number of machinery was also increased during that time, especially hand tractors and tractors. The number of farmers who used modern machineries such tractors, hand tractors, pesticide/herbicides sprayer, spraying machines and pumping machines was higher and higher in the village. During that time rice producers also faced with serious drought and flood in their rice cropping systems. Particularly, flood occurred in 2011 which majority of paddy rice in the study area was damaged.

5.2.2 Land use systems in Low-water land

As the results of group discussion and field observation, the study found that there are also four periods of land use changes in Boeng Teum village as the same as Borset village in the Middle-water land. However, these periods differ in time frame a bit. Boeng Teum village was chosen among the three others to better illustrate the changes in local farming systems.

First period (1981-1991)

The first period started in 1981 and lasted till 1991. During that time there were approximately 215 households in the village with the residential land equal to 136 hectares. The majority of the land (3,234 ha) was covered by forests, while the agricultural land occupied 820 hectares. Agricultural land was used for paddy rice cultivation particularly floating rice, in a close distance to the village. They always practised traditional techniques and used internal human resources. During that time farmers were not able to access better infrastructure and market in order to sell the products as well as purchasing modern equipment for their agriculture. Hence, they used their animals such as cattle or buffalos as the main draught power, especially for land preparation and agricultural products transportation. Furthermore, they had never received any agricultural training from any government officers or non-government organisation (NGO). Farmers relied particularly on the natural resources provisioning such as rainfalls and floodwater from Tonle Sap Lake for their rice cropping systems.

Second period (1992-2006)

During the second period in 1992-2006, the new agricultural policy of the government was implemented in the study area by distributing the forest land to farmers for their agricultural cultivation. During this time, agricultural land was increased mainly for rice cropping systems. Floating rice was rapidly rose from 820 to 1,655 hectares (49.54%) comparing to the previous period. At the meantime, forest area was decreased by 32.31% to 2,189 hectares resulting from agricultural land expanding as well as residential land demands driven by rapid population growth. Furthermore, farmers started to cultivate the high-yield rice cropping systems such as early season rice and receding rice on the approximately 209 hectares due to the high-yield rice varieties, mainly IR, which were introduced to farmers as the same year as in the Middle-water land. The areas of high-yield rice cropping systems were located near the residential area. Compare to previous period, the infrastructure was improved and developed in the village, which provided the availability to farmers to access better markets for selling their agricultural products and purchasing agricultural inputs such as chemical fertilisers, pesticides and herbicides. Additionally, farmers have changed and adopted new technologies using modern agricultural equipment such as hand tractors, pesticide/herbicide hand sprayers and spraying machines, but they hired tractors from the other villages for their land preparation stage. These kinds of inputs were used particularly for high-yield rice cropping systems such as early season rice and receding rice. Regarding to agricultural adoption, there were approximately 40% of farmers started to use these kinds of inputs in their rice production. The rice cropping systems rely mainly on annual floodwater and rainfall in rainy season during April to November. For irrigation system, a stream namely Steung Chas located near the village and always fulfilled by floodwater from Tonle Sap Lake had played a crucial role in providing fresh water to the rice cropping systems. Moreover, farmers started to be provided agricultural technical trainings by officers from provincial department of agriculture and non-governmental organisation.

Third period (2007-2010)

In the third period (2007 – 2010), the forest was continuously cleared due to increasing of demand for agricultural land and population growth. Comparing to the previous period, forest land declined by 6% and reached 2,063 hectares. Area for floating rice slightly decreased to 1,611 hectares as farmers have switched to cultivate high-yield rice, such as early season rice and receding rice. High-yield rice cultivated area grown up rapidly by 54.1% to 322 hectares. Furthermore, the residential land also was expanded to 196 hectares. In this period, farmers have practised the same techniques, but noticeably used more modern machinery especially tractors and hand tractors. Anyways, they started using or hiring external labours in their rice production mostly during the harvesting period. Farmers still received the agricultural technical training from relevant stakeholders the same the second duration as well as ability to access to the better market. Regarding to the flood pulse and climate has changed, farmers faced with constraints such as flood, drought, diseases and pest (rats).

Fourth period (2011-present)

The last period after 2011 until the present, the forest in the floodplain areas in Boeng Teum and entire Tonle Sap Lake was destroyed excessively by slash-and-burn agriculture for mainly growing rice and inappropriate techniques of forest products collection and fishing. As a result, rice field for floating rice was quickly increased to 3,674 hectares during this period while the high-yield rice land and residential land remained constant. Farmers have practised the same farm techniques as the previous period, but ultimately changed their simple agricultural equipment to modern agricultural equipment. They reduced using external labours for harvesting or cultivation as manual owing to the harvesting machines were available in their location for hiring with reasonable price and less time-consuming. During this period, the farmers are widely able to access to the better market for selling their agricultural products and purchasing the inputs. The number of cattle and buffalos declined since farmers were able to access the modern machinery in their agricultural production. On the other hand, during the last few years, the flood pulse and climate have changed which strongly affected on their paddy rice. Particularly their paddy rice was damaged and destroyed by flood, in 2011.

Table 6 Land use system in Boeng Teum village in Low-water land

Indicators	Duration of changes			
	1981-1991	1992-2006	2007-2010	2011-present
Population (household)	215	420	630	840
Residential land (ha)	136	136	196	196
Agricultural land (ha)	820	1,864	1,933	3,996
Forest land	3,234	2,189	2,063	almost 0
Fertiliser use	own (dung)	own and artificial	artificial only	Overuse of fertiliser
Technology advance	simple equipment	simple equipment + machinery	modern machineries	modern machineries
Land intensification	the same	the same	change	change
Market	no access to better markets	able to access to better	able to access to better	able to access to better
Floodwater	sufficient	sufficient	sufficient	insufficient
Constraints	no	no	flood, drought, diseases	flood, drought, diseases, and pest

5.3 Visualisation of land use system in Boeng Teum and landscape of both areas

Figure 2 shows the clear viewing of land used in Boeng Teum village which has been increasingly changed utile the present. During the first period (1981-1991) most of the lands were cover by forest area (3,234 hectares) while agricultural land cultivated particularly for floating rice on 820 hectares. The initial residential land was 136 hectares. After that, during the second period (1992-2006), high-yield rice varieties were introduced to farmers and cultivated on 209 hectares of agricultural land where existed near the village. At the meantime, floating rice area was expanded to 1,655 hectares which led to decreasing forest land to 2,189 hectares while the residential land was the same.

After that, during the third duration (2007-2010) the forest land was slightly decrease to 2,063 hectares and floating rice area also shrunk to 1,611 hectares due to the high-yield rice cropping systems enlargement and residential land demands. During the last duration (2011-present), the forest land was excessively declined and completely disappeared in the area due to noticeably increasing the land expansion for floating rice to 3,674 hectares while the land for high-yield rice and residential land were constant.

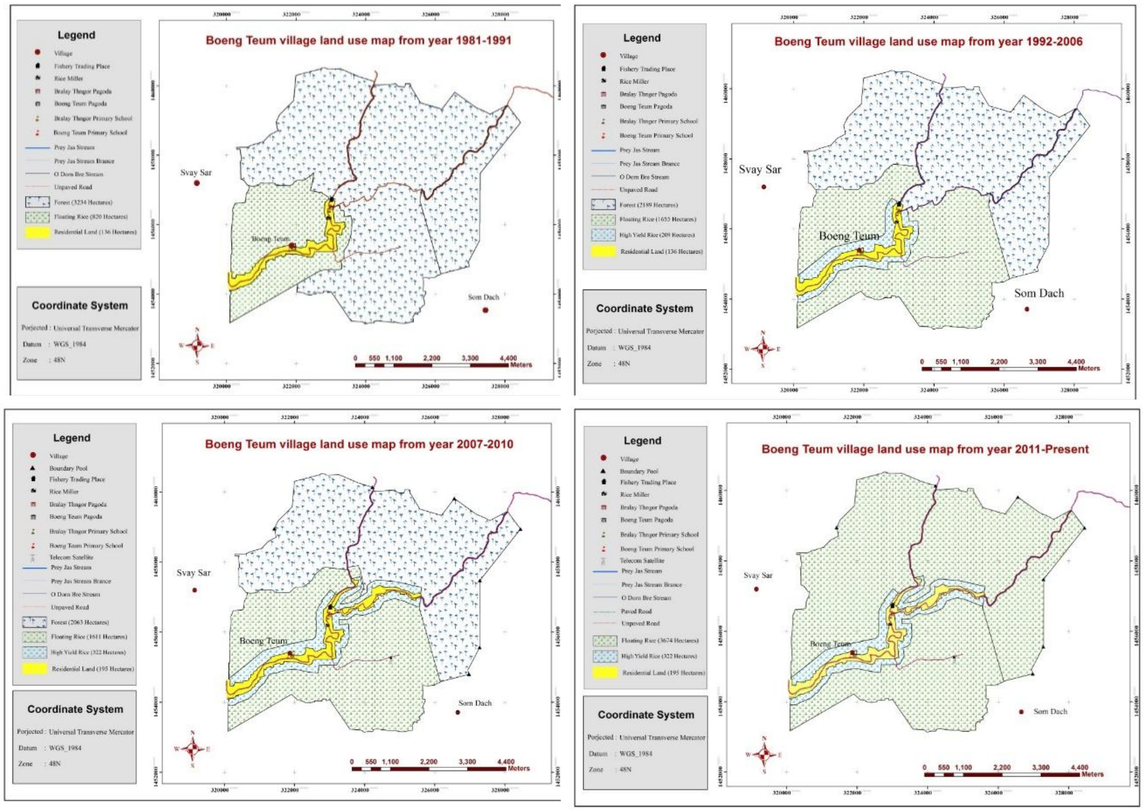
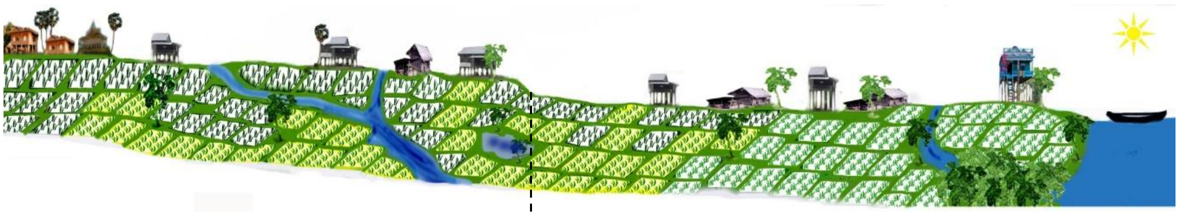


Fig. 11 Maps of the land use system changes in Boeng Teum village in Low-water land

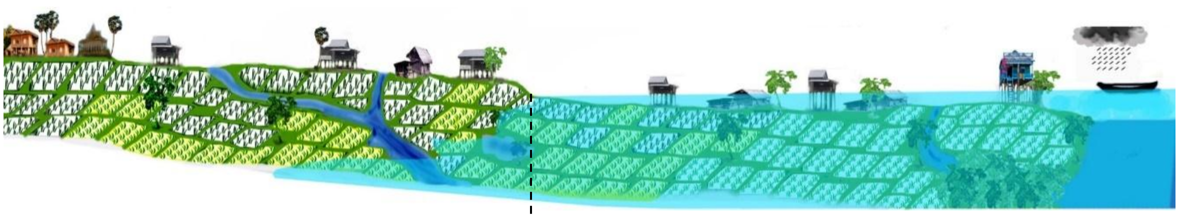
The two distinct ago-ecological zones selected for this study which were zone 1 called Middle-water land or middle field and zone 2 called Low-water land. Zone 1 namely Middle-water land was located near the upper zone where is nearest to the national road $N^0$5. This zone is higher altitude than zone 2 and not so often to be covered by floods. Sometimes, the flood level reached this area from 0-1 m unless there is flooding. Agricultural land is sharply cultivated rice cropping system such as long-term rice and short-term rice (early season rice and dry season rice). There are not many fruit trees or vegetable grown in this area. There are available supplementary irrigation systems in this zone which suitable for cultivating short-term rice cropping systems.



Zone 1: Middle-water land or middle field
- Higher altitude
- Flood level <1m
- Cultivated areas for long-term and short-term rice (early season rice and dry season rice)
- Little fruit trees and vegetation
- Use high chemical fertiliser/lower soil fertility

Zone 2: Low-water land or low field
- Lower altitude
- Flood level <3m
- Cultivated areas for floating rice, long-term rice, short-term rice (early season rice, receding rice and dry season rice)
- Little fruit trees and vegetation
- Use lower chemical fertilisers/higher soil fertility

Fig. 12 Present landscape during dry season (November-April)

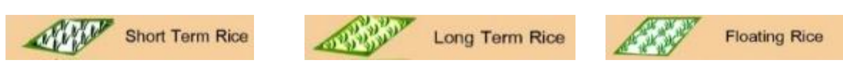


Zone 1: Middle-water land or middle field
- Higher attitude
- Flood level <1m
- Cultivated areas for long-term and short-term rice (early season rice and dry season rice)
- Little fruit trees and vegetation
- Use high chemical fertiliser/lower soil fertility

Zone 2: Low-water land or low field
- Lower attitude
- Flood level <3m
- Cultivated areas for floating rice, long-term rice, short-term rice (early season rice, receding rice and dry season rice)
- Little fruit trees and vegetation
- Use lower chemical fertilisers/higher soil fertility

Fig. 13 Present landscape during wet season (May-October)

Note:



Zone 2 namely Low-water land or low field is located near to the lake. This zone is lower altitude than zone 1 and usually flooded by floodwater from Tonle Sap Lake. Normally, the flood level in this zone is more than 1 m. Agricultural land is also mainly cultivated rice cropping systems such as floating rice, long-term rice and short-term rice (early season rice , dry season rice and receding rice). Floodwater provides high soil fertility which favourable for rice cropping systems and lead to use lower chemical fertiliser in some rice cropping systems comparing to zone 1. Similarly, there are not many fruit trees or vegetable grown in this area. The supplementary irrigation systems are inadequate in this zone which is high risk for cultivating short-term rice cropping systems.

5.4 Rice cropping systems cultivation

Regarding to the results in the Figure 14, it clearly reveals that there are three kinds of rice cropping systems are cultivated in the same in Middle-water land and Low-water land such as long-term rice, early season rice and dry season rice. Anyway, there are five rice cropping systems such as long-term rice, early season rice, receding rice, early season rice with dry season rice and floating rice, which are cultivated in Low-water land. There are just only three kinds of rice cropping system such as long-term rice, early season rice, and early season rice with dry season rice existing in Middle-water land. It shows that the highest number of rice cropping system which grown by farmers in Low-water land is floating rice (64%) while in Middle-water land is long-term rice (73%). There are not many farmers grow double rice cropping system in both areas, just only 12% of farmers in Low-water land while 14% in Middle-water land.

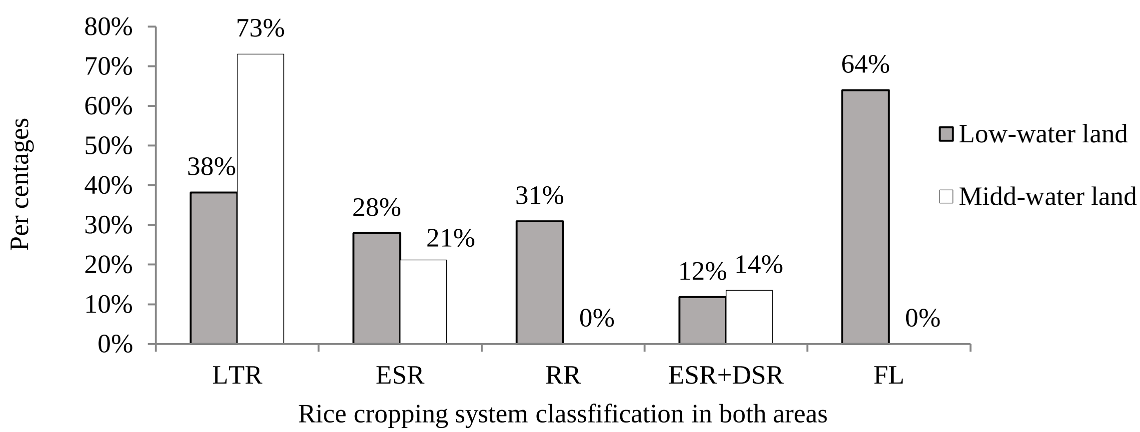


Fig. 14 Rice cropping systems cultivation in Low-water land and Middle-water land

5.5 The constraints, changes and economic comparison of rice cropping systems

Figure 15 represents the limitations of rice production in both agro-ecological systems. The result shows that there are five main challenges for farmers in their rice cropping system such as drought, flood, pest (rats), insect and weed. The majority of farmers in Low-water land have faced main such as drought (87%), pest (85%) and flood (86%) while 86%, 65% and 67% in Middle-water land also faced the same challenges. Since the other constraints can be controlled by farmers, the farmers in Low-water land faced with insect (19%) and weed (8%) while 3% and 6% in the Middle-water land. Thus, farmers in Low-water land area are more vulnerable than farmers in the Middle-water land since they face higher rates of constraints.

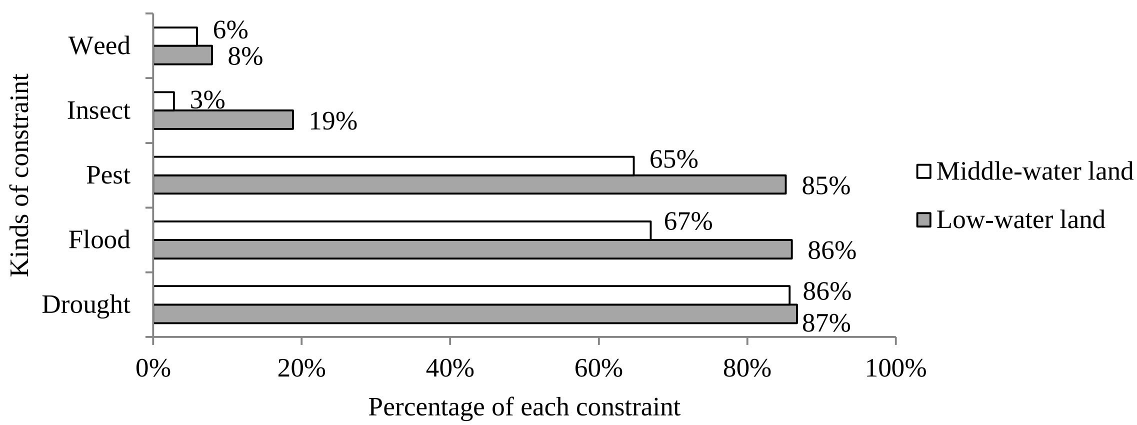


Fig. 15 Main constraints in rice production in both study areas

Figure 16 shows the percentages of farmers who have changed their rice cropping systems**.** As a result, farmers have changed their rice cropping systems several times especially in these reason years. Actually, in Low-water land area most of the farmers dramatically changed their rice cropping system, which is more than 60% of them comparing to Middle-water land is 60%. They turned to grow other rice varieties due to many perspectives and experiences in their rice productions. In particularly years, they changed from growing floating rice to long-term rice or from floating rice to early season rice and receding rice.

They also changed from early season rice or receding rice to long-term rice regarding to economic and climate condition.

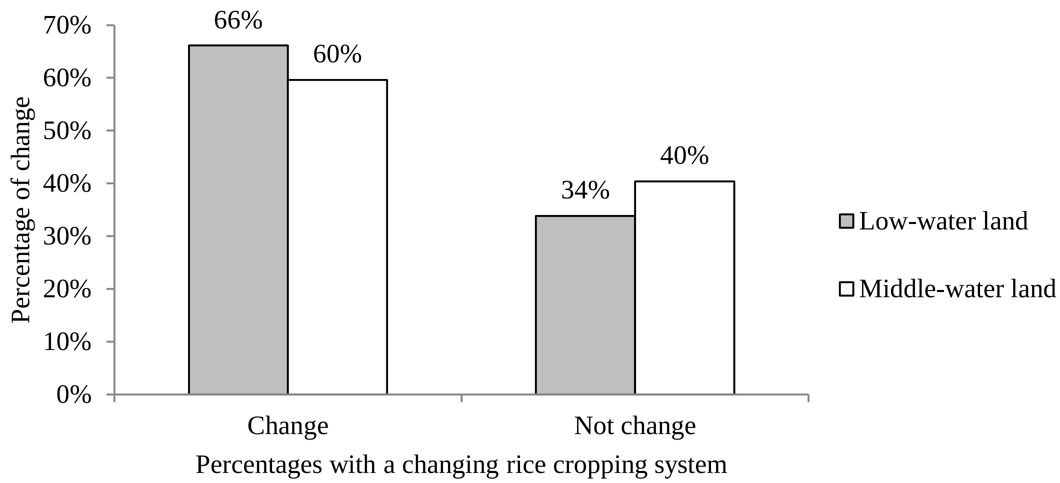


Fig. 16 Percentages of households who changed their rice cropping systems since initial stage

Farmers changed their rice cropping systems due to four primary drivers or perspectives such as new rice varieties introduced, having enough irrigation, decreased flood level, and economic perspective. Among these reasons of changes, flood pulse alteration and declining floodwater is the main influencing factor to farmers in the agro-ecological areas, Low-water land and Middle-water land which led them to switch their old rice cropping systems to adopt a new innovation. As a result, more than 40% of farmers in Low-water land mentioned it as a cause of changing their cropping system (floating rice to long-term rice and high-yield rice) while lower than 40% of farmers in the Middle-water land mentioned. Figure 17 indicates the percentages of each reason of change in rice cropping systems.

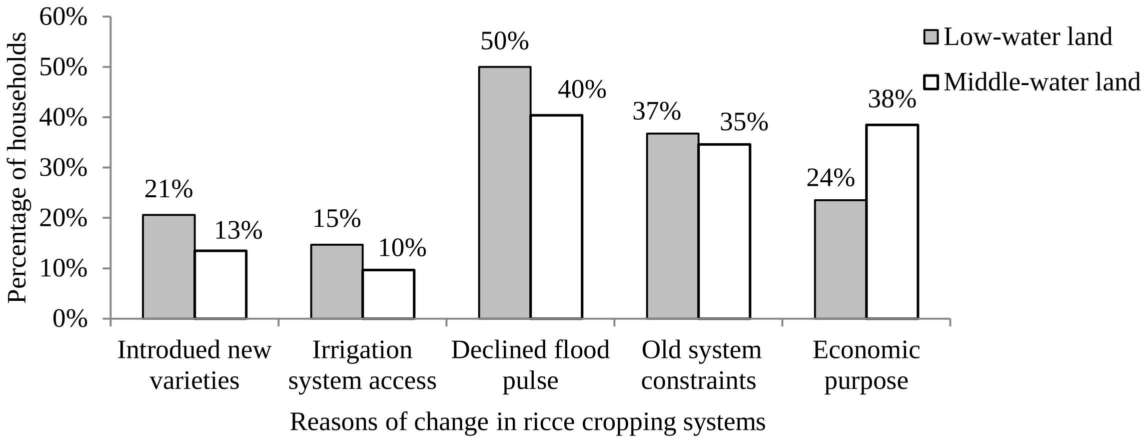


Fig. 17 Percentages of reasons of changes in rice cropping systems in both areas

Table 7 describes the economic performance of rice cropping systems in Low-water land and Middle-water land. The result shows that floating rice had low GVA per hectare comparing to the modern rice cropping systems. Long-term rice cropping system in Middle-water land was the highest land productivity comparing to Low-water land and other rice cropping systems. Among short-term rice, early season rice cropping systems in both areas were relative low of GVA per hectare compared to the others. However, receding rice cropping system in low-water land was profitable.

Table 7 The economic performance of rice cropping systems

Variables		Low-water land (n=68)					Middle-water land (n=52)		
	Unit	FR	LTR	ESR	RR	ESR+ DSR	LTR	ESR	ESR+ DSR
Area	ha	2.89	2.17	2.18	1.94	2.40	2.80	1.82	1.90
Price per unit	USD	0.19	0.21	0.29	0.20	0.33	0.26	0.21	0.18
Total harvest	kg	2,447.37	3,454.00	1,663.73	4,604.49	4,707.18	5,970.96	2,034.14	7,408.33
Goss outputs	USD	472.70	725.76	482.34	923.18	1,553.37	1,552.45	427.28	1,333.68
Intermediate inputs	USD	338.35	329.63	317.75	357.40	935.14	559.45	279.57	745.28
Labour per ha	man-days	11.42	18.96	24.29	18.42	29.80	16.40	27.78	34.81
GVA	USD	134.35	443.54	164.77	565.78	618.55	993.00	147.71	789.40
GVA per ha	USD	46.49	182.45	75.52	276.75	257.73	354.03	81.16	310.41

5.6 Comparison of economic of three rice cropping systems in both areas

Table 8 represents the economic performance and inputs used in early season rice in Low-water land and Middle-water land. As a result, it shows that there were significant differences of soil preparation, broadcasting and seeds between both areas. It also reveals that there was no significant difference between the mean value of gross output, chemical fertiliser, and harvesting, intermediate inputs, gross value-added and labours.

Table 8 Comparison of economic performances of early season rice in both areas

Variables	Early season rice				
	Low-water land (n=68)		Middle-water land (n=52)		2-tialed (p-value)
	Mean	SD	Mean	SD	
GO per unit area (USD/ha)	221.16	162.68	234.77	149.05	0.924
Chemical fertilisers (USD)	35.24	36.55	42.32	58.32	0.744
Seeds (USD)	79.70	68.31	55.27	58.32	0.009**
Soil preparation (USD)	54.24	34.44	43.42	12.81	0.011**
Broadcasting (USD)	27.45	20.93	25.65	15.48	0.070 *
Harvesting (USD)	87.99	44.85	75.17	57.52	0.433
Intermediate inputs per ha (USD)	317.75	173.20	279.57	130.97	0.120
GVA per ha (USD)	75.52	137.85	81.16	137.24	0.931
Labour per ha (man-days)	24.29	18.78	20.78	11.85	0.932

Note: * * Significant at 10%, ** Significant at 5%

Aside from early season rice, Table 9 also represents the comparison of economic performance of long-term rice cropping system. The results suggested that there were statistically significant differences between gross outputs, chemical fertilisers, intermediate inputs, gross value-added and harvesting. Furthermore, regarding to the mean rank of Mann-Whitney U Test performance shows that gross output per hectare, chemical fertilisers, harvesting, intermediate inputs and GVA per hectare in Low-water land were lower than Middle-water land. However, the labour used in Low-water land was lower than Middle-water land. Additionally, there were not significant differences between seeds, soil preparation and broadcasting.

Table 9 Comparison of economic performances of long-term rice in both areas

Variables	Long-term rice Low-water land (n=68) Mean	Mean rank	Middle-water land (n=52) Mean	Mean rank	Asympo. 2-tialed (p-value)
GO per area unit (USD/ha)	334.27	23.08	553.48	37.87	0.079*
Chemical fertilisers (USD)	49.58	22.40	140.06	38.98	<0.001***
Seeds (USD)	94.00	29.00	105.63	34.74	0.228
Soil preparation (USD)	43.43	34.76	36.68	31.05	0.347
Broadcasting (USD)	17.33	28.60	29.52	35.00	0.180
Harvesting (USD)	141.44	28.64	210.36	34.97	0.093*
Intermediate inputs (USD)	329.63	27.32	559.45	35.82	0.075*
GVA per area unit (USD/ha)	182.45	23.08	354.03	37.87	0.002**
Labour per area unit (Man-day/ha)	18.96	26.60	16.40	30.81	0.130

Note: * Significant at 10%, ** Significant at 5%, *** Significant at 1%

Table 10 shows the double rice cropping systems cultivated in both study areas. As a result, farmers in Low-water land applied chemical fertilisers lower than who are in Middle-water land significantly. In the contrary, the amount of seed was also significant difference which used in Low-water land was higher than Middle-water land than farmers in Middle-water land. Yet, aside from these inputs, there were not significant difference in both agro-ecosystem.

Table 10 Comparison of economic performances of early season rice + dry season rice in both areas

Variables	Low-water land (n=68)		Middle-water land (n=52)		
	Mean	SD	Mean	SD	2-tialed (p-value)
GO per area unit (USD/ha)	647.37	346.87	703.69	579.24	0.708
Chemical fertilisers (USD)	196.77	159.82	210.95	195.23	0.067*
Seeds (USD)	302.93	235.45	146.90	67.75	0.050**
Soil preparation (USD)	85.60	50.29	37.56	15.95	0.672
Broadcasting (USD)	32.91	13.28	37.59	6.30	0.541
Harvesting (USD)	264.69	196.18	241.81	124.09	0.625
Intermediate inputs (USD)	935.14	256.98	745.28	155.03	0.442
GVA per area unit (USD/ha)	257.73	271.09	310.41	368.95	0.256
Labour per are unit (Man-day/ha)	29.80	33.14	27.78	14.66	0.767

Early season rice + Dry season rice

Note: * Significant at 10%, ** Significant at 5%

5.7 Sensitivity index analysis

Based on the result, table 1 represents the sensitivity index of farmer's rice productions in between the best, normal and worse year. The production in each circumstance is entirely different almost 50%. It shows that during the best year farmers invest more capital and labours in expanding their farming, but they finally generate more income than normal and worse year as the same as labour use which is high in the best year since they need to process in the whole production entirely. Long-term rice cropping system gets the highest yield in the best year which is more than 3 tonne per hectare comparing to high-yield rice cropping systems is approximately 2.5 tonne per hectare similarly to floating rice. Among all rice cropping systems, floating rice is the most vulnerable because it friendly depends on natural resource provisioning especially floodwater in TSL. During the worse year, the rice cropping systems receive similar yield, 1.06 tonne per hectare for floating rice while the others are approximately one and a half tonne per hectare.

The best year refers to the occasion that farmers get a favourable condition for their rice productions including good climate condition, regular raining, sufficient floodwater and no drought. Best year for farmers, raining always come early (during April and May) in rainy season allowing farmers to start their cultivation accordingly and fruitfully. During the best year, farmers get high yield than normal and worse year based on flooding level, which has provided not only fresh water, but also soil regulation and fertility in their rice fields, using less chemical fertiliser, and leads their rice grown well. Additionally, during the best year, farmers do not face several constraints in their production such as grass, insects, rate and water restriction. On the contrary, in the worse year refers to a dangerous condition or unfavourable year for rice farmers.

Table 11 Sensitivity index analysis of rice cropping systems corresponding to the year variation

	Rice cropping systems	Labour (number)	Yield (tonne/ha)	Cost of inputs (USD/ha)	Revenue (USD/ha)
Best year	Long-term rice	3.00	2.48	142.87	363.44
	Receding rice	3.00	2.86	210.92	461.62
	Early season rice	3.09	1.41	369.40	395.91
	Dry season rice	3.00	2.14	240.33	555.52
	Floating rice	3.56	1.66	127.25	304.91
Normal year	Long-term rice	3.00	1.35	128.82	243.04
	Receding rice	2.11	2.11	211.27	275.10
	Early season rice	3.10	1.31	161.97	313.66
	Dry season rice	3.00	1.92	238.42	365.29
	Floating rice	3.07	1.06	118.07	343.04
Worse year	Long-term rice	2.87	1.30	118.35	182.09
	Receding rice	2.71	1.35	178.83	112.73
	Early season rice	3.17	1.27	119.07	166.25
	Dry season rice	2.67	1.29	182.90	103.39
	Floating rice	2.97	1.03	85.08	176.80

There are several constraints that farmers always faced especially rats, flooding, and drought. Regarding to farmer's observation, rates always appear when there is not suitable flooding level from TSL especially in the low-water area. On the other hand, the climate is also worse; the rain falls late sometimes until mid of rainy season and torrential rains at the end of the seasons which damage farmer's paddy rice during maturing and harvesting period. Moreover, drought also happens in worse years. Floodwater in TSL recently changed and fluctuated which somehow farmers did not consider it as important since their rice paddy was destroyed by flooding.

5.8 Ecosystem service awareness and perception

5.8.1 Farmer's awareness of ecosystem services

As a result, the study found that farmers provided different information of awareness. The number of respondents who are aware the ecosystem services in the Low-water land is higher than who are in the Middle-water land. The result shows that 80% of farmers in the Low-water land were aware the ecosystem services provided by Tonle Sap Lake in their rice cropping systems annually while 60% of farmers in the Middle-water land. Furthermore, 40% of farmers in the Middle-water land are not aware those Ecosystem services while 20% in the Low-water land.

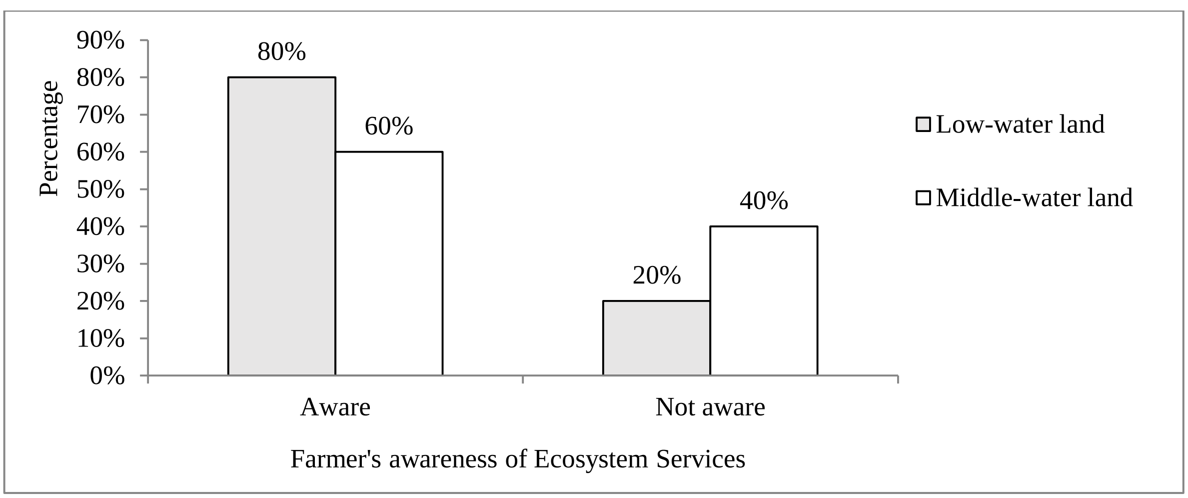


Fig. 18 Farmer's awareness of ecosystem services for rice cropping systems in both areas

Additionally, farmers provided their level of awareness on four specific ecosystem services such as water, wildlife, fish, and forest contributed in their rice cropping systems. Figure 7 indicates the farmer's opinions on those ecosystem services. For water, 40% of farmers in Low-water land agreed that this ecosystem service had played a significant role in their rice cropping system while 20% in the Middle-water land. On the contrary, 40% of farmers in Middle-water land strongly disagree whereas 30% in the Low-water land. On the other hand, 50% of farmers in Low-water land agreed that wildlife contributed in their rice cropping systems and only 10% of them have disagreed for this while 20% of farmers in the Middle-water land have agreed, 40% of farmer said somewhat agree, and 30% disagreed. For the forest, 60% of farmers in Middle-water land mentioned disagree, while 40% in the Low-water land.

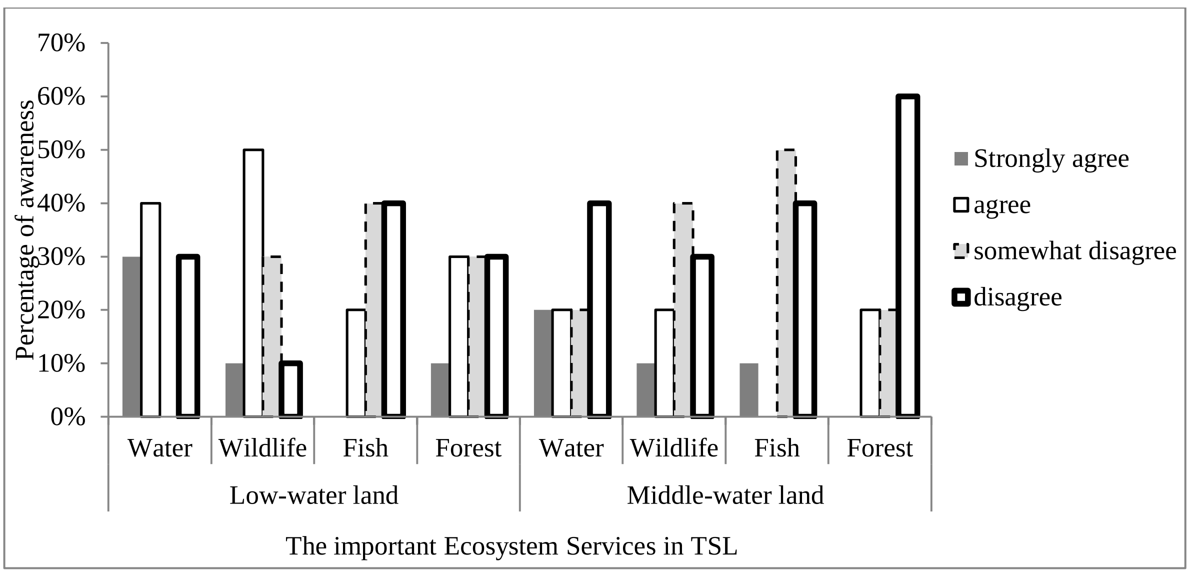


Fig. 19 Farmer's awareness of specific Ecosystem services for rice cropping systems

5.8.2 Farmer's perceptions of ecosystem services

Table 8 shows the evidence of labour and capital investment as well as yield and income of rice cropping systems categorised into three years such as best year, normal year and worse year. It exactly influences on farmer's perceptions of ecosystem services in Tonle Sap

Lake. As a result, most of the farmers in both areas have similar perceptions of ecosystem services such as floodwater, wildlife, fish and forest and they perceived that those ecosystem services had been declined and changed. The amount of fish was indicated by more than 50% of farmers in the Middle-water land as strongly decrease, and more while in the Low-water land is 60%. Floodwater is the most important ecosystem services for rice farmers, and more than 40% of farmers in Low-water land recognised somewhat decreased while more than 30% of interviewed farmers in the Middle-water land have the same perception of that. On the contrary, among the interviewed rice producers had a different opinion of floodwater. They have mentioned that floodwater was strongly increased which more than 5% of them in both area perceived while more than 2% of farmers in the Middle-water land have noticed that somewhat increase.

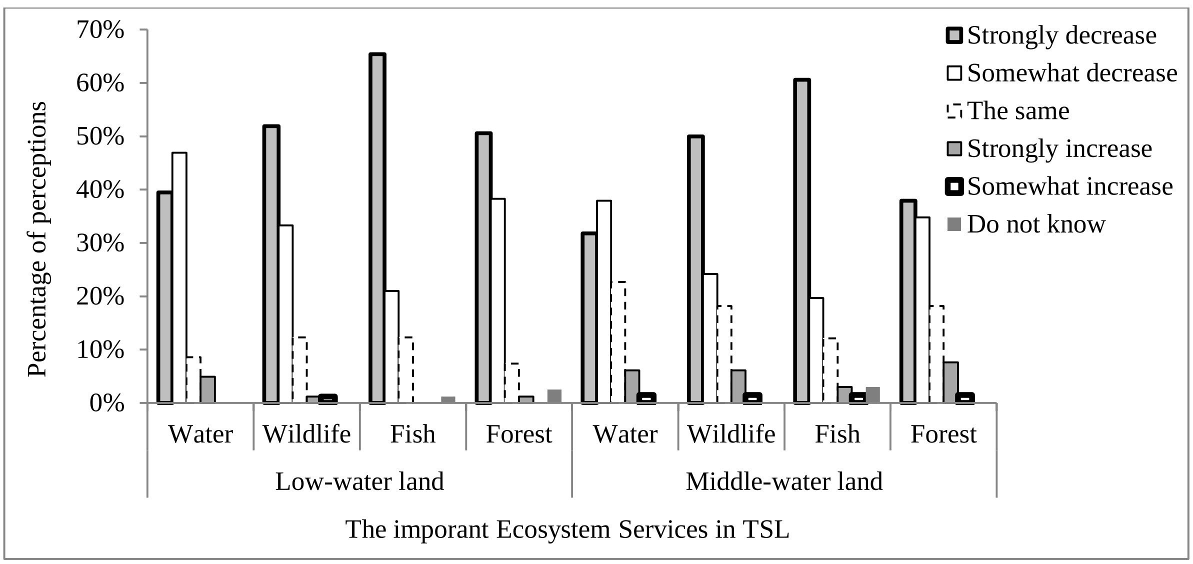


Fig. 20 Farmer's perceptions of Ecosystem services changed in Tonle Sap Lake

5.8.3 The importance of ecosystem services

Figure 8 shows the farmer's perceptions of the importance of ecosystem services in Tonle Sap Lake for their rice cropping systems. As the results, more than 80% of local farmers show that the ecosystem services are necessary for their rice cropping system particularly floodwater. Meanwhile, 7% of farmers in Low-water land mentioned that not all of the ecosystem services are important while 2% of farmers in the Middle-water land also mentioned. Additionally, among those farmers also did not know whether these ecosystem services are important or not which indicated by 10% of farmers in Low-water land and 17% in the Middle-water land.

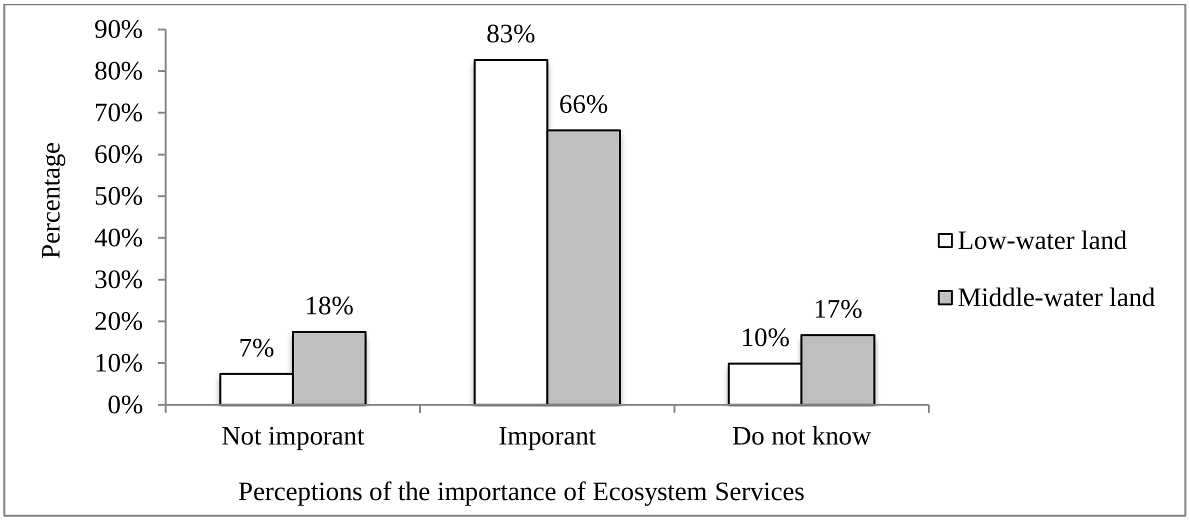


Fig. 21 Farmer's perceptions of the importance of ecosystem service for rice cropping systems

6 Discussion

This thesis sought to understand and analyse rice cropping systems in Battambang province and to document farmer's awareness and perception of ecosystem services provided to those systems by Tonle Sap Lake (TSL). There were two agro-ecosystems in the study area observed, Low-water land, which was located close to the TSL and Middle-water land, located further form TSL. Farms in both systems varied in size as households from Low-water land were larger compared to Middle-water land, 3.76 ha and 2.90 ha respectively. Nevertheless, both values exceed the national average almost two times (Chea, 2015; National Institute Statistics, 2015) and thus we have to consider these farmers as not typical small-holders in the country. Generally, the agricultural land was predominantly used for rice cropping systems (almost 90%) in both study sites, which were concentrated mainly on the floodplains of Mekong River basin and TSL (Sarom et al., 2001; Sophea, 2012; Chea, 2015). It is necessary to mention that present picture of the rice cropping systems is based on a long-term development and reflects recent changes in Mekong river stream and in climate dynamics. The land-use system in the study areas have noticeably changed during particular four periods, starting from 1970s and 1980s respectively, till present time and reflecting main socio-economic and environmental changes. Farmers in the Low-water land have been able to expand the agricultural land since the initiative period until now particularly via transformation of flooded forest land. On the other hand, farmers in the Middle-water land were not able to enlarge their agricultural land after the third period (2007-2010) due to limited land resources availability and policy restrictions. Generally, the land-use transformation in both study areas has a clear linkage with the population growth and environmental changes in the TSL and which led to converting of forest land to agricultural and residential land. These findings, indicating linkages between the population growth and shift have often effects on the land-use transformation, correspond to the studies from Mekong region Chann (2011), South-East Asia (Dhas, 2008) or even from Europe (Hunter, 2001). Lower altitude made however Low-water land areas more sensitive to changes of Mekong River water flow as well as to dramatic changes in the dynamics of floodwater from TSL.

The majority of farmers were cultivating single rice cropping systems while not many of them were also growing double rice cropping systems, 10% in Low-water land, 12% in Middle-water land respectively, particularly due to inability to access supplementary irrigation systems. Water and climatic variation posed the constraints that always occur in the recent years. Most of the farmers faced drought and floods as well as pests, diseases, weeds, and insects, which negatively affected their rice production which similar results conducted by Sarom (2007); MAFF (2015) and Chea (2015). As the observation, rats always appear during the occurrence of drought and limited floodwater from TSL. MRC (2010) indicated that the flooding pattern was hydrological unique and having huge influences on the natural ecosystem including rice ecosystems on/around the floodplains. For example, serious flooding occurred in the year 2011 suggested by Kamoshita & Ouk (2015) the proportions of paddy rice fields in the whole country (>11%) and entire Sangkae district (>30%) damaged (see Table 2). Floating rice cropping system mainly existing in Low-water land was the most vulnerable while the flood pulse changed because of its ecological system strongly depends on floodwater (Kamoshita & Ouk, 2015; Maclean, 2002)

Based on the historical changes in both study areas, the high-yield rice varieties introduced and reached the study areas during 2000s, which corresponded to government's agricultural policy implementation (Vuthy & Ra, 2010; Sarom et al., 2001; Rio et al., 2013; MAFF, 2015). As a result, majority of farmers (>60%) in Low-water land and (60%) in Middle-water land have adopted this innovation by changing their old rice cropping systems, which practised with traditional techniques and mainly relied on natural resources provisioning, to the new rice cropping systems which confirmed by keskinen (2013). This proportion is similar to number of interviewed farmers in similar region of this study area (Keo, 2015). Farmers have changed their rice cropping systems because of several reasons (see Figure 15). Yet, the study found that farmers have low adaptive capacity while the climate and ecosystem services variability have occurred in their areas which similar to the studies in rainfed areas in Nigeria (Idrisa et al., 2012) and rainfed upland in Cambodia (Yusf & Francisco, 2009). Insufficient supplementary irrigation systems and depend on unreliable rainfalls and floodwater from TSL led farmer's rice cropping systems to low productivity improvement while they have shifted to cultivate high-yield rice cropping systems in their areas which consistent with Sophea (2012).

In our study, also highlight the advantages and disadvantages of rice cropping systems practised by smallholders in the study areas. Floating rice cropping system was, traditional system, required the low cost of production compared to high-yield rice cropping system. Additionally, farmers exercised this cropping system with lower labour and cost of inputs. Due to favourable condition of soil, high fertility, farmers did not applied chemical fertilisers. It also provided high ecosystem services to the environment in Tonle Sap Lake (Malyne, 2015 and Akara, 2010). Furthermore, majority of farmers grown it for mainly household's consumption which similar to Sarkkula et al. (2003) who stated that floating rice is significant for the poorest households on floodplain area due to its cost-efficiency. However, it generated lower land productivity per hectare (GVA=47 USD) then the other rice cropping systems in the study areas as well as lower than four times compared to a study conducted by Malyne (2015). It was due to from low total harvest which caused by the production constraints, such as limited floodwater, drought and rats have occurred seriously in recent years. For the other cropping systems, early season rice in Low-water land received lower GVA per hectare (76 USD) compare to Middle-water land (81 USD) respectively while there are significant differences between its inputs such as such as seeds and soil preparation and these results were also relatively low than result observed by Malyne (2015) (see Table 8). On the other hand, the land productivity of these rice cropping systems in both areas lower than the other high-yield rice cropping systems such as long-term rice, receding rice and double rice due to drought, in the early rainy season and flooding, mid-rainy reason, constraints which also the same to the report and other researches were done by Meertens et al. (1999); Seng et al. (2014) and MAFF, (2016). In the meantime, the study indicated that long-term rice cropping system in Middle-water land received highest GVA/ha (354.03 USD/ha) compared to the other single and double rice cropping systems. This result was contradicted to Malyne (2015) who found that the double rice cropping system was a high productive system compared to the other rice cropping systems in floodplain areas. Since the soil fertility in Middle-water land was lower than Low-water land, farmers in the Middle-water land applied higher chemical fertilisers in their long-term rice cropping system than farmers in Low-water land significantly in order to intensively improve their land productivity. Additionally, double rice cropping system provided also higher land productivity than single rice cropping systems in term of short-term rice. Farmers received high GVA/ha equal to 258 USD/ha in Low-water land and 310 USD/ha in Middle-water land. It might be due to the paddy rice field for this rice cropping systems still high fertility. High-yield rice cropping systems also required higher fertilisers, pesticides, herbicides and labours for management and supplementary irrigation system. Indeed, the irrigation systems were more likely limited in both study areas as Chea et al. (2004) and Sophea (2012) similarly found that these are the most constraints for rice farmers in rainfed lowland and entire Cambodia. Generally, farmers used high amount of seeds (>100 kg/ha) in their rice cropping systems in both study areas, which leads to the increase intermediate inputs. Based on their experiences, the main purposes of using high quantity of seeds prevent the rates of seed lost, damaged by climatic variation, insects, and pests. However, the recommended rates of Sophea (2012) and Kleinhenz et al. (2013) was 60kg to 70kg per hectare which was lower than seed used by farmers in the study area.

Most of the households in the both agro-ecosystems were aware of a wide range of ecosystem services provisioning from TSL for their rice cropping systems such as freshwater, wildlife, flooded forest, and fish. This awareness was hither among the farmers from Low-water land, compared to Middle-water land, 80% and 60% respectively. However, both values were lower compare to 90% observed in Nigeria (Zhang et al., 2016). It explicitly explained that farmers in the Low-water land might be closely interacted and depended on the ES from TSL for their rice cropping systems while farmers in the Middle-water land slightly interacted and depended on those ES from TSL relatively similar to a study conducted in Philippines (Lasco et al. 2016) and main areas of European grasslands (Lamargue et al. 2011). Generally, it seems that farming experiences and education of household heads may positively affect the awareness of contribution of ecosystem services to their rice cropping systems even though there is no statistical evidence provided by this study. Nevertheless, such findings correspond to the other study from northern Greece (Lithourgidis et al., 2016), but more studies are needed to understand socio-economic impact on awareness about ecosystem services in Cambodia.

Our study also found that households in both study areas had similar perceptions of the changes of the ES. The majority of them perceived that ES provided by TSL were decreased. As the results of historical of land-use, it provided clear supporting evidences for the variation of these ES. Among those interviewed households also expressed their opinion on the causes of the ES changing in TSL which included hydropower dams development on the Mekong River, climate change, land clearance for agricultural and residential land, illegal activities of fishing (clearing forest for fishing), and hunting. In the meantime, the two main causes led to changing ES in TSL mentioned by interviewed households such as hydropower dams on the Mekong River and global climate change which are consistent to the other surveys conducted in floodplain areas Keskinen et al. (2013) and Arias et al. (2014). Farmer's household characteristics were not significant difference between farmers in Low-water land and Middle-water land. Nonetheless, farmers in the Low-water land were more likely to be aware the causes of changing while farmers in the Middle-water land were not widely aware. The linkages between their livelihood and ecosystem services in TSL also might highlight their different perceptions of ES. Due to the Low-water land located very near distance to TSL and most of farmers actively and directly relied on those ecosystem services which lead them to well recognising the causes of changes. Moreover, sensitivity analysis of rice cropping systems provided evidences associated with farmers' perception of the importance of ES for their rice cropping systems. Hence, the worse year occurrence led them to perceptions of these ES due to their production yield variation. The majority of farmers stated that those ES were necessary for their rice cropping systems, 83% in Low-water land and 66% in Middle-water land. However, the results also reveal that still among of them, (18%) in the Middle-water land and Low-water land (7%), did not perceive all of ES as important in their rice cropping systems.

Based on our findings we can come up with following recommendations. First, providing capacity building to farmers in the study area in order to confront the change of climate in their rice cropping systems is necessary. Thus, stakeholders have a significant role with this issue including provincial departments of agriculture, and provincial department of water resources and meteorology. Farmers should be provided with more training on agricultural technique to adapt to the current climate change and ecosystem services variability in their areas. Furthermore, they should be provided widely explicit and reliable information of meteorology on climate change, temperature, flood pulse change as well as emergent shocks or stresses which are important for them to adapt those constraints. Due to insufficient irrigation systems occurred in the study area especially in Low-water land where depend mainly on natural services provisioning, rainfall, so the government should improve and expand the irrigation systems in those areas in order to enable them to cultivate their rice cropping systems sufficiently. Moreover, farm gate price of paddy rice was the most constraint for farmers. The price was always fluctuated to lower during harvesting period. On the other hand, the price of inputs was also high which led to increasing the cost of production. Thus, government should also intervene in these challenges. Farmers themselves should actively apply all knowledge and experiences received from the trainings or workshops in their rice cropping system.

In order to better understand the role of ecosystem services in changing rice cropping systems as well as to come up with more suitable and effective recommendations, more research is necessary. For another study would be great idea to focus on the factors influencing on the farmer's awareness and perceptions of ES around Tonle Sap Lake including role of gender, economic development and increasing pressure on commercialization of local farming systems. While the ecosystem services have changed, farmers were negatively affected in their rice cropping systems and livelihood. Thus, in order to improve their adaptation capacity those changes, ecosystem services and climate dynamics, the suggested further studies to analyse farmers' coping strategies toward above mentioned issues would be also relevant.

Our survey is not without limitations. The study was taken place in the rural areas where farmers depend on agriculture as their main source of income. Thus, this study faced some constraints to obtain the sufficient information from farmers. The constraint was approaching the farmers for interview due to they were so busy with starting rice cultivation. Most of them were not home in the morning until the evening, so enumerators had to make an appointment with farmers in advance. However, they were friendly to provide all information based on their memorising. The cooperation of the local institution and administration was potential influence for this study. However, those local institution and administration was not well organised in term of administrative tasks which led constraint for the study to use time inefficiently. Furthermore, our study results are not representative farming households in national perspective which is not easy generalization. Hence, it represents the farming households in the region.

7 Conclusion

Target households in both study areas had larger farm size compare to national average and were practicing five different rice cropping systems. ecosystem services and climate variability led to land transformation and changing of rice cropping systems since 1970s and 1980s respectively. There were important changes in land-use systems resulting particularly in vast deforestation and replacing traditional rice varieties by modern cropping systems of the households'. Such changes also affected the profitability of particular systems. Middle-water land households had more valuable cropping systems compare to Low-water land households, except for the early season rice was slightly different. As the results, farmers in Middle-water land generated higher productivity for all rice cropping systems, long-term rice (354 USD/ha), early season rice (81 USD/ha), and double rice (310 USD/ha) while farmers in Low-water land were 182 USD/ha, 76 USD/ha, and 258 USD/ha. ecosystem services variation affected the households' livelihood particularly the poorest households in the floodplains because they were highly vulnerable in ensuring food security and source of income due to inability to practise the new rice cropping systems while their traditional systems were being disappeared. However, this condition had an added advantage to the farmers who practise the modern rice cropping systems. Conversely, changing of the rice cropping system provided highly negative impacts on ecosystems in Tonle Sap Lake, using high chemical fertilisers, pesticides and herbicides among inputs.

Farmers were more vulnerable and prone to high risk for their rice cropping systems due to low adaptive capacity, lack of supplementary irrigation systems and explicit reliable sources of metrological information to confront with ecosystem services and recent climate change. Majority of farmers in both study sites perceived ecosystem services from Tonle Sap Lake as important. However, not all of them perceived that ES provided by TSL are important to them while those ES changed particularly flood pulse which in particularly year their rice cropping systems were seriously damaged by flooding. Moreover, they were aware about the changes in freshwater, fish, wildlife, and flooded forest. It seems farmers in Low-water land were aware the causes of change of ecosystem services higher than among farmers in Middle-water land due to their closely interaction between ecosystems in TSL.

8 References

Akara, A. 2010. The Study On The Contribution Of Organic Rice In Environment Conservation And Poverty Reduction In Stoeung Sen Oganic Agriculture Development Community In Stoeung Sen City, Kampong Thom Province. Phnom Penh, Cambodia: Royal University of Agriculture.

Arias M. E, Cochrane T. A, Kummu M, Lauri H, Holtgrieve G. W, Koponen J, Piman T. 2014. Impacts of hydropower and climate change on drivers of ecological productivity of Southeast Asia's most important wetland. Ecological modelling, 272, 252-263.

Arias M. E, Piman T, Lauri H, Cochrane T. A, Kummu M. 2014. Dams on Mekong tributaries as significant contributors of hydrological alterations to the Tonle Sap Floodplain in Cambodia. Hydrology and Earth System Sciences, 18(12), 5303.

Barral S, Touzard I, Ferraton N, Rasse-Mercat E, Pillot D. 2012. Assessing smallholder farming. Diagnostic analysis of family-based agricultural systems in a small region. Los Banos: Southeast Asian Region Center for Graduate Study and Research in Agriculture.

Braat L, Groot R. 2012. The Ecosystem services agenda: bridging the worlds of natural science and economics, conservation and development, and public and private policy. Ecosystem services, 4-15.

Baran E, Myschowoda C. 2009. Dams and fisheries in the Mekong Basin. Aquatic Ecosystem Health & Management, 12(3), 227-234.

Boyd J, Banzhaf S. 2007. What are Ecosystem services? The need for standardized environmental accounting units. Ecological economics, 63(2), pp.616-626.

Cochet H. 2006. “Note Méthodologique Fonctionnement et Performances Économiques Des Systèmes de Production Agricole : Une Démarche À L ’ Échelle Régionale L” 15: 578–83.

Cooperman M. S, So N, Arias M, Cochrane T. A, Elliott V, Hand T, Koponen J. 2012. A watershed moment for the Mekong: newly announced community use and conservation areas for the Tonle Sap Lake may boost the sustainability of the world’s largest inland fishery. Cambodian Journal of Natural History, 2012, 101-106.

Cochet H. 2012. *The systeme agraire concept in francophone peasant studies*: Paris Institute of Technology for Life, Food and Environmental Sciences (AgroParisTech), Comparative Agriculture and Agricultural Development Research Unit. Paris, France.

Chea S. 2015. Evaluating cropping system options for farmers in the lowland rice-based systems of Cambodia.

Chea S, Cramb R. and Fukai S. 2004. The economics of rice double-cropping with supplementary irrigation in the rainfed lowlands of Cambodia: a survey in two provinces. Water in agriculture, 116, pp.32-44.

Chann S, Wales N, Frewer T. 2011. An investigation of land cover and land use change in Stung Chrey Bak Catchment, Cambodia. Phnom Penh: Cambodia Development Research Institute.Working papper series N0 53.

Dale V. H, Polasky, S. 2007. Measures of the effects of agricultural practices on Ecosystem services. Ecological economics, 64(2), 286-296.

Devendra C. 2016. Rainfed agriculture: its importance and potential in global food security.

Devendra C., & Thomas, D. 2002. Nairobi, Kenya: International Livestock Research Institution.

De Groot R. S. 2010. Protecting natural capital for human wellbeing and sustainable development. Science for environment policy, 2010 (Special Issue 20).

De Groot, R.S., Alkemade, R., Braat, L., Hein, L. and Willemen, L. 2010. Challenges in integrating the concept of Ecosystem services and values in landscape planning, management and decision-making. Ecological complexity, 7(3), pp.260-272.

Dale, V.H, PolaskyS. 2007. Measures of the effects of agricultural practices on Ecosystem services. *Ecological economics*, *64*(2), pp.286-296.

Dan Z, Qingwen M, Lu H, Shengkui C, Jianmin F. 2010. Value of Ecosystem services in conventional and organic rice paddies: A case study in Wannian, Jiangxi, China. *Chinese Journal of Population Resources and Environment*, *8*(2), pp.47-54.

Dhas A.C. 2008. Population Pressures and Land Use Changes in Southeast Asian Countries: Recent Evidences.

Egoh B, Rouget M, Reyers B, Knight A.T, Cowling R.M, van Jaarsveld A.S, Welz A. 2007. Integrating Ecosystem services into conservation assessments: a review. Ecological Economics, 63(4), pp.714-721.

Fukai S, Sittisuang P, Chanphengsay M. 1998. Increasing production of rainfed lowland rice in drought-prone environments. Plant Production Science, 1(1), 75-82.

Fisher B, Turner R. K, Morling P. 2009. Defining and classifying Ecosystem services for decision making. Ecological economics, 68(3), 643-653.

Ganesh T, Raghav G. 2011. *Smallholder Farming in Asia and the Pacific:* Challenges and Opportunities. Italy: International Fund for Agricultural Development.

Gómez-Baggethun E, De Groot R, Lomas P. L, Montes C. 2010. The history of Ecosystem services in economic theory and practice: from early notions to markets and payment schemes. Ecological economics, 69(6), 1209-1218.

Hortle K. G. 2007. Consumption and the yield of fish and other aquatic animals from the Lower Mekong Basin. MRC technical paper, 16, 1-88.

Hauck J, Görg C, Varjopuro R, Ratamäki O. Jax K. 2013. Benefits and limitations of the Ecosystem services concept in environmental policy and decision making: some stakeholder perspectives. *Environmental Science & Policy*, *25*, pp.13-21.

Hunter I.R. 2001. What do people want from urban forestry?—The European experience. Urban Ecosystems, 5(4), pp.277-284.

Itoh M, Sudo S, Mori S, Saito H, Yoshida T, Shiratori Y, Suga S, Yoshikawa N, Suzue Y, Mizukami H, Mochida T. 2011. Mitigation of methane emissions from paddy fields by prolonging midseason drainage. *Agriculture, ecosystems & environment*, *141*(3), pp.359-372.

Idrisa Y. L, Ogunbameru B. O, Ibrahim A. A, Bawa, D. B. 2012. Analysis of awareness and adaptation to climate change among farmers in the Sahel savanna agro-ecological zone of Borno State, Nigeria. British Journal of Environment & Climate Change, 2(2), 216-226.

IRRI. 2013. International Rice Research Institute. Available at: http://ricestat.irri.org:8080/wrs: Accessed: 2017-03-01

Ingram J.C, Wilkie D, Clements T, McNab R.B, Nelson. F, Baur E.H, Sachedina H.T, Peterson D.D, Foley C.A.H. 2014. Evidence of Payments for Ecosystem services as a mechanism for supporting biodiversity conservation and rural livelihoods. *Ecosystem services*, *7*, pp.10-21.

Keo S. 2015. September. The impact of Climate Change on Agricultural Production in North-West Cambodia. In Conference on International Research on Food Security.\

Kamoshita A, Ouk M. 2015. Field level damage of deepwater rice by the 2011 Southeast Asian Flood in a flood plain of Tonle Sap Lake, Northwest Cambodia. Paddy and Water Environment, 13(4), 455-463.

Keskinen M. 2003. Socio-Economic Survey of the Tonle Sap Lake, Cambodia. Water Resources Laboratory (Espoo: Helsinki University of Technology). Available online at: http://users. tkk. fi/u/mkeskine/dippa. pdf.

Keskinen M. 2006. The Lake with floating villages: Socio-economic analysis of the Tonle Sap Lake. International Journal of Water Resources Development, 22(3), 463-480.

Keskinen M, Kummu M, Salmivaara A, Someth P, Lauri H, Moel H, Pech S. 2013. Tonle Sap now and in the future? Final Report of the Exploring Tonle Sap Futures study.

Keskinen M, Kummu M, Salmivaara A, Someth P, Lauri H, Moel H, Ward P, Pech S. 2013. Tonle Sap now and in the future? Final Report of the Exploring Tonle Sap Futures study.

Kleinhenz V, Sophon C. H. E. A, Ngin H. U. N. 2013. Survey of Rice Cropping Systems in Kampong Chhnang Province, Cambodia. Rice Science, 20(2), 154-164.

Kögel-Knabner I, Amelung W, Cao Z, Fiedler S, Frenzel P, Jahn R, Kalbitz K, Kölbl A. and Schloter M. 2010. Biogeochemistry of paddy soils. Geoderma, 157(1), pp.1-14.

Knoblauch C, Maarifat A.A, Pfeiffer E.M, Haefele S.M. 2011. Degradability of black carbon and its impact on trace gas fluxes and carbon turnover in paddy soils. *Soil Biology and Biochemistry*, *43*(9), pp.1768-1778.

Kummu M, Tes S, Yin S, Adamson P, Józsa J, Koponen J, Richey J, Sarkkula J. 2014. Water balance analysis for the Tonle Sap Lake–floodplain system. *Hydrological Processes*, *28*(4), pp.1722-1733.

Liese B, Isvilanonda S, Nguyen K, Nguyen L, Pananurak P, Romnea P, Shwe T, Sombounkhanh K, Möllmann T, Zimmer Y. 2014. Economics of Southeast Asian rice production. *Agri Benchmark: Braunschweig, Germany) Available at http://www. agribenchmark.org/fileadmin/Dateiablage/B-Cash-Crop/Reports/Report-2014-1-rice-FAO. pdf [Verified 26 September 2016* .

Lamberts D. 2001. Tonle Sap fisheries: a case study on floodplain gillnet fisheries in Siem Reap, Cambodia. FAO Regional Office for Asia and the Pacific, Bangkok, Thailand. RAP Publication 2001/11, 133 p.

Lasco R. D, Espaldon M. L. O, Habito, C. M. D. 2016. Smallholder farmers' perceptions of climate change and the roles of trees and agroforestry in climate risk adaptation: evidence from Bohol, Philippines. *Agroforestry Systems*, *90*(3), 521-540.

Lithourgidis, C. S, Stamatelatou, K, & Damalas, C. A. 2016. Farmers' attitudes towards common farming practices in northern Greece: implications for environmental pollution. Nutrient Cycling in Agro-ecosystems, 105(2), 103-116.

Lamarque, P, Tappeiner, U, Turner, C, Steinbacher, M, Bardgett, R. D, Szukics, U, Lavorel, S. 2011. Stakeholder perceptions of grassland Ecosystem services in relation to knowledge on soil fertility and biodiversity. *Regional Environmental Change*, *11*(4), 791-804.

Likert R. 1932. A Technique for The Measurement of Attitudes. New York: New York University.

Maclean J. L. 2002. Rice almanac: Source book for the most important economic activity on earth. Int. Rice Res. Inst.

MAFF. 2016. Annual report on agricultural sector in Cambodia. Phnom Penh: Ministry of Agriculture, Forestry and Fisheries.

MAFF. 2015. Annual report on agricultural sector in Cambodia. Phnom Penh: Ministry of Agriculture, Forestry and Fisheries.

MAFF. 2013. Plan of action for disaster risk reduction in agriculture 2014-2018. Phnom Penh: Ministry of Agriculture, Forestry and Fisheries.

Malyne N. 2015. Maintaining Ecosystem services Provided by Rice Production Systems in Cambodia: Identifying Costs For Farmers and Consumers' Preferences. The University Clermont Auvergne: Clermont-Ferrand, France.

Milne S. and Chervier C. 2014. A Review of payments for environmental services (PES) experiences in Cambodia (Vol. 154). CIFOR.

Masumoto, T, Shimizu, K, & Hai, P. T. 2004. Roles of floods for agricultural production in and around Tonle Sap Lake. In ACIAR Proceedings (Vol. 116).

Meertens, H. C. C, Ndege, L. J, & Lupeja, P. M. 1999. The cultivation of rainfed, lowland rice in Sukumaland, Tanzania. Agriculture, ecosystems & environment, 76(1), 31-45.

Millennium Ecosystem Assessment. 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

MRC. 2010. Impacts on the Tonle Sap Ecosystem, Basin Development Plan Programme, Phase 2, Mekong River Commission, Vientiane, Lao PDR.

Mainuddin M, Kirby M, Hoanh C.T. 2011. Adaptation to climate change for food security in the lower Mekong Basin. Food Security, 3(4), pp.433-450.

Murthy C.S, Laxman B, Sai M.S, Diwakar P.G. 2014. Analysing agricultural drought vulnerability at sub-district level through exposure, sensitivity and adaptive capacity based composite index. The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, 40(8), p.65.

Naklang K, Harnpichitvitaya D, Amarante S. T, Wade L. J, Haefele S. M. 2006. Internal efficiency, nutrient uptake, and the relation to field water resources in rainfed lowland rice of northeast Thailand. Plant and soil, 286(1), 193-208.

Nkonya E, Anderson W, Kato E, Koo J, Mirzabaev A, von Braun J, Meyer S. 2016. Global cost of land degradation. In Economics of Land Degradation and Improvement–A Global Assessment for Sustainable Development (pp. 117-165). Springer International Publishing.

Nguyen Y.T, Kamoshita A, Araki Y, Ouk M, 2013. Water availability, management practices and grain yield for deepwater rice in Northwest Cambodia. Field Crops Research, 152, pp.44-56.

Provincial Department of Planning. 2015. Profile on economic and social in year 2015: based on commune databases in Sangkae district, Battambang province.

Provincial Department of Planning. 2016. Profile on economic and social of Battambang province in year 2015: based on commune and district databases.

Panith C, Malyne N. 2012. The impact of climate change on rice production in Cambodia. Phnom Penh, Cambodia: The NGO Forum on Cambodia, Environment Programme's Agricultural Policy Monitoring Project.

Pishgar, S.H, Rafiee S, Sefeedpari P. 2011. Energy Use Pattern And Sensitivity Analysis Of Rice Production: A Case Study Of Guilane Province Of Iran. African Crop Science Journal, 19(2), Pp.117-124.

Poulton P. L, Dalgliesh N. P, Vang S, Roth, C. H. 2016. The resilience of Cambodian lowland rice farming systems to future climate uncertainty. Field Crops Research, 198, 160-170.

Portman, M.E. 2013. Ecosystem services in practice: challenges to real world implementation of Ecosystem services across multiple landscapes–a critical review. Applied Geography, 45, pp.185-192.

Phnom Penh Post. 2014. Cambodia Farms at Risk. Available at http://www.phnompenhpost.com/national/cambodia-farms-risk

Pan G, Zhou P, Li Z, Smith P, Li L Qiu D, Zhang X Xu X, Shen S, Chen X. 2009. Combined inorganic/organic fertilization enhances N efficiency and increases rice productivity through organic carbon accumulation in a rice paddy from the Tai Lake region, China. Agriculture, ecosystems & environment, 131(3), pp.274-280.

RGC. 2010. National Strategic Development Plan Update 2009-2013, Royal Government of Cambodia (RGC).

Rode J, Wittmer H, Emerton L, Schröter-Schlaack C. 2016. 'Ecosystem service opportunities': A practice-oriented framework for identifying economic instruments to enhance biodiversity and human livelihoods. Journal for Nature Conservation, 33, pp.35-47.

Rio m. S, Charlesworth P, Kunthea K. 2013. Good practices in agricultural adaptation in response to climate change in Cambodia. Phnom Penh: SNV Netherlands Development Organisation.

Sok K. 2013. Innovation in Rice Cropping, Ayeyarwaddy Delta, Myanmar: reasons for adoption and non-adoption. Montpellier, France: Montpellier SupAgro/ Institut des Régions Chaudes.

Sophea K. 2012. The rice situation in Cambodia. Phnom Penh, Cambodia: Asian Development Bank.

Sou S. 2014. Phnom Penh Post: Cambodia Farms at Risk. Available at http://www.phnompenhpost.com/national/cambodia-farms-risk: Accessed 2017-01-12.

Sarom M. 2007. Crop management research and recommendations for rainfed lowland rice production in Cambodia. International rice commission newsletter, 56, pp.57-62.

Sarom M, Ram C. C, Edwin J, Ouk M, Sakhan S, Hun Y, Say P. 2001. Description of rice varieties released by the varietal recommendation committee of Cambodia (1999–2000). Cambodian Agricultural Research and Development Institute: Phnom Penh, Cambodia.

Smith H, Sullivan C. 2014. Ecosystem services within agricultural landscapes—Farmers' perceptions. Ecological Economics, 72-80.

Seng V, Craswell E, Fukai S, Fischer K. S. 2004. Water in Agriculture-ACIAR Proceedings 116. In Water in Agriculture (Vol. 116). Australian Centre for International Agricultural Research.

Stallman H.R. 2011. Ecosystem services in agriculture: determining suitability for provision by collective management. Ecological Economics, 71, pp.131-139.

Shams N. 2007. Contribution of rice field ecosystems to food security strategies in northwest Cambodia. Journal of sustainable agriculture, 29(4), pp.109-133.

Swinton S.M, Lupi F, Robertson G.P, Hamilton S.K. 2007. Ecosystem services and agriculture: cultivating agricultural ecosystems for diverse benefits: 245-252.

Smith H.F, Sullivan C.A. 2014. Ecosystem services within agricultural landscapes—Farmers' perceptions. Ecological Economics, 98, pp.72-80.

Sarkkula J, Kiirikki M, Koponen J, Kummu M. 2003. Ecosystem processes of the Tonle Sap Lake. In Ecotone II-1 workshop, Phnom Penh/Siem Reap, Cambodia.

TEEB (The Economics of Ecosystems and Biodiversity). 2010. Mainstreaming the Economics of Nature: A Symthesis of the Approach, Conclusions, and Recommendations of TEEB.

Tilman D, Cassman K.G, Matson P.A, Naylor R, Polasky S. 2002. Agricultural sustainability and intensive production practices. Nature, 418(6898), pp.671-677.

UKNEA. (2012). Ecosystem services concepts. Available at http://uknea.unep wcmc.org/ Ecosystem AssessmentConcepts/EcosystemServices/tabid/103/Default.aspx

World Bank. 2015. Cambodian Agricultural in Transition: Opportunities and Risk. Agriculture Global Practice East Asia and Pacific Region. Washington, D.C: World Bank Publication 186p.

Xiao Y, Xie G, Lu C, Ding X, Lu Y. 2005. The value of gas exchange as a service by rice paddies in suburban Shanghai, PR China. Agriculture, ecosystems & environment, 109(3), pp.273-283.

Yu X, Kai A, Gaodi X, Chunxia L. 2011. Evaluation of Ecosystem services provided by 10 typical rice paddies in China. Journal of Resources and Ecology, 2(4), pp.328-337.

Yusuf A. A, Francisco H. 2009. Climate change vulnerability mapping for Southeast Asia. Economy and Environment Program for Southeast Asia (EEPSEA), Singapore, 10-15.

Yu B, Fan, S. 2011. Rice production response in Cambodia. Agricultural Economics, 42(3), pp.437-450.

Vuthy T, Ra K. 2010. Review of agricultural policy and policy research. Presentation made at the Cambodia Food Security and Agricultural Policy Stocktaking Roundtable, Phnom Penh, Cambodia.

Zhang W, Ricketts T.H, Kremen C, Carney K, Swinton S.M. 2007. Ecosystem services and dis-services to agriculture. Ecological economics, 64(2), pp.253-260.

Zhang W, Kato E, Bhandary P, Nkonya E, Ibrahim H.I, Agbonlahor M, Ibrahim, H.Y, Cox C. 2016. Awareness and perceptions of Ecosystem services in relation to land use types: Evidence from rural communities in Nigeria. Ecosystem services, 22, pp.150-160.

Appendix 1: Questionnaire

I. General information of households

All members of household						
HH mem. ID	Relation to HH (1)	Marital status (2)	Age	Sex 1.Male, 2.Female	Year of schooling	Farm experiences
1						
2						
3						
4						
5						

Code:

[1]: 1.HH head, 2.Husban/wife, 3.Son/Daughter, 4.Stepson, 5.Adopted son/daughter, 6.Father/mother, 7.Brother/sister, 8.Grandson/Granddaughter, 9.Niece/Nephew, 10.Son/daughter in law, 11.Brother/sister in law, 12.Father/mother in law, 13.Other relative, 14.Servant, 15.Other (please specified…………)
[2]: 1.Single, 2.Married, 3.Widow, 4.Divorce, 5.Seperate

II. Land use and cropping changes (Land access and land distribution)

Land use	Land size	Land property right? 1.Yes (Type.....) 0.No	How many times per year?	Previous land use?
Agricultural land	Total:……ha			
Rice land	Plot 1……ha Plot 2……ha Plot 3…....ha Plot 4……ha	Plot 1…… Plot 2…… Plot 3…… Plot 4……	Plot 1…… Plot 2…… Plot 3…… Plot 4……	Plot 1……… Plot 2……… Plot 3……… Plot 4………

Have you changed any crops in each plot and when? (as example the change from floating rice to early season and receding rice)	☐ 1 yes ☐2 no Specify the year……	If yes, please specify kind of cropping system: Plot 1…………..…………… Plot 2……………………….. Plot 3………………………… Plot 4……………………………
Why did you change them?	☐1 New short-term varieties introduced ☐2 Enough irrigation system ☐3 Decreasing water level ☐4 Difficult to control old system 5☐ Economic purpose	

	☐Others…………………………………………………………………..
What are the constraints?	……………………………………………………………………….

III. Access to information

What are your three main sources of information you get concerning the agriculture in the table?	
Description of issues	Answers
Prices of goods or crops	
Agricultural extension	
Meteorology information	
Others, please specify ……………………………	

IV. Rice production

4.1 Floating rice: Month……………… surface………..ha Year of growing:………………..

Revenue								
Plot	Surface	Rice varieties	Duration	Productions (kg)	Sold (Kg)	Consumption (kg)	Price (USD)	Income (USD)

Cost of Inputs and labour								
Input type	Quantity	Price (USD/unit)	Labour		Hire	Total	Where did you buy?	Before(can be different system)
			Internal (M-day)	External (M-day)				
Seed Rate								
Chemical fertiliser								
Pesticide								
Herbicide								
Sack								
Soil preparation								
Broadcasting								
Weeding/Grass								
Rats controlling								
Harvesting								
Returning rice sheaf								
Transportation								
Threshing								
Post-harvesting								
Rental land								
Other…………								

……									

4.2 Early season rice: Month……………… surface………...ha Year of growing:………………

Revenue								
N^0 Plot	Surface	Rice varieties	Duration	Productions (kg)	Sold (Kg)	Consumption (kg)	Price (USD)	Income (USD)

Cost of Inputs and labour						
Input type	Quantity	Price (USD/ unit)	Labor		Hire	Total
			Internal (M-day)	External (M-day)		
Seed						
Chemical fertiliser						
Pesticide						
Herbicide						
Sack						
Soil preparation						
Broadcast						
Weeding						
Fertilizing						
Rats controlling						
Harvesting						
Transportation						
Threshing						
Post-harvesting						
Other………… ……						

4.3 Receding rice: Month……………… surface………...ha Year of growing:……………..

Revenue								
N^0 Plot	Surface	Rice varieties	Duration	Productions (kg)	Sold (Kg)	Consumption (kg)	Price (USD)	Income (USD)

Cost of Inputs and labour						
Input type	Quantity	Price (USD/ unit)	Labor		Hire	Total
			Internal (M-day)	External (M-day)		
Seed Rate						
Chemical fertiliser						

Pesticide						
Herbicide						
Sack						
Soil preparation						
Broadcast						
Weeding						
Fertilizing						
Rats controlling						
Harvesting						
Transportation						
Threshing						
Post-harvesting						
Rental land						
Other………………						

4.4 Dry Season rice Month……………… surface………...ha Year of growing:…………….

Revenue								
N^0 Plot	Surface	Rice varieties	Duration	Productions (kg)	Sold (Kg)	Consumption (kg)	Price (USD)	Income (USD)

Cost of Inputs and labour						
Input type	Quantity	Price (USD/ unit)	Labour		Hire	Total
			Internal (M-day)	External (M-day)		
Seed						
Chemical fertiliser						
Pesticide						
Herbicide						
Sack						
Soil preparation						
Broadcast						
Weeding						
Fertilizing						
Rats controlling						
Harvesting						
Transportation						
Threshing						
Post-harvesting						
Other………… ……						

4.5 Long-term rice Month……………… surface………...ha Year of growing:…………….

Revenue								
N^0 Plot	Surface	Rice varieties	Duration	Productions (kg)	Sold (Kg)	Consumption (kg)	Price (USD)	Income (Riel)

Cost of Inputs and labour						
Input type	Quantity	Price (USD/ unit)	Labour		Hire	Total
			Internal (M-day)	External (M-day)		
Seed						
Chemical fertiliser						
Pesticide						
Herbicide						
Sack						
Soil preparation						
Broadcast						
Weeding						
Fertilizing						
Rats controlling						
Harvesting						
Transportation						
Threshing						
Post-harvesting						
Other………………						

V. Sensitivity analyses

How much of paddy rice do you get per ha during the best, normal and worse year ?												
Crops	Best year				Normal Year				Worse year			
	Labour	Yield	Cost	Revenue	Labour	Yield	Cost	Revenue	Labour	Yield	Cost	Revenue
Early season rice												
Dry season rice												
Floating rice												
Receding rice												
Long-term rice												

VI. Awareness and perception of ecosystem services by farmers

1. To what extent, are you aware the Ecosystem services from Tonle Sap Lake contributed in your agriculture (rice)? (1= Yes/ 2= No)

Categories of ES	**Scales of awareness (1= strongly agree, 2= Agree, 3= Somehow, 4= Disagree)**
1.1 Fresh water (flooding)	
1.2 Soil fertility	
1.3 Wild animals (snake, other animals)	
1.4 Fishes	
1.5 Flooded forest	

2. To what extent, do you think these Ecosystem services from Tonle Sap Lake are important to your agriculture (rice)? (1= yes, 2= no).............

Categories of ES	**Scales of perceptions (1= Very important, 2= Important, 3= less important, 4= Not important)**
2.1 Fresh water (flooding)	
2.2 Soil fertility	
2.3 Wild animals (snake, other animals)	
2.4 Fish	
2.5 Flooded forest	

3. To what extent, do you agree these ES in Tonle Sap are being changed comparing to previous time (before 2008)?

Categories of ES	Scales of perceptions (1= Strongly change, 2= Somehow, 3= The same, 4= Don't know)	(A) Why?
4.1 Fresh water (flooding)		
4.2 Soil fertility		
4.3 Wild animals (snake, other animals)		
4.4 Fish		
4.5 Flooded forest		
4.6 Climate		

Appendix 2: Group discussion

Appendix 3: Farmers interview

Appendix 4: In depth interview and field observation

Appendix 5: Traditional rice field

Appendix 6: Chemical fertilisers applied by farmer in short-term rice