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Sustainable Water Management under Variable Rainfall Conditions in River Communities of Champhone District, Savannakhet Province, Lao PDR

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Abstract

A large majority of the rural population of Lao PDR remains dependent on agriculture for their livelihood and food security, for which access to and management of irrigated and rain-fed water sources is critical. Crop choices and planting calendars follow a monsoonal (dry season/wet season) weather system and are vulnerable to variations in the supply of rainfall, particularly deficits in the dry season and oversupply in the wet season. Climate change projections show that flood vulnerable areas like Champhone district, Savannakhet province might face worse problems in future, affecting food security and agricultural development.

This study examines how households are being affected by flooding and drought in Xe Champhone district. Flood vulnerability was assessed by calculating the rainfall variation to determine the water balance during rainy season and dry season. This was combined with analysis of social data from household surveys, together with institutional capacity at different levels and coping strategies currently used by farmers. Constraints and opportunities are identified to strengthen adaptive capacity and resilience to climate change in the Xe Champhone River basin of Savannakhet province. Hydrology data show that the water balance was unstable during both the rainy and dry seasons. The minimum runoff is very low in dry season (Q = 2.4 m^3/sec), while the maximum runoff is high in rainy season (Q = 274 m^3/sec). Harvesting rainwater in the wet season for use in dry season could reduce the vulnerability of farmers. This study aims to support small-scale community water management initiatives in Lao PDR.

Keywords: rainfall variability, vulnerability, community water management, climate change adaptation, river, rice production, Lao PDR

1. Background

Globally, the rainfall patterns that farmers depend on are being increasingly disrupted by climate change, requiring new coping strategies. Rice production is facing challenges such as water shortages, flooding and other factors that limit the capacity of farmers to grow their crops (e.g.,Tao et al., 2007; Peng et al., 2004). As the main food crop of Asia, the vulnerability of rice production to climate change has therefore become of key concern xboth currently and also for the future food security of the region. The Lao People's Democratic Republic (Laos) is highly challenged by this situation because of the combination of low state capacity to respond (including technical knowledge and budget) and lack of systems to predict or control drought or flood.

A large majority of the rural population of Laos remains dependent on agriculture for livelihoods and food security, for which access to and management of both irrigated and rain-fed water sources is critical. Crop choices and planting calendars follow a monsoonal (dry season/wet season) weather system, and are very vulnerable to variations in the supply of rainfall, particularly deficits in the dry season and oversupply in the wet season. Economic development and population growth in Laos will require increases in agricultural output to support human consumption, and farm technologies and cultivar breeding supporting rice farming will face challenges beyond the farm level to ensure and increase rice production for future climate change conditions (Boulidam, 2012).The lack of solutions to both flood and drought limits agricultural development in the central and southern part of Laos, where Savannakhet province is located, which contains the largest area of paddy cultivation in the country, covering194,157 hectares or more than 20 percent of Laos' total paddy land (DOA, 2009).Several modeling studies have been carried out in Laos, including simulation of climate change impacts on lowland paddy rice production potential in Savannakhet Province (IPCC, 2007),and projections from the International Panel on Climate Change (IPCC, 2014)show that flood-vulnerable areas like Savannakhet Province might face increasing problems in the future. IPCC's Fifth Assessment Report (AR5) forecasts an enhanced hydrological cycle and an increase in area-averaged annual mean rainfall over Asia, while working Group II of AR5 also projected that higher rainfall intensity, particularly during the summer monsoon, could increase flood-prone areas in temperate and tropical Asia (Hijioka, et al., 2014).

The local population in Champhone district, Savannakhet province consists mainly of rural farming households, with rice as their most important food crop, which also provides income for some families. These communities rely on the local Xe Champhone River to irrigaterice paddies during rainy season, but as is the case in many locations of Laos, when the water level is too high,substantial damage to crops can result A recent flood assessment of 10, 20 and 50-year return periods in Champhone district found a large area to be highly vulnerable to flooding at depths of greater than 6m (Hazaraki et al. 2008).After floods, people often lack sufficient stocks of food to maintain household consumption, forcing them to change from consuming own production and selling surplus to buying from other areas to continue accessing food.Local livelihoodsand food security are therefore highly vulnerable to flood impacts, while in the dry season, the same communities often lackenough water fora second crop of rice or other dry season crops.Lack of access to irrigation heightens water stress faced by farmers during the dry season and otherwise limits the ability of farmers to manage their water supply. A recentclimate change adaptation project in Champhone districtemphasized the need to develop irrigation, though was only able to expand1000m of irrigation canal due to limited budget (MRC, 2014). This highlights the importance of local water storage methods and tools to retain water from periods of heavy rainfall to use in drierperiods, in order to manage variability and support local communitiesin terms of food security and income. The high costs of infrastructure such as irrigation canalsmean that these methods and tools have to be based on local capacity and pay particular attention to their feasibility within economic constraints.Instead of waiting for budget to manage water supply by irrigation methods, other countries facing similar problems (e.g. Nepal, Kattel,2007) have tried community-based water management methods to seek ways to store water,though these approaches can also be expensive – one aim of this study is to findfeasible solutions for water management that will be appropriate to local conditions.

This research was designed to understand in the study locations (see next section) the impacts of rainfall variability, and draw on the experiences of community members to identify ways to protect their water supply against climate variability through storage methods, as well as how to adapt crop types. The study focuses on the possibility of community and household-based water management in the context of the resources and capacity available in Champhone District, Savannakhet Province, with the following objectives:

- To assess impacts of climate change, especially rainfall variability, on crop production patterns along the Xe Champhone River.
- To identify community capacity to protect their water supply against rainfall variability through storage methods, and also to understand how to adapt crop types.
- To recommend adaptation options to safeguard local food security and livelihoods.

2. Materials and Methods

2.1 Description of the Study Area

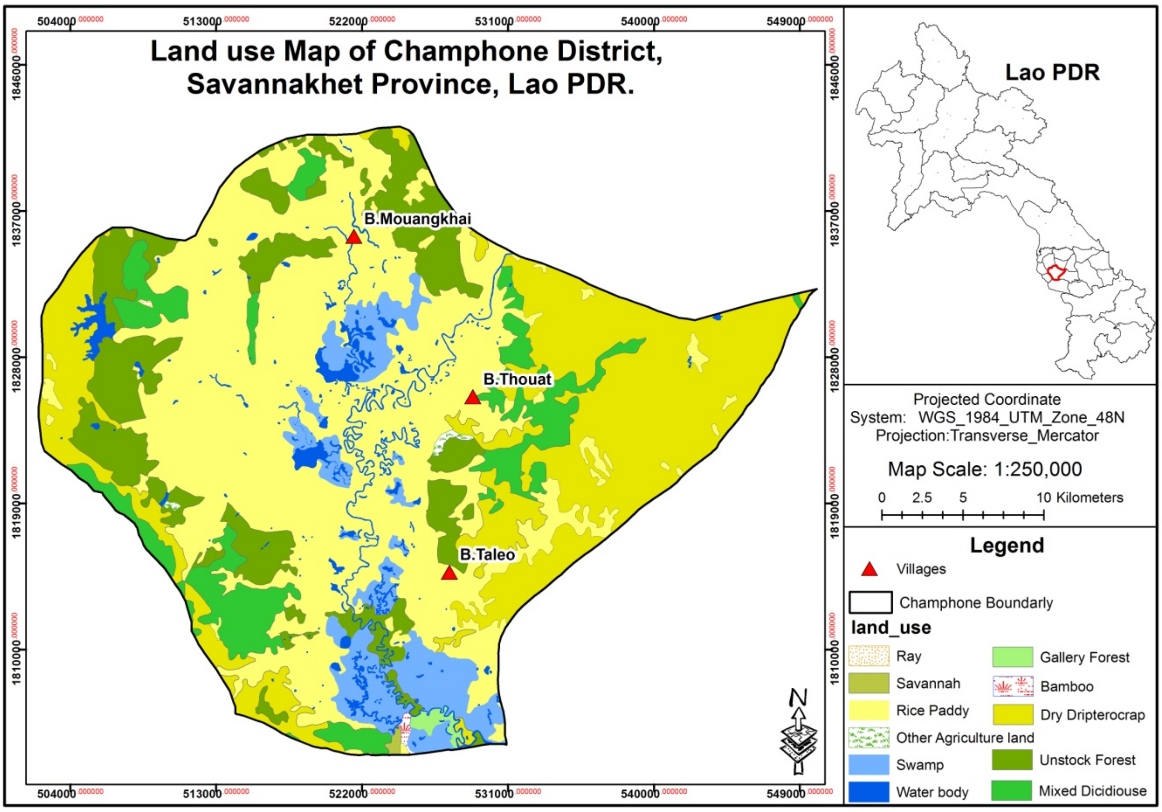

Figure 1. Map of study areas in Champhone District of Savannakhet Province, Lao PDR

The study focused on the three villages of Mouangkhai, Thouat and Taleo in Champhone District of Savannakhet Province, Laos (Figure 1). The three villages are located on the low-lying floodplain in upstream, middle and downstream areas of the Xe Champhone river, and are characterized by high flood vulnerability (Hazarika et al., 2008). The elevation of the area is 94 to 227m above sea level, and features a wide area of paddy land, swamps and limited areas of forest. The total area of Champhone District is 102,984 ha, with agriculture covering 93.61% of the area.

2.2 Respondents of the Study

Survey interviews were conducted based on the priority areas affected by flooding for sampling from the 3 villages. Respondents were considered because of their agriculture land near the Xe Champhone being vulnerable to damage from the flooding. To characterize social and economic drivers of flood vulnerability in the study locations, household interviews were conducted during the dry season based on the availability of farmers, using a structured questionnaire with respondents located near and along the riverbanks in the 3 villages of Mouangkhai, Thouat and Taleo. Focus Group Discussions (FGDs) were also conducted at the local level, with follow-up group FGDs after the rainy season to understand issues faced by the farmers through the planting cycle.

2.3 Secondary Data

Documents were also sourced from the concerned institutions of the Lao government. Historical weather data for 1995-2015 were obtained from the Provincial Meteorology Station Office (PMS) of Savannakhet. River information of the district came from the Department of Natural Resources and Environment in the provincial capital of Savannakhet. Water discharge was analyzed using the Bradshaw Model (Bradshaw et al., 1978).

3. Results and Discussion

3.1 Hydrological Analysis

3.1.1 Monthly Rainfall

Table 1. Flood records of the Xe Champhone River from 1988-2015 (Zero of Gauge from Mean Sea Level:130.378m (MSL))

No.	Year	Maximum Gauge Height	Date observed	Maximum Gauge height reading from MSL	Remark
1	1988	8.12	5-Aug	138.498	Flood + Drought
2	1989	6.75	25-JuL	137.128	
3	1990	7.85	1-Sep	138.228	Flood
4	1991	8.57	20-Aug	138.948	Flood
5	1992	7.26	6-Sep	137.638	
6	1993	6.54	10-Aug	136.918	
7	1994	7.56	31-Aug	137.938	
8	1995	7.81	1-Sep	138.188	Flood
9	1996	**10.15**	18-28-Sep	140.528	Severe flood
10	1997	8.27	18-Aug	138.648	Flood
11	1998	7.47	17-Sep	137.848	
12	1999	7.80	27- July	138.158	
13	2000	8.37	12-16 Sep	138.448	Flood
14	2001	8.13	12- 13 Aug	138.508	Flood
15	2002	7.70	1-Aug	138.078	
16	2003	7.83	14-Sep	138.208	
17	2004	8.04	11- 12 Sep	138.418	Flood
18	2005	8.52	11-15 Sep	138.898	Flood (2 occasions)
19	2006	7.72	17-Aug	138.098	
20	2007	8.20	6-11 Oct	138.578	Flood
21	2008	7.72	22-Sep	138.098	
22	2009	7.86	12-14-Aug	138.238	
23	2010	7.93	29- 31-Aug	138.308	Flood
24	2011	8.76	08- 14 Aug	139.138	
25	2012	8.04	04-07 July	138.418	Flood
26	2013	8.00	23 Sept	138.378	
27	2014	8.24	6 August	138.618	
28	2015	8.07	4 Sept	138.448	Flood

Remark: The historical maximum flood level in the Xe Champhone was recorded at11.26m or 141.638MSL, and occurred on 17/8/1978, lasting 28 days.

Flood records of the Xe Champhone river in table 1 show the frequency of flooding during the rainy season, often peaking in the statistics during August-September, while in the dry season from December to May the area can become very dry. Table 1 also shows how often near-flood conditions are reached in the Xe Champhone, highlighting the vulnerability of local farmers. According to a key informant interview with the head of the

Provincial Department of Environment, the overall observed trend is towards higher frequency of extreme events and increased rainfall intensity, while the total rainfall and number of wet days has decreased.

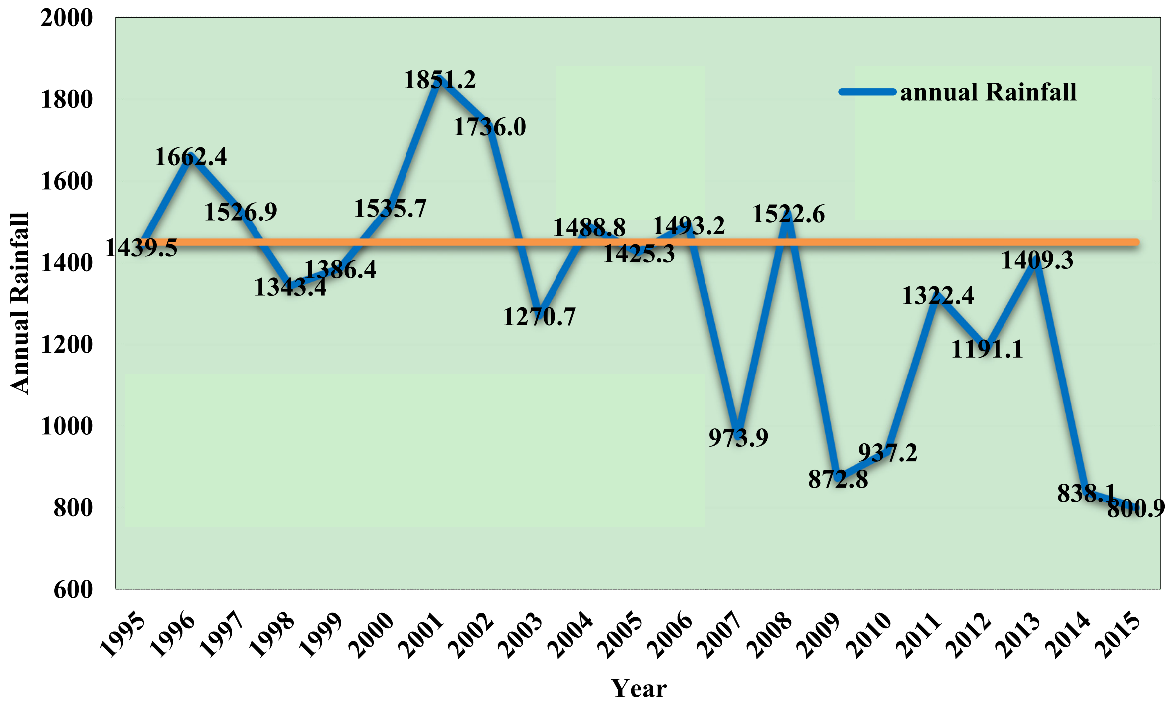

Figure 2. Variation of rainfall in Savannakhet Province from 1995-2015

Figure 2 shows a downward trend in the frequency of maximum 24-hour rainfall above 150 mm/day after 2003, but higher overall variation compared with beforehand. IPCC research projects an increase in extreme rainfall events (IPCC, 2014), which could generate further flooding at the study sites.

Table 2. Water discharge in the dry season and rainy season at Xe Champhone station

	Dry season minimum Q in (m³/sec) Xe Champhone at M. Kengkok						**Rainy season maximum Q in (m³/sec)** Xe Champhone at M. Kengkok					
Year	Jan	Feb	Mar	Apr	Nov	Dec	May	Jun	July	Aug	Sep	Oct
1995	3.859	2.897	1.99	1.252	5.629	21.052	27.654	209.413	425.283	452.148	468.409	28.271
1996	3.415	1.334	1.829	1.318	6.342	4.092	62.134	63.057	266.894	438.613	803.607	318.725
1997	2.897	2.073	1.252	0.685	4.331	1.829	35.851	193.688	391.128	524.242	377.413	29.525
1998	5.492	4.21	3.523	3.099	0.637	0.176	3.099	28.271	18.966	66.815	422.882	20.257
1999	8.395	1.527	0.837	0.505	9.084	11.711	80.303	196.948	477.284	459.617	436.174	52.013
2000	13.149	5.089	3.745	2.702	6.196	2.997	160.367	385.384	501.793	357.3	536.326	102.562
2001	6.052	5.629	6.342	7.732	4.702	3.523	19.735	444.74	443.511	509.66	438.613	24.097
2002	3.859	3.859	3.745	6.943	7.412	5.222	124.921	439.835	459.617	453.388	422.882	39.427
2003	3.859	3.415	2.799	2.422	5.492	4.261	41.279	143.834	51.593	396.915	469.672	35.851
2004	3.099	3.633	2.997	2.073	3.633	2.607	22.688	20.785	416.908	465.889	495.284	54.567
2005	0	0	0	0	0	0	0	340.959	492.045	511.637	560.907	271.678
2006	0	0	0	0	0	0	0	0	428.898	453.388	201.888	453.388

2007	0	0	0	0	0	0	0	83.468	318.725	407.438	316.646	514.939
2008	0	0	0	0	0	0	0	344.197	156.697	436.174	455.875	0
2009	0	0	0	0	0	0	284.315	109.16	332.4	473.47	46.69	274.569
2010	0.018	0.022	0.027	0	3.415	2.158	131.523	38.336	241.795	482.393	472.836	472.836
2011	3.308	1.334	4.21	2.158	4.27	1.908	75.669	74.407	419.89	593.827	482.393	281.374
2012	1.318	1.285	1.125	0.376	0.685	0.13	26.143	488.173	496.582	135.226	417.504	12.939
2013	0.141	0.152	0.228	0.287	0.465	0.526	16.989	94.179	392.86	374.023	491.399	344.738
2014	0.734	0.371	0.176	0.13	0.548	0.685	0.837	199.822	486.242	522.242	342.036	94.179
2015	0.637	0.592	0.214	0.02	10.544	4.639	0.919	203.964	397.496	367.846	499.836	277.961
Mean	**2.868**	**1.782**	**1.669**	**1.51**	**3.495**	**3.215**	**53.1**	**195.4**	**362.7**	**423**	**436.2**	**176.4**
	2.4						***274***					

The higher overall variation rainfall (figure 2), in combination with the high maximum daily water height of the river, suggests occurrence of flooding. Similar observations also occurred in August in 1995, 2005, 2006 and 2012. This indicates that flooding is likely to occur in August as well as in July, which would initially bring irrigation water for rice farms along the river on the floodplain. This is supported by the difference of discharge amount during the dry season and rainy season (Table 2), showing the water balance in Champhone station: while the minimum runoff is very low in dry season ($Q = 2.4$ m³/sec), the maximum runoff is high in rainy season ($Q = 274$ m³/sec).

3.1.2 Maximum and Highest Minimum Daily Water Level of Xe Champhone River

In 2011, severe flooding occurred in August and September when the differences between maximum and highest daily minimum water depths of the Xe Champhone were low. Similar phenomena occurred in 2005 and 1997 (Table 3). This suggests that the river overflowed its banks and inundated the floodplain. Similar events happened in the month of August in 2004 and 2001, indicating that flooding occurred. The severe lower values, particularly when this does not measure a minimum water level indicates that drought occurred during the dry season.

Table 3. Maximum and highest minimum daily water level of Xe Champhone River

Year	Maximum of Water level		Minimum of water level	
	Gauge	MSL	Gauge	MSL
1995	7.82	138.198	0.74	131.118
1996	10.12	140.498	0.79	131.168
1997	8.25	138.628	0.68	131.058
1998	7.45	137.828	0.04	130.418
1999	7.89	138.268	0.53	130.908
2000	8.34	138.718	0.90	131.278
2001	8.14	138.518	1.04	131.418
2002	7.75	138.128	1.06	131.438
2003	7.83	138.208	0.93	131.308
2004	8.03	138.408	0.85	131.228
2005	8.52	138.898	0.00	130.378
2006	7.70	138.078	0.00	130.378
2007	8.18	138.558	0.00	130.378
2008	7.72	138.098	0.00	130.378
2009	7.86	138.238	0.00	130.378

2010	7.93	138.308	0.30	130.678
2011	8.76	139.133	0.87	131.248
2012	8.04	138.418	0.52	130.898
2013	8.00	138.378	0.53	130.903
2014	8.24	138.613	0.51	130.883
2015	8.07	138.443	2.43	132.808
Average	8.13	138.50	0.61	130.98
Max	**10.12**	140.50	2.43	132.81
Min	7.45	137.83	**0.00**	130.38

3.2 Projected Rice Security

Table 4. Projected rice security with and without severe flood at the district scale

Year	(1) Population	(2) Rice Consumption (Ton)	WITHOUT FLOODING				WITH FLOODING	
			(3) Rice Production (Ton)	(4) Available Rice for cash (Ton)	(5) Income from Rice (USD)	(6) Income per Month (USD)	(7) Rice Production	(8) Rice Deficit (Ton)
2016	111970	36390.3	77,103.0	40,712.8	10,178.2	848.182	52,430.0	16,039.8
2017	114209	37118.1	77,103.0	39,984.9	9,996.2	833.020	52,430.0	15,312.0
2018	116494	37860.4	77,103.0	39,242.6	9,810.6	817.554	52,430.0	14,569.6
2019	118823	38617.6	77,103.0	38,485.4	9,621.3	801.779	52,430.0	13,812.4
2020	121200	39390.0	77,103.0	37,713.0	9,428.3	785.688	52,430.0	13,040.1
2025	133815	43489.7	77,103.0	33,613.3	8,403.3	700.277	52,430.0	8,940.3
2030	147742	48016.2	77,103.0	29,086.8	7,271.7	605.976	52,430.0	4,413.9
2034	159921	51974.2	77,103.0	25,128.8	6,282.2	523.516	52,430.0	455.8
2035	163119	53013.7	77,103.0	24,089.3	6,022.3	501.860	52,430.0	(583.7)
2040	180097	58531.4	77,103.0	18,571.6	4,642.9	386.908	52,430.0	(6,101.4)
2045	198841	64623.4	77,103.0	12,479.6	3,119.9	259.991	52,430.0	(12,193.4)
2050	219537	71349.5	77,103.0	5,753.5	1,438.4	119.865	52,430.0	(18,919.5)
2053	232974	75716.7	77,103.0	1,386.3	346.6	28.882	52,430.0	(23,286.6)
2054	237634	77231.0	77,103.0	(128.0)	(32.0)	(2.666)	52,430.0	(24,800.9)
2055	242386	78775.6	77,103.0	(1,672.6)	(418.2)	(34.846)	52,430.0	(26,345.6)
2060	267614	86974.6	77,103.0	(9,871.6)	(2,467.9)	(205.659)	52,430.0	(34,544.6)
2070	326220	106021.6	77,103.0	(28,918.6)	(7,229.6)	(602.471)	52,430.0	(53,591.6)
2080	397661	129239.7	77,103.0	(52,136.7)	(13,034.2)	(1,086.182)	52,430.0	(76,809.7)
2085	439050	142691.1	77,103.0	(65,588.1)	(16,397.0)	(1,366.419)	52,430.0	(90,261.1)
2086	447831	145544.9	77,103.0	(68,441.9)	(17,110.5)	(1,425.873)	52,430.0	(93,114.9)
2087	456787	148455.8	77,103.0	(71,352.8)	(17,838.2)	(1,486.517)	52,430.0	(96,025.8)
2090	484746	157542.5	77,103.0	(80,439.5)	(20,109.9)	(1,675.823)	52,430.0	(105,112.5)
2100	590903	192043.4	77,103.0	(114,940.4)	(28,735.1)	(2,394.592)	52,430.0	(139,613.4)

[1] Population growth rate= 2.1%

[2] Rice consumption= 0.36*Population

[3] Rice production without severe flood= 3 ton/ha* Rice area

[4] Excess rice for cash= Rice production – Rice consumption

[5] Income from rice = Excess rice (ton)* 200 USD/ton

[6] Income per month/household= Income from rice/ Number of Household

[7] Rice production during severe flood= production without flood – 32% (Production without severe flood)

[8] Rice deficit for rice consumption

Rice production in the study location is unstable because of the clear risk of both flooding and drought, as depicted in the historical data above, and which is likely to increase with climate change (MRC, 2010). Without climate change disturbances, especially the increasing heavy rainfall events that cause flooding, households could produce enough rice for their own consumption with surplus for sale. In the flooded conditions to which the study sites are very vulnerable however, the households cannot produce sufficient harvests. Moreover, the communities lack adaptive capacity to severe flooding along social and economic dimensions, and as a consequence need to secure rice from other areas during such events. The projected climate conditions would also increase the vulnerability of these communities with the increasing population and hence demand for rice.

Utilizing the household dataset even with the basic replacement level population growth rate of 2.1% (likely below the real figure), projected periods with a secure rice supply in non–flooded conditions varies among villages. Households could maintain rice security for longer periods of time, but this depends mainly on whether rice remains the main source of cash income. If the communities experience severe flooding with 32% damage to the wet season rice crop from the average damage in household interview estimations, households have to find cash income from non-rice sources or otherwise sell rice for household consumption, which they must then purchase later.

3.3 Livelihood Analysis

3.3.1 Crop Calendar

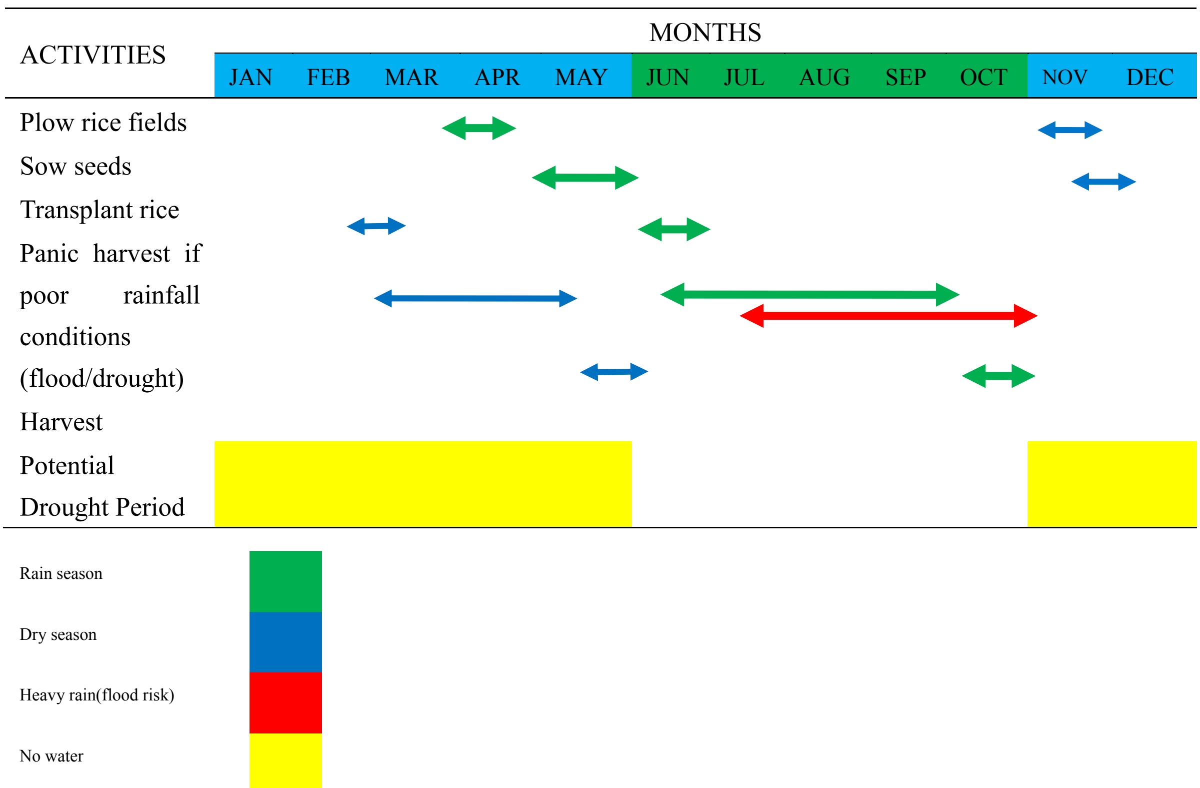

Figure 3. Crop calendar of the study sites

Figure 3 shows the sequencing of rice growing activities during the crop calendar.

After preparing the land, farmers start to plow rice in the beginning of the rainy season whenever there is enough water, without knowing potential weather conditions for the year, in terms of if flooding is likely or not. This means that panic harvesting is common during flood conditions; while in the dry season farmers have no water for growing a second rice crop (which could mitigate losses in flood years).

3.3.2 Sensitivity of the Rice Production System

Figure 3 highlights the sensitivity of the rice production system to flooding events at various stages of the wet season cropping period. Rain starts at the end of May and is heaviest from June to August, with the most severe flooding from August to October (Figure 3).During November to May, most farmers cannot grow a dry season rice crop due to lack of water supply. The sensitivity of rainfed rice systems to climatic risks is hence high at most stages of the cropping season. A majority of the respondents in the household survey did not want to change their rice cropping period unless an irrigation project is developed to reduce flood damage to their crops. With short maturing varieties and an irrigation project, the communities could reduce, if not avoid, flooding damages.

3.3.3 Adaptation in Rice Production Systems

Household interviews identified the present level of adaptation in rice production systems based on responses about rice replanting, pumping irrigation water from the river, use of short maturing rice varieties and development of irrigation systems. Just under4% of respondents from the three villages could replant after flooding (Table 5), while over 93% could not replant. Few respondents observed that their crops can recover after flooding, depending on the degree of damage, while many said their rice fields were destroyed by flooding. One respondent had decided not to plant rice during the rainy season due to flood damage during the previous several years. Meanwhile, 99.5% of respondents said they were unable to change the rice planting date to respond to changing weather conditions. This was because they are unable to predict rainfall frequency over the year, and cannot plant early if there is insufficient water. Therefore, farmers begin plowing rice whenever there is enough available water. This highlights the very narrow boundaries of adaptation that farmers work within in terms of the planting cycle, and the need for state support in terms of information and alternative techniques.

Table 5. Respondents adapted on flooding in the study site

Criteria	Farmer Response	
	Frequency	Percent
Respondents able to replant rice after flooding in the study site		
Yes	6	4
No	144	96
Total	150	100
Respondents change the planting date		
Yes	1	0.9
No	149	99.5
Total	150	100

According to the respondents, the commonly used Thasano and Thadokham rice varieties are not short maturing, taking 135-145 days with a height of 95-115 cm. The respondents also stated that short maturing varieties that can be direct seeded to reduce exposure to flooding have not yet been introduced in the area. Based on interviews, a project aimed to expand the irrigation system in Thouat, but has not yet been implemented and the people continue to wait. Overall awareness of plans for irrigation to secure rice production remains low, while wet season production is insufficient according to the respondents.

3.3.4 Correlation between Rice Production and Social Sensitivity Factors

Table 6. Correlation between rice production and socio-economic factors

Various	Number of Household	Age	Gender	Education	Occupation	HH income	Rice size	Rice Variety	Have fish pond	Source of emergency money	Rice Production
Number of Household	1	.092ns	-.058ns	-.045ns	.183*	.168*	.085ns	-.020ns	-.105ns	.306**	.181*
Age		1	-.018ns	-.214**	.209**	.110ns	-.022ns	.029ns	-.012ns	-.060ns	.067ns
Gender			1	.238**	-.019ns	.138ns	.141ns	-.133ns	-.153ns	.146ns	.232**
Education				1	.242**	.438**	.128ns	-.215ns	-.176*	-.047ns	.134ns
Occupation					1	.372**	.029ns	-.130ns	-.082ns	.131ns	.201*
HH income						1	.152ns	-.099ns	-.143ns	.003ns	.274**
Rice size							1	-.232ns	-.208*	.164ns	.499**
Rice Variety								1	.089ns	-.150ns	-.193ns
Have fish pond									1	-.313**	-.432**
Source of emergency money										1	.330**
Rice Production											1

ns. Not significant*. Significant at the 0.05 level **. Significant at the 0.01 level

Rice production has significant correlation with household income and farm size (P<0.01) (Table 6),as well as the number of household members, their education and age. This in agreement with other studies such as Bornales (2004) in Mt. Malindang, Philippines, in that those with higher income can afford to purchase farm inputs to enhance rice production, coupled with using greater experience in maximizing yields. Adaptation that is specific to social factors such as gender, age, health, social status, ethnicity, and class could reduce vulnerability to impacts of climate change (Smit et al., (2001); Adger et al., (2009)).

3.3.5 Economic Sensitivity

Table 7. Rice farm profile in the three villages

Criteria	Farmer Response	
	Frequency	**Percent**
Occupation		
Rice farmer	130	84.4
Government official	14	9.1
Worker	3	1.9
Retired	4	2.6
Other	3	1.9
Total	154	100.0
Income		
.00	7	4.7
7-186.9	113	75.8

187-373.9	16	10.7
374-559.9	13	8.7
Total	149	100.0
Status of Land Tenure		
Owned	149	97.4
Rented	2	1.3
Tenant	2	1.3
Total	153	100.0
Livestock		
Yes	146	94.8
No	8	5.2
Total	154	100.0
Pond		
Yes	53	34.4
No	101	65.6
Total	154	100.0

The respondents in the three villages are generally small-holder farmers who additionally raised livestock in their backyards (Table 7). Incomes are predominantly very low, although a few households have greater earnings by trading, owning shops or raising relatively larger herds of livestock.

3.3.6 Economic Adaptation

Sources of money for labor and in times of need, and participation in fishing livelihoods to diversify income and food sources were utilized to identify the households' ability to adapt economically. The respondents generally have weak economic adaptation strategies, borrowing money for hired farm labor at 10% interest to be paid at the end of the harvest. The households also undertook distress sales of poultry and livestock in times of need. Younger members of the family worked as hired labor outside their village, and even as far as neighboring Thailand to support family income. Labor borrowing against an unpredictable rice harvest highlights the high economic sensitivity of communities which depend mainly on rice production for household food supply and cash needs. Meanwhile distress sales place the farmer in a poor bargaining position to gain good prices for their livestock, especially when many others are trying to sell animals at the same time, for example following crop failures after a flood event. Fishing in the river or trapping fish in water impoundments is a livelihood buffer for many residents.

3.4 Water Accessibility and Management in Agriculture

3.4.1 Water Accessibility for Rice Growing

Table 8. Season of growing rice in study sites

Season Planting	**Farmer Response**	
	Frequency	**Percentage**
Rainy	92	59.7
Dry	3	1.9
Both	58	37.7
Non	1	0.6
Total	154	100

While rice production in the study communities is almost entirely rainfed, according the head village interviewed, several respondents in Thouat village could plant two rice crops by accessing irrigation. However, only 46% of the paddy area in the village (and just 0.7% of Taleo village)could be irrigated by pumping water from the river or ponds during the dry season, and the cost was higher than the benefit overall. Most farmers preferred not to plant during dry season and instead went to the provincial capital of Savannakhet or neighboring Thailand to find jobs.

3.4.2 Water Management in Agriculture

Table 9. Water management conditions in study sites

Criteria	Farmer Response	
	Frequency	**Percent**
Presence of irrigation program development		
Yes	94	61
No	59	38.3
Total	153	99.4
Missing	1	0.6
Total	154	100
Why farmers do not find water storage methods		
Non-Education	5	3.2
Don't know how to find the source	22	14.3
No answer	73	47.4
No budget	18	11.7
No water	33	21.4
Other	2	1.3
Total	153	99.4
Awareness of water harvesting		
Yes	115	74.7
No	39	25.3
Total	154	100

According to interviews, irrigation expansion had been discussed in Thouat and Taleo villages since 2011, but no follow-up implementation had taken place until the time of the research, and farmers were not aware of any further information about the project. In Mouangkhai, no such work had been undertaken at the time of the research. According to the Irrigation Division of the Provincial Agriculture and Forestry Office, the project is under review and consideration for budget, and could commence in 2020. Table 9 also shows that 73% of respondents were unable to answer why they did not find water storage methods, indicating that no information or methods had been made accessible to the study sites before the period of the survey. However, after our explanation of water harvesting, 115 households or 74.5 %of respondents stated awareness of water harvesting, and farmers indicated interest to participate in a program for this purpose.

3.5 Adaptation Strategies on Water Management for a Climate Change Resilient Community

Table 10. Recommendations for adaptation strategies on water management and related factors

Scale	Flow Adaptation	Stock adaptation	Remark
Community	Planting high-value and low water-consuming crops after rice	Disaster risk reduction team	Planting of legumes, corn, sorghum and other crops after rice to use the residual moisture in the paddy after harvesting rice would add to the food supply during rainy months and provide alternative income to rice
	Small scale dikes		Green soybean and vegetables can be planted on the sides of dikes to augment protein supply of the households
	Crop calendar changes		Reduce flood damage
	Livestock		Additional income during drought
District	Training and promoting on water harvesting and on-farm management	Pond irrigation	Storage of rainwater to reduce flood and drought impacts
	Market Accessibility	Tolerant rice varieties and crops	Increasing income, resistant to flood/drought and using less water
		Disaster risk management unit	Support local information
		River bank engineering	Reduce impacts from water overflow
		Off-farm activities	Upgrading local skills and knowledge to provide the communities with better off-farm employment opportunities; fruits, vegetables, and medical plant production around households can help augment food supply while excess products can be sold in local markets; livestock should be kept in enclosures to prevent damage to crops; root crops can serve as survival crops during flooding
Province	Soil Analysis	Irrigation and watershed development	Upgrading irrigation together with watershed improvement of the source of irrigation water is necessary to benefit more areas in the dry season, which would reduce exposure of rice crops to flooding and provide water in dry season; riparian zones of the river have to be improved to prevent stream bank erosion
National	Public funding	Policy on water management in response to climate change	Climate change impacts on water resources will become more significant –national policy needs to promote different scales of water management to respond to water crises

This study considers integrated flow and stock adaptation strategies (Agrawala et al, 2010) as necessary to increase resilience to climate change impacts in the three study villages. These are also part of different levels of adaptation at community, district, province and national scale, but focus on how people can manage water locally based on adaptive capacity and climatic conditions (Table 10). Flow adaptation covers shorter term options that are relatively cheap to put in place, and provide immediate benefits. Stock adaption requires higher investment for long-run benefits that might not be immediately felt by the community, and are instead preparing for major impacts of future climate change that have not happened yet. Higher confidence is therefore needed in the ability of stock adaptation options to cope with future climate risks than flow adaptations which adjust to current, immediate risks.

4. Conclusion and Recommendations

Hydrological, social and economic analyses have shown rice production in the study locations to be highly vulnerable to flooding, in combination with the difference in values of water balance calculations in the Xe Champhone river, to describe water conditions and management for agriculture in the dry season and rainy season in upstream, middle stream and downstream locations. Severe flooding usually occurred in September and October resulting in insufficient rice supply. Non-flood tolerant rice varieties remain in use, resulting in low or non-existent rice yields during the worst flooding. Meanwhile, the farms are rainfed and depend on the overflowing river for irrigation, hence the high sensitivity of the rice production system to extreme events. This sensitivity is both driven by and contributes to the socioeconomic vulnerability of the communities, lack of water for rice production in dry season and non-adaptation in terms of how to store water from the rainy season for use in dry season. Strengthening the climate change resilience of the communities in sustainable water management requires significant planning considerations at different scales, including the community, district, province and nation by a range of flow and stock adaptation options that should be considered in an integrated way to form local adaptation strategies.

Recommendations

Based on the results of this study, the recommendations for future research and development are as follows:

1) Promoting water harvesting for crops and vegetables to diversify planting rice in non-irrigated areas to improve income.
2) Research cropping systems after the rice harvest by planting high-value crops in elevated areas and around households to improve food supply.
3) Development of:
   a) Disaster Risk Reduction Management and Climate Change Adaption (DRRM-CCA) committee in each village.
   b) Watershed management to improve the source of irrigation water and irrigation system.

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References

Adger, W. N., & Barnett, J. (2009). Four reasons for concern about adaptation to climate change. *Environment and Planning A, 41*(12), 2800-2805. http://journals.sagepub.com/doi/abs/10.1068/a42244

Aggarwal, P. K., & Mall, R. K. (2002). Climate Change and Rice Yields in Diverse Agro-Environments of India. I. *Evaluation of Impact Assessment Models.* Retrieved from https://link.springer.com/content/pdf/10.1023%2FA%3A1013702105870.pdf

Bornales, R. G. (2004). Adaptation and vulnerability of Subanen community to the adverse environmental conditions in Mt. Malindang National Park, Philippines. *Journal of Environmental Science & Management, 7*(1), 56.

Boulidam, S. (2012). *Simulation of Climate Change Impact on Lowland Paddy Rice Production Potential in Savannakhet Province, Laos.* Retrieved from https://zidapps.boku.ac.at/abstracts/download.php?dataset_id=10413&property_id=107

Bradshaw, M. J., Abbott, A. J., & Gelsthorpe, A. P. (1978). *The Earth's Changing Surface.* Wiley.

Department of Agriculture (DOA). (2015). Annual crop production statistics.

Hazarika, M. K., Bormudoi, A., Phosalath, S., Sengtianthr, V., & Samarakoon, L. (2008). Flood Hazard In Savannakhet Province, Lao PDR Mapping Using Hec-Ras, Remote Sensing And Gis. Conference paper presented at 6th Annual Mekong Flood Forum, 27-28 May, 2008, Phnom Penh.

Hijioka, Y., Lin, E., Pereira, J. J., Corlett, R. T., Cui, X., Insarov, G. E., … Surjan, A. (2014). Asia. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [V. R. Barros, C. B. Field, D. J. Dokken, M. D. Mastrandrea, K. J. Mach, T. E. Bilir, … L. L. White (Eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1327-1370. Retrieved from https://www.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5-Chap24_FINAL.pdf

IPCC. (2007). Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R. K., & Reisinger, A. (Eds.)]. IPCC, Geneva, Switzerland, 104 pp. Retrieved from https://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_full_report.pdf

IPCC. (2013). Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [T. F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, … P. M. Midgley (Eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp. Retrieved from https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/WG1AR5_Frontmatter_FINAL.pdf

IPCC. (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R. K. Pachauri, & L. A. Meyer (Eds.)]. IPCC, Geneva, Switzerland, 151 pp. Retrieved from http://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf

Kattel, R. R. (2015). *Rainwater Harvesting And Rural Livelihoods In Nepal.* SANDEE Working Paper No. 102–15. Retrieved from http://www.sandeeonline.org/uploads/documents/publication/1078_PUB_Working_Paper_102_Rishi.pdf

MRC Management Information Booklet Series No. 4, Impacts of Climate Change and National Institute of Disaster Management (NIDM) and Naational disaster Management Authority (NDMA). (2010). Handbook on Disaster Risk Management Mainstreaming in Development. Author. Islamabad. Retrieved March 15, 2013, from http://ndma.gov.pk/publiccations_One_UN_DRM/DRR%20Mainstreaming/13_stardard_handbook_DRM_Mainstreaming.pdf

MRC. (2010). Annual Mekong Flood Report 2009, Mekong River Commission, Office of the Secretariat in Phnom Penh, 80 pages. Retrieved from http://www.mrcmekong.org/assets/Publications/basin-reports/Annual-Mekong-Flood-Report-2009.pdf

Peng, S., Huang, J., Sheehy, J. E., Laza, R. C.,Visperas, R. M., Zhong, X., … Cassman, K. G. (2004). Rice yields decline with higher night temperature from global warming. *Proc. Natl. Acad. Sci. U.S.A. 101*(27), 9971–9975. Retrieved from http://www.pnas.org/content/pnas/101/27/9971.full.pdf

Smit, B., Pilifosova, O., Burton I., Challenger, B., Huq, S., Klein, R. J. T., & Yohe, G. (2001). Adaptation to climate change in the context of sustainable development and equity. In: Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change [J. J. McCarthy, O. F. Canziani, N. A. Leary, D. J. Dokken, & K. S. White (Eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 877-912. Retrieved from https://www.ipcc.ch/ipccreports/tar/wg2/pdf/wg2TARchap18.pdf

Tao, F., Hayashi, Y., Zang, Z., & Sakamoto, T. (2007). Global warming, rice production, and water use in China: Developing a probabilistic assessment. *Journal of Integrative Agriculture, 13*(7), 1555-1564.