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Using Reservoirs to Adapt to Drought in Agriculture: A Cost-Benefit Analysis from Cambodia

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Front cover photo credit: The main gate of Kvit Reservoir in Kampong Speu Province, Cambodia by Chhinh Nyda

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March, 2015

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All opinions, analyses, and suggestions in this report are those of the authors and do not necessarily reflect the views of EEPSEA or any other organization referred to in this report. The authors are responsible for all mistakes and shortcomings.

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LIST OF ACRONYMS

AEC	Annual expected cost
CBA	Cost-benefit analysis
CDRI	Cambodia Development Resource Institute
CRED	Centre for Research on the Epidemiology of Disasters
ECA	Expected costs avoided
HH or hh	Household
IPCC	Inter-Governmental Panel on Climate Change
KPS	Kampong Speu (Province)
MAFF	Ministry of Agriculture, Forestry and Fisheries
MoE	Ministry of Environment
NCDD	The National Committee for Sub-national Democratic Development
PCDM	Provincial Committee for Disaster Management
PL	Peang Lvea (Commune)
RGC	Royal Government of Cambodia
SP	Sopor Tep (Commune)
UN/ISDR	United Nations secretariat of the International Strategy for Disaster Reduction
USD	United States Dollar
WB	World Bank
WFP	World Food Program

USING RESERVOIRS TO ADAPT TO DROUGHT IN AGRICULTURE: A COST-BENEFIT ANALYSIS FROM CAMBODIA

Chhinh Nyda, Cheb Hoeurn, Chea Bora, and Heng Naret

EXECUTIVE SUMMARY

There are two major natural hazards that Cambodia is exposed to, namely, floods and droughts. Millions of people are affected by these on a regular basis and millions of hectares of rice paddies have been destroyed. Rice cultivation is the main economic activity of the country. The government has thus prioritized agricultural development in its overall aim of poverty reduction. Targeting the most vulnerable communes, this study aimed at estimating the costs of drought at the household level in the rural communes of Kampong Speu Province and assessing the costs and benefits of restoring a water reservoir as an adaptation option to deal with drought. Questionnaires were used to collect data from households for two rice ecosystems (totally rain-fed and with supplementary irrigation) in Kampong Speu. The study found that the expected loss from drought in a rain-fed farm was USD 53.47 per hectare compared to USD 23.01 per hectare for an irrigated farm. This study analyzed the costs and benefits of the restoration of a completely damaged reservoir. At a 6% discount rate, the repair of the reservoir will yield a net present value of about USD 914,835 with a benefit-cost ratio of 2.18. If the reservoir is restored, it will not only increase rice production, but will also stabilize food security in the area. Agricultural diversification, especially fish raising, animal raising, and vegetable planting will become more viable for farmers.

1.0 INTRODUCTION

1.1 Droughts in Kampong Speu Province, Cambodia

Droughts and floods have been recognized as major natural hazards in Cambodia (MoE 2001; RGC 2010; WFP 2003; World Bank 2006) that affect not only millions of people but also destroy hundreds of thousands of hectares of rice paddies, which form the main source of rural livelihoods and represent the backbone of the Cambodian economy (CRED 2012). Due to the country's geography, the frequency of natural hazard occurrences differs from province to province. The top three provinces in terms of climate change vulnerability are Mondol Kiri, Rotanak Kiri and Kampong Speu (KPS) (Yusuf and Francisco 2010). Drought is found to be more serious in KPS in particular compared to other provinces based on the damage to rice fields (MAFF 2010).

According to Chann and Kong (2013), KPS Province is vulnerable because of its exposure to both floods (for those communes located close to the river) as well as droughts (for those areas located far from the river like mountainous areas). In terms of agricultural vulnerability, the frequent occurrence of natural hazards and the sensitivity of rural livelihoods play crucial roles in increasing the degree of spatial and temporal vulnerability. Climatic events have mostly affected farmers in KPS who suffer a high poverty rate mainly because of low agricultural productivity. In addition, low agricultural outputs contribute to poor health of both humans and livestock, loss of agricultural labor, increased domestic violence, more migration, increased numbers of school drop-outs, damaged infrastructure (especially roads and irrigation systems), and loss of natural resources (Heng and Sen 2013).

The findings of Chhinh and Cheb (2013), based on a household vulnerability assessment, show that KPS is more highly prone to drought in comparison to floods and windstorms. No valuation of the economic costs of drought impacts has been done in KPS other than the extent of paddy areas damaged by drought reported by the Department of Agriculture (DA) and Provincial Committee for Disaster Management (PCDM). In terms of physical damage, the PCDM's report shows that KPS has experienced more severe droughts than floods, especially in 2004 (PCDM 2011).

Securing water for rain-fed farmers in Cambodia is the key to reducing the vulnerability of farmers to drought. There are at least four definitions of drought related to meteorological, agricultural, hydrological, and socioeconomic droughts (UN/ISDR 2007; Wilhite and Glantz 1985; Nagarajan 2009). The common central factor among them is the deficit of water for domestic consumption and/or an established economy (McKee, Doesken, and Kleist 1993). In any event, temporal and spatial distribution of rainfall is the entry point for any kind of drought (Heim 2002; Wilhite and Glantz 1985). In the case of rain-fed rice production, the total amount and temporal distribution of rainfall are very critical to productivity[1] (Ros, Nang, and Chhim 2011).

Seeing drought as a serious threat to the Cambodian economy as a whole and to the achievement of poverty reduction, the Royal Government of Cambodia has prioritized agricultural development. For example, the National Strategic Development Plan Update 2009-2013 contains a commitment to further rehabilitate and construct physical infrastructure so that the agricultural sector, especially rice production, will be strengthened (RGC 2010).

1.2 Drought Impacts on Rice Production in Kampong Speu Province

Normally, the wet season rice production lasts from May to November in a rain-fed rice ecosystem. If there is good rainfall, the farmers will cultivate their (traditional) late-maturing variety[2]. If there is less rainfall from May to July, they will cultivate the medium and/or short-duration varieties (see Figure 1).

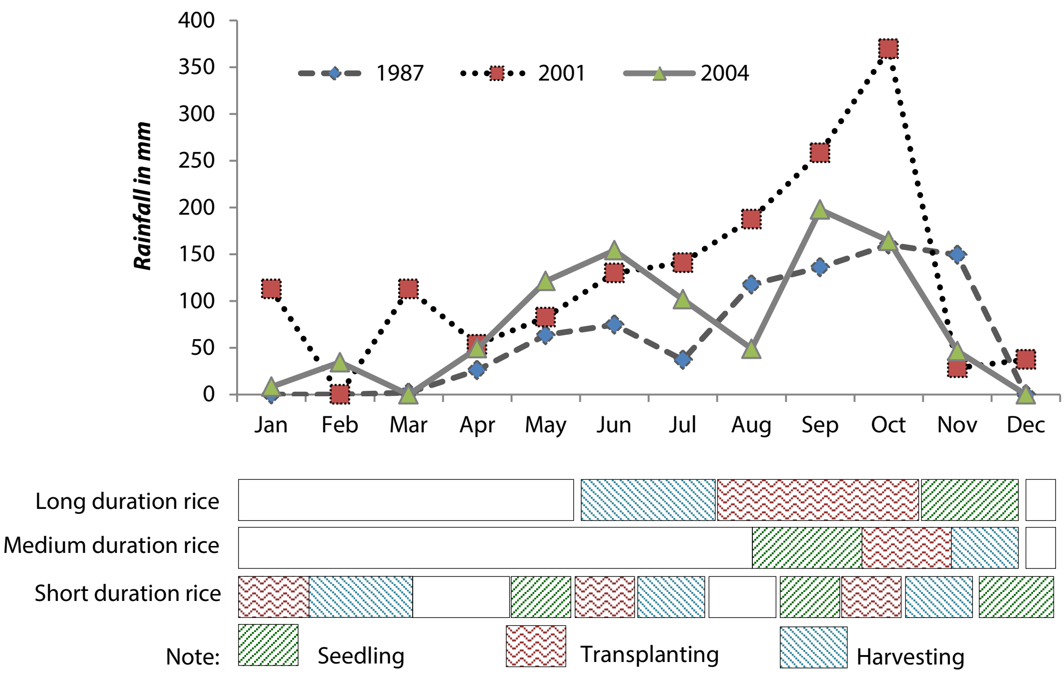

Figure 1. Monthly rainfall distribution and rice crop calendar in Kampong Speu

KPS is located in a rain shadow region[3]. The province's topography varies from 4 to 1,776 meters above sea level from east to west and it receives less rainfall than other provinces. Figure 1 shows the total monthly rainfall of the wettest year (2001), driest year (1987), and the most severe drought year (2004). The distribution and trend of rainfall among the three years are highly similar. For agriculture, June and September are the peak months while August and November are the drought-prone periods.

[1] Less rainfall in late June and early July is known as early-season drought (ESD). Less rainfall in August is known as mid-season drought (MSD), and if it happens in November and early December, this is known as late-season drought (LSD).

[2] The ten rice varieties promoted by the Royal Government of Cambodia since 2011 are: 1) Sen Pidao, 2) Chul'sa, 3) IR66 (short duration), 4) Phka Rumdoul (internationally known as Phka Mali or Cambodian Jasmine Rice), 5) Khka Romeat, 6) Phha Romdeng, 7) Phka Chan SenSar (medium duration), 8) Riang Chey, 9) CAR4, and 10) CAR6 (long duration).

[3] A rain shadow region is a rainless area where mountain ranges block the passage of rain-producing winds. The mountain ranges cast a 'shadow' of dryness behind them (see Whiteman 2000 for further explanation).

If the prediction by the MoE (2001) that rainfall patterns will become more extreme comes to pass, there will more rain in June-July and September-October while it will be drier in August and November-December.

The most susceptible to drought are the long-duration or late-maturing rice varieties. A dry spell of more than two weeks in August will damage young seedlings. In this case, the farmers have to restart their paddy sowing with medium or short-duration varieties. Low rainfall distribution during the growing season will result in low yields. The harvested area will be less than the cultivated area if there is early cessation of rain.

The medium and short-duration varieties are less vulnerable to drought. Farmers cultivate these varieties in late August and September when the soil is full of moisture. However, early cessation of rain will affect the productivity of these as well.

1.3 Study Objectives

This study is part of the second phase of projects under a grant from IDRC on "Building Capacity to Adapt to Climate Change in Southeast Asia". The first phase was to identify the vulnerability characteristics of rural Cambodia, especially in the KPS Province. According to the first phase studies (i.e., Chhinh and Cheb 2013; Heng and Sen 2013; and Chann and Kong 2013), KPS households often face drought. Interventions are necessary and urgently required, especially in relation to agriculture. Agricultural and water resource experts from KPS have been calling for the rehabilitation of irrigation facilities that have been damaged since the war.

This study aimed to investigate the impact of drought on the most vulnerable communes in KPS by 1) estimating the annual economic costs of drought on rice production in both rain-fed and supplementary-irrigated rice ecosystems, and 2) analyzing the costs and benefits of restoring the Kvit reservoir, an old reservoir damaged and out of use since the last war.

Section 2 describes the methods used in estimating the economic costs of drought on rice production and presents how the cost-benefit analysis was conducted while Section 3 reports the research findings. Conclusions are given in Section 4.

2.0 METHODOLOGY

Drought has been the most pervasive hazard in Kampong Speu (KPS) Province since the 1990s while storms and flashfloods affect only certain parts of the province. Based on the findings of Chhinh and Cheb (2013) and Chhinh and Poch (2012), and discussions with local and provincial government officials and NGOs in KPS in this study, a number of proposed adaptation options emerged. These were: 1) improving agricultural extension services, 2) construction or restoration of existing irrigation systems, 3) constructing wells, 4) changing crop calendars (from six to three-month varieties), and 5) offering crop insurance. This study focused on the second option.

2.1 Study Site Selection

In selecting the key study site, we considered how it was exposed to and affected by drought, and the sensitivity of the local sources of livelihood to drought impacts. We also considered the time and scale of this study. We would be able to do a feasibility study on the proposed adaptation option of restoring the Kvit Reservoir with a fund-raising proposal to be written after the study was completed. In terms of scale, the proposed adaptation would potentially benefit around several hundred hectares of rice fields. Taking all these factors into account, Peang Lvea (PL) Commune in Odongk District of KPS Province was selected as the most suitable for economic analysis (Figure 2).

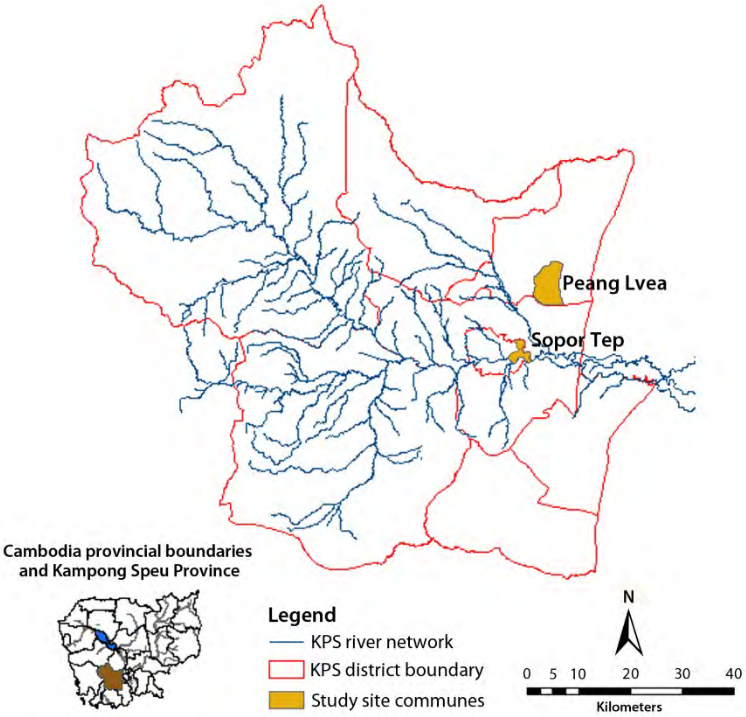

Figure 2. Map showing the two study site communes (Peang Lvea and Sopor Tep)

In 2003, the World Food Program (WFP 2003) conducted a mapping study on natural disasters in Cambodia. The WFP used meteorological data and Normalized Difference Vegetation Index (NDVI) to assess natural disasters, especially droughts. PL Commune was found to be one of the communes in Odongk District most affected by drought. Subsequently, the Provincial Committtee for Disaster Management (PCDM) of KPS produced a hot spot map of the province in 2010. The PCDM used time series data of areas affected by drought and consulted with local authorities; they identified 20 communes in six districts as drought-affected communes. PL was among the 20. A year later, Chann and Kong (2013) conducted a climate change vulnerability asessment and identified many vulnerable communes, including PL. They used the Intergovermental Panel on Climate Change (IPCC) framework in which vulnerability is defined as a funtion of hazard, sensitivity, and adaptive capacity. Therefore, the selection of PL Commune was sound across these studies.

PL Commune was also selected because of the sensitivity of the livelihood of its residents to drought. Located in the northern part of KPS, PL is administratively located in Odongk District, and there are 18 villages in it. Households in PL are primarily dependent on agriculture. With a total population of 7,859 households, 99.2% of the labor force works on agriculture (NCDD 2009). There are no plots of irrigated farmland in PL (NCDD 2009), and 49.95% or 748 families own farms less than one hectare in size. Wet season rice yields dramatically reduced from 1.5 tons per hectare in 2008 and 2009 to 1 ton per hectare in 2010 (NCDD 2009).

By consulting with local experts in the Department of Agriculture and Department of Water Resource and Meteorology, the Sopor Tep (ST) Commune in Chhbar Mon District was selected as the counterpart to PL Commune. The reason was that ST had irrigation water supply all year long.

2.2 Sample Selection

Sopor Tep (ST), which is located about 7 km from the provincial centre, can be considered as an urban or semi-urban commune. The total population of ST is 7,129 (NCDD 2010). During a non-drought year, 92.6% of ST households have access to the Roleang Chrey irrigation system for agricultural production, especially paddy fields. On the other hand, Peang Lvea (PL) is located about 18 km from the provincial center, with a total population of 8,224 (NCDD 2010). It has no irrigation system and the local farmers depend on the rain, small ponds, wells, and other temporary water sources for cultivation.

Based on Chann and Kong (2013), PL's vulnerability is high (vulnerability index of 0.53) while ST's is moderate (vulnerability index of 0.44)[4]. The major contributors to their vulnerability are exposure to frequent droughts and low adaptive capacity. With access to irrigation, the ST commune can produce rice twice per crop calendar year compared to only once for PL. The average rice yield in ST is 2.5 tons per hectare compared to 1.5 tons per hectare in PL. Both communes are agriculturally dominant in lowland areas, with 76.4% of the households in ST and 99.2% in PL working as farmers.

Purposive and random sampling methods were employed to select a survey sample of 400 households, with 200 households from each commune. All enumerators were trained by the research team before conducting the interviews using a prepared questionnaire.

2.3 Focus Group Discussions

Six focus group discussions (FGDs) were organized to obtain qualitative data on the socioeconomic impacts of droughts (see Appendix 1 for FGD questions). Three FGDs were conducted in each rice ecosystem. Among the three FGDs, one contained a mix of participants in terms of sex, age and social group (women/men, rich/poor, government official/local community member, religion); the second consisted of only women; and the third, only children.

2.4 Key Informant Interviews

Key informant interviews (KIIs) were also conducted to obtain an overview of irrigation and cultivation practices in the study sites (see Appendix 2 for KII questions). The respondents comprised elderly residents, members of religious groups, non-governmental organizations, and local and sub-national authorities, particularly those involved in drought-related issues, including representatives from the Department of Agriculture, the Department of Water Resources, and the Provincial Committee for Disaster Management.

2.5 Costs of Drought

Wilhite and Glantz (1985, p. 118) put forward three kinds of impacts of droughts, namely economic, social and environmental, with a list of losses, costs and damage. Logar and van den Bergh (2013) reported that there were three types of drought costs, i.e., direct, indirect and non-market (intangible) costs. For example, a direct cost of drought in agriculture would be the reduction in crop production.

The costs of drought examined in this study were at the household level. They were *interruption costs* from increases in labor and inputs, *remaining damage costs* from yield reduction or low productivity despite the additional labor and inputs on the same cultivated and harvested area, and *damage costs* where the harvested area is smaller than cultivated area.

***Interruption costs*.** Interruption costs cover seedling, transplanting and labor costs, incurred for all rice varieties. For long-duration rice (LDR), the costs occur if there is early-season drought (ESD) and/or mid-season drought (MSD). An ESD forces farmers to pump water from nearby sources to avoid seedling damage. Assuming that farmers are able to survive the ESD, less rainfall in August (also known as MSD or a dry period in the wet season) may force farmers to pump water from nearby sources or restart their cultivation using medium-duration rice (MDR) if there are no water sources nearby.

For MDR, interruption costs occur when the farmers have to pump water into the paddy fields during an MSD. Normally, September to early October is the second rainfall peak time when paddy fields will be full of water. If farmers do not cultivate their rice until this period, they will then grow short-duration rice (SDR). A late-season drought (LSD) can also impose interruption costs on SDR.

[4] Vulnerability indices range from 0 to 1. Taking an index of 0.5 as the threshold, a vulnerability index higher than 0.5 indicates vulnerability.

Remaining damage costs. Yield reduction caused by drought or water constraints throughout the cropping season has been reported in literature such as Helmers and Jegillos (2004) and MoE (2005). These costs are estimated based on yield comparisons between normal and drought years. Remaining damage costs can also be called the costs of low productivity.

Damage costs. The early cessation of rain will destroy crops and result in smaller harvested areas compared to cultivated areas. These results have been well documented by the local authorities and the Department of Agriculture in KPS Province. The costs of these have also been estimated based on yield comparisons between normal and drought years.

The costs of drought faced by rain-fed farmers can be estimated depending on the nature of the drought (i.e., drought in the middle of wet season rice growing, water constraints throughout the growing season, or early cessation of rain). A year in which such occurrences happen and farmers cannot transplant their rice seedlings at the normal time (usually June or July) is called a drought year.

2.6 Assessing the Use of Reservoirs to Adapt to Drought

To reduce the vulnerability of farmers to climate change impacts in the rural areas of KPS, Chhinh and Cheb (2013) identified a number of options with the local authorities. These included securing water for rice production through reservoirs, pumping machines, and digging tube wells. They concluded that providing irrigation systems for farmers in rural KPS was necessary and urgently required.

Irrigation, using reservoirs, may not help paddy productivity in the case of normal rainfall distribution where farmers are able to cultivate their crops according to the traditional calendar[5] and the rice plant grows normally until harvest time with crop yields as expected. Now, however, farmers are no longer able to rely on normal temporal rainfall distribution and must adapt to changes in the climate, especially those who depend on rain-fed rice production. In the case of late onset or lower amounts of rain during the starting period of the cropping season, farmers must either delay their planting or transplant the seedlings to their paddy fields without water, hoping that the rain will come soon and risking the destruction of the new plants if it does not. Many farmers in Cambodia have had this experience. In such cases, reservoirs can play a very significant role in providing supplemental water during the growing period to compensate for inadequate rain. Reservoirs will thus enable the avoidance of costs associated with drought; it will also enable farmers to plant the rice varieties of their preference.

Reservoirs will also generate benefits for the local rural communities during the dry season, especially for domestic water usage, home gardening, double cropping, aquaculture and animal husbandry. In addition, they can provide indirect benefits such as improving sanitation in rural areas.

Currently, if water is needed in rice fields where there are no irrigation systems, the water is pumped from small ponds and underground water sources nearby. Using these practices, the area that can be watered will be relatively small in scale and such methods will not be able to address severe and widespread drought.

In assessing the benefits of using reservoirs to mitigate drought, the costs of drought should be compared as follows: 1) between rain-fed and irrigation-supplemented rice systems, and 2) between a drought and non-drought year (see Callaway 2003 for such a climate risk assessment framework).

In a long run, the annual expected costs (AEC) (also known as expected costs avoided or ECA) from drought for a rain-fed farm are more than those in an irrigation-supplemented farm (using Equation 1). The costs of drought faced by farmers having access to reservoir water can be estimated based on the nature of the drought in the rain-fed location.

AEC = (annual probability of drought) x (costs in drought year) (Equation 1)

[5] Using late-maturing or long-duration varieties (6 months), sowing is done in May/June and harvesting in November/December. With medium-duration varieties (4 months), sowing is done in August/September and harvesting in November/December. Short-duration varieties (3 months) are used early in the wet season (May-July) and late in the wet season (Jan-Mar).

2.7 Cost-Benefit Analysis

An extended discussion of the cost-benefit analysis (CBA) economic framework can be found in many textbooks including those by Layard (1972) and Mishan (2007). The benefits of using a CBA in this study, particularly in relation to risk-based studies, are outlined by Mechler (2005), who identifies the principles of CBA as including a 'with' and 'without' approach, the selection of a 'best-option' if there is more than one option, a societal point of view, and clearly defined boundaries of analysis. A CBA will be more complex if social and environmental issues are incorporated.

The merits of a CBA is that it is used widely as a decision-making tool by many organizations globally including the World Bank, government agencies, and private investors. The traditional criteria for evaluation include the net present value (NPV), the benefit-cost ratio (BCR), and the rate of return. However, caution must be taken when choosing a discount rate, which is extensively discussed in the Stern Review (see Dietz 2008; Nordhaus 2007). Uncertainty and other aspects such as equity must also be taken into account.

Using the 'with' and 'without' approach, it is possible to compare an investment project having no water reservoir (without), for instance, and building a water reservoir (with) in a community. Since the costs of construction are normally incurred in the first or first few years and the operation and maintenance (O&M) costs during the lifespan of the reservoir while the benefits from the reservoir are distributed in the future, these can be calculated at present value (PV) (Equation 2), and net present value (NPV) (Equation 3)

$$PV\ (X) = X_t \frac{1}{(1+r)^t} \qquad \text{(Equation 2)}$$

$$NPV = \sum B_t(1 + r)^{-t} - \sum C_t(1 + r)^{-t} \qquad \text{(Equation 3)}$$

where *X* is the present value of costs (*C*) or benefits (*B*) at time (*t*) at the discount rate (*r*). The project starts from year 1 (*t=1)*.

This study compares the NPV of two development scenarios (with and without a reservoir) over a period of 20 years (based on the lifespan of a water reservoir). The 'with' scenario includes farm households that have access to supplementary irrigation water. We examined two time periods, a drought and a non-drought year, and requested respondents to recall the costs of rice production associated with drought episodes. We compared the two rice ecosystems selected for comparison: an irrigation-supplemented site (ST) and a totally rain-fed site (PL).

3.0 FINDINGS

3.1 Demographic Characteristics

The majority of the respondents (66%) were female: 73% from PL and 59% from ST, with ages ranging from 20 to 65 years. On average, the household size in the two communes was six people (6 in ST and 5.78 in PL). Overall, the educational attainment of household members in ST was relatively higher than in PL. There were 37 households where the heads were female and aged between 18 and 69. Most of the household heads (88%) had low education, of which 67% had finished primary school and 21% had finished secondary school.

There were more sources of income in ST than in PL (Table 1) although not significantly so. However, there was a slight difference in income diversification (Table 2). All the households in the communes were farming households, but only about 18% depended solely on farming for income.

The second highest income source after rice (100%) was from working in the garment sector at 46% of total sample. Selling vegetables, livestock and poultry were done by 18%, 17% and 14% of the total sample, respectively. PL has more households earning from garment work while ST has more households selling vegetables (52 in ST compared to 17 in PL). This is because there is a provincial market less than 7 km away from SP.

In PL, there were 63 cases of land sales compared to 34 in ST. It is worth examining why households sell rice land in both communes. Informal discussions with some community members revealed reasons like low land productivity and needing money to send their daughters to work at garment factories, especially in PL Commune.

Table 1. Sources of income in Peang Lvea and Sopor Tep

Sources of income	Peang Lvea (PL)	Sopor Tep (ST)	Total (%)
Rice (hh)	200	200	400 (100%)
Garment worker (person)	98	88	186 (46%)
Construction worker (person)	42	25	67 (17%)
Livestock (hh)	35	40	75 (17%)
Poultry (hh)	26	33	59 (14%)
Selling vegetables/petty trade (hh)	17	52	69 (18%)
Civil servant (person)	8	23	31 (8%)
Remittances (hh)	3	7	10 (3%)
Aquaculture (hh)	2	3	5 (1%)
Others (hh)	28	30	58 (15%)

Table 2. Income diversification in Peang Lvea and Sopor Tep

Commune	Frequency of households by number of income sources						Total
	1	2	3	4	5	6	
Peang Lvea (PL)	39	92	45	20	3	1	200
Sopor Tep (ST)	34	86	39	29	10	2	200
Total no. of households	**73**	**178**	**84**	**49**	**13**	**3**	**400**

3.2 Rice Varieties

Normally, the local farmers use long-duration rice varieties regardless of whether they are in a normal or drought year or have access to irrigation or not. From our sample households, more than 84% transplanted late-maturing varieties during a normal year while 55% did so during drought years. In the latter, some farmers delayed their cultivation while approximately 45% from each of the two communes used short-duration rice varieties. The medium-duration varieties were less popular than both the long and short-duration varieties.

Table 3 shows that some households in both communes keep more than one type of variety. However, PL Commune uses much more of the short-duration variety than ST. This is highly related to water security as we know that ST households have access to supplementary irrigation while PL households depend on rainwater. Short-duration varieties enable households to cope with drought episodes. The late-maturing varieties, however, are traditional varieties which are also drought-tolerant but not to as great a degree as the modern, short-duration varieties. The most common variety used is a medium-duration rice variety called *Phka Mali* or Cambodian Jasmine Rice.

Table 3. Distribution of households by rice variety grown in Peang Lvea and Sopor Tep

Commune	Long-duration	Medium-duration	Short-duration	Total
Peang Lvea	149	45	116	**310**
Sopor Tep	116	29	70	**215**

3.3 Land Ownership by Farmers

Almost every household in our sample from PL owns rice land. In ST, there are six households that have no rice fields; they are regarded as landless. The majority of farmers own very small plots of land for paddy cultivation as shown in Figure 3. About 28%, 31% and 23% of the farmers own less than 0.5 ha, between 0.5-1 ha, and 1.5 ha or less of paddy land, respectively.

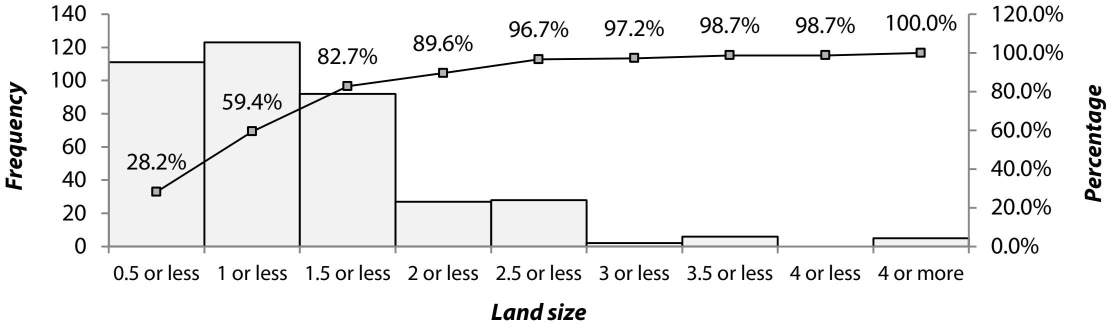

Figure 3. Agricultural land distribution by household in Peang Lvea and Sopor Tep

3.4 Farmers' Experience of Drought

The sample farmers defined drought in their own ways, but they generally agreed that drought occurs when there is a delay in rainfall and their paddy plants are dying as a result. Some said that drought is when they have to pump water into their paddy fields. For those without supplementary irrigation, drought events are considered to have occurred when their rice plants are not growing well and/or the paddy fields are damaged.

As shown in Table 4, between 1990 and 2010, 99% of the sample households experienced drought between one and nine times. Given that PL Commune is totally rain-fed, only four households reported that they never experienced drought; this figure is far fewer than in ST where 32 households reported that they had not experienced drought in the same period. Those farmers who claimed not to have experienced drought had secure access to supplementary irrigation.

Table 4. Distribution of drought events in Peang Lvea and Sopor Tep (1990-2010)

Drought events	Frequency	Cumulative frequency	% Cumulative frequency
3 or fewer	287	287	78.8
6 or fewer	72	359	98.6
9 or fewer	5	400	99.9

3.5 Yearly Rice Production

According to the results of the household survey, the PL respondents cultivated a total of 209 ha. In a non-drought year, the 200 respondent-farmers could produce 1.4 tons of rice per hectare amounting to 292.6 tons of rice. In a drought year, the farmers in PL still cultivated 209 ha of land, but their harvested area decreased to 57.6 ha. Production could reach 51.26 tons (i.e., 0.89 tons per hectare). The respondents could earn USD 80,465 in a non-drought year and USD 14,096.50 in a drought year (Table 5). This means that droughts have had a severe impact on rice production in PL Commune.

On the other hand, the total cultivated land for the 200 respondent households in ST Commune was 129.1 ha. The farmers could produce 3.01 tons of rice per hectare in non-drought years which amounted to 388.59 tons a year. In drought years, the farmers could only produce 2.21 tons per hectare or 272.5 tons per year while the harvested areas decreased slightly from 129.1 to 123.3 (Table 5). The respondents in ST could earn USD 106,862.25 in a non-drought year and USD 74,937.50 in a drought year. This shows that rice production in drought and non-drought years was not as markedly different as in PL because of the irrigation system in ST. It should be noted that supplementary irrigation did not only allow farmers to grow both wet season rice and dry season rice during droughts but also enabled them to do double cropping every year.

Table 5. Yearly rice production in Peang Lvea and Sopor Tep in drought and non-drought years

	Description	Unit	Peang Lvea	Sopor Tep
Non-drought Year (2012)	Area grown	ha	209	129.10
	Area harvested	ha	209	129.10
	Average production	ton/ha	1.40	3.01
	Total production	ton	292.60	388.59
	Unit price	USD/ton	275	275
	Total production	USD	80,465.00	106,862.25
Drought Year (2004)	Area grown	ha	209	129.10
	Area harvested	ha	57.60	123.30
	Average production	ton/ha	0.89	2.21
	Total production	ton	51.26	272.50
	Unit price	USD/ton	275	275
	Total production	USD	14,096.50	74,937.50

Source: Household survey, 2012

3.6 Production Costs per Hectare

The calculation for production costs per hectare was based on the household survey on rice production in 2012. Farmers from the two communes claimed that 2012 had been a typical normal year and 2004 had been the most severe drought year to date. So we used these two years as baseline years for comparison between drought and non-drought years.

In 2012, ST could produce 3.01 tons per hectare while PL could only produce 1.4 tons per hectare (Table 5). The reason for this difference was the level of agricultural investment. The farmers in ST invested more in rice planting than those in PL because they had irrigation and were confident with their investments. Unlike the ST farmers, the PL farmers did not feel secure enough to make more agricultural investments.

The costs were generated over the four stages of rice production: seedling, transplanting, growing, and harvesting. The seedling stage involves costs for seedbed preparation, selection and/or purchase of rice seeds, sowing, and 'pulling' seedlings (taking out seedlings from the seedling bed to be transplanted). The transplanting stage consists of the costs of land preparation for transplanting, labor, pumping water (hire of a pumping machine and/or fuel), and fertilizers. The growing phase covers the costs of fertilizers, pesticides, pumping water, and labor. Lastly, harvesting entails labor and transportation costs.

Table 6 shows the production costs per hectare for ST and PL communes in a non-drought year (2012). Among the four stages of cultivation, it was only in the transplanting stage that farmers in PL invested more than ST farmers. This is because most of them ploughed their land twice before transplanting. The farmers in PL invested less in farm inputs than those in ST. PL farmers spent KHR 188,500 (USD 47.12) on fertilizers only but not on pesticides while ST farmers spent KHR 642,857 (USD 160.71) on both fertilizers and pesticides. It can be said that the farmers in PL relied more on their own labor while the farmers in ST invested more in fertilizers and pesticides.

Table 6. Production costs per hectare in Peang Lvea and Sopor Tep in a non-drought year

Stage	Peang Lvea (USD)	Sopor Tep (USD)	
	Wet season	Wet season	Dry season
Seedling	114.21	109.82	258.57
Transplanting	223.96	178.57	NA
Growing	261.50	283.93	395.36
Harvesting	146.67	224.17	109.14
Total	**746.34**	**796.49**	**763.07**

The calculation of inputs and labor employed constant prices in the non-drought and drought years. To generate the total production costs, household labor was counted; otherwise the real costs would be underestimated. The labor cost in both the communes was set at KHR 10,000 (about USD 2.50)[6] for four hours work per person[7].

The farmers in PL employ traditional methods of cultivation, for example, using cattle to plough the land and manually harvesting their paddy. They believe that using hand tractors and harvesting machines would increase their production costs by 40%. Conversely, the farmers in ST employ technology for their rice production, especially harvesting machines. This is one of the reasons why their productivity is higher than PL.

The average productivity level in PL was 1.4 tons per hectare (during a normal year). The farm gate price of rice was USD 275 per ton, so the revenue generated from rice production was USD 385 per hectare in 2012. The production cost of rice in PL in 2012 was USD 746.34 per hectare (Table 6). The net benefit of rice production in PL was therefore USD -361.34 per hectare. It can be concluded from this that farmers in PL are making losses in their rice production if their own labor is included in the production costs.

On the other hand, farmers in ST could earn USD 827.75 per hectare with a production cost of USD 796.49 per hectare with wet season rice in 2012. So the net benefit of wet season rice in ST was USD 31.26 per hectare. Therefore, it can be concluded that the farmers in ST make a profit not a loss from rice cultivation. For dry season rice in the same year, their cost was USD 763.07 per hectare against a benefit of USD 833.25, providing a net benefit of USD 70.18 per hectare. This shows that dry season rice is more profitable for ST farmers than wet season rice.

3.7 Costs of Droughts

3.7.1 Types of drought costs

We investigated the impacts of three types of droughts: early-season, mid-season, and late-season droughts. Early-season droughts increase interruption costs while mid-season droughts can decrease productivity (and increase the costs of low productivity). Late-season droughts can destroy the crop thereby increasing damage costs.

Interruption costs. Interruption costs normally occur during the seedling and transplanting stages and are more likely in rain-fed systems than irrigated fields. Each household usually prepares its own seedbed and seedlings for rice cultivation. The farmers in both communes reported that, during drought, they lost more during the seedling stage than during transplanting (Table 7). The respondents could not recall how much the interruption costs were exactly, but they estimated that during a drought year, the total production costs would be 15% higher compared to a non-drought year. This happened four times in the last 20 years (1990-2010).

Table 7. Frequency of seedling and transplanting damage in Peang Lvea and Sopor Tep

Commune	Seedlings (hh/%)	Transplanting (hh/%)
Peang Lvea	104 (52%)	71 (35.5%)
Sopor Tep	17 (8.5%)	10 (5%)

Low productivity or remaining damage costs. Low productivity or remaining damage costs were incurred more in the rain-fed area (85% of PL households) than in the irrigation-supplemented area (24% of ST households). In a non-drought year, the average yield for the former was around 1.5 tons per hectare compared to about 3 tons per hectare for the latter. The yield reduction due to drought was reported by the farmers to be about 30% in PL and 35% in ST. This happened two times in the last 20 years (1990-2010).

[6] The exchange rate used was 1 USD = KHR 4,000.
[7] 'Own labor' was calculated at the market price of KHR 2,500 per hour or KHR 10,000 for 4 hours' work.

Damage costs. The total area of cultivation for both normal and drought years was 338.1 ha (209 ha and 129.1 ha in PL and ST communes, respectively), meaning that the farmers always cultivated all their land regardless of whether there was drought or not. However, both communes faced a reduction in the areas harvested during the drought year in 2004, from 209 ha to 57.6 ha in PL (a 72% reduction) and from 129.1 ha to 123.3 ha in ST (a 4.49% drop). So there was a huge difference in the area harvested during the drought year in PL.

The loss in PL during the drought year was 82% of total production (241.1 tons) compared to ST's 20% (66.7 tons) of total production. This happened only once in the last 20 years (1990-2010) in 2004. If PL were to be equipped with the same type of irrigation facilities as ST, then the harvested area of PL during a drought year could be estimated to be 199.61 ha[8] and the yield, 441.14 tons[9]. This would be higher than the current production output of PL. This is due to the fact that farmers with access to an irrigation facility can produce more.

3.7.2 Expected losses for farmers in rain-fed areas during drought years (Peang Lvea)

The expected losses from drought were estimated for the period 1990-2010. The damage costs were estimated based on the fact that there was: 1) damage at the seedling and transplanting stages once every 5 years, 2) yield reduction once every 10 years, and 3) harvest losses once every 20 years.

Costs of seedling and transplanting damage (interruption costs). In a normal year in PL, the cost of seedlings was USD 23,869 (or USD 114.21 per hectare); for transplanting, it was USD 46,807 (or USD 223.96 per hectare) (Table 6). About 52% and 35.5% of the households in PL reported that they experienced damage to their crops during the seedling and transplanting stages, respectively (Table 7). Assuming that these figures also represented the total increase in production costs (farmers re-preparing their seedlings and re-transplanting), the cost increase would amount to USD 12,411.88 for seedlings and USD 16,616.49 for transplanting. Hence, the total cost from damage to seedlings and during transplanting would be USD 29,028.37 in a drought year for the 209 ha in PL.

Costs from yield reduction (remaining damage costs). Based on the normal yield (1.4 tons per hectare in 2012) in a rain-fed paddy field in PL, the total production was 292.6 tons worth USD 80,465 (USD 275 per ton at the 2012 farm gate price). For the drought year, 85% of the households reported yield reductions of about 30% which translated to 217.99 tons or USD 59,946.43. The cost of yield reduction or lowered productivity was thus USD 20,518.58 in a drought year for the 209 ha in PL.

Damage cost. Based on Table 5, the total harvested area in the sample site in PL during a severe drought year was 57.6 ha with total production of 51.26 tons. During the drought, the farmers' production was worth only USD 14,096.50 while in a non-drought year, they could produce up to the value of USD 80,465 (based on the 2012 production at 1.4 tons per hectare). Thus damage to the harvested area was estimated at USD 66,368.50 (total revenue in a normal year minus total revenue in a drought year).

Table 8 shows the risks of rain-fed agriculture calculated as a loss-frequency function. The total expected loss from drought in rain-fed rice production was estimated at USD 11,175.66 per annum for the 209 ha in PL or USD 53.47 per hectare. This was based on recurrent periods of different drought intensities associated with damage during the four stages of cultivation.

Table 8. Risks of rain-fed agriculture in Peang Lvea

Recurrent period (years)	Annual probability	Damage (USD)	Risk = Probability * Damage (USD)
5	0.20	29,028.37	5,805.67
10	0.10	20,518.58	2,051.86
20	0.05	66,368.50	3,318.43
		Annual expected damages	**11,175.96**

[8] 199.61 ha = [123.3 ha (ST in drought-year)/129.1 ha (ST in non-drought year)] * 209 ha (paddy area in PL)
[9] 441.14 tons = 199.61 * 2.21 (yield of ST in drought-year)

3.7.3 Expected losses for farmers with supplementary irrigation during drought years (Sopor Tep)

The period used to estimate the expected losses and the costs of drought in an irrigation-supplemented area was the same as for the rain-fed area, which was from 1990-2010.

Costs of seedling and transplanting damage (interruption costs). The cost of seedling and transplanting damage was USD 2,357.78 in a drought year for the 129.1 ha in ST. In a normal year, the cost of seedlings was USD 14,177.76 (or USD 109.82 per hectare); transplanting cost was USD 23,053.39 (or USD 178.57 per hectare) (Table 6). Based on Table 7, 8.5% and 5% of households in ST reported that they experienced crop damage during the seedling and transplanting stages. Assuming that these figures also represent the total increase in production costs (for farmers re-preparing their seedlings and re-transplanting), the cost increase would be USD 1,205.11 for seedlings and USD 1,152.67 for transplanting.

Costs from yield reduction (remaining damage costs). Based on the normal yield for irrigated paddy (3.01 tons per hectare in 2012), the total production in ST was 388.59 tons per annum, equal to USD 106,862.25 (USD 275 per ton at the 2012 farm gate price) (Table 5). During the drought, 24% of the households reported yield reductions of about 35%. Thus, production would be 355.75 tons after yield reduction amounting to USD 97,831.25 (Table 9). Thus the cost of yield reduction would be USD 9,031 in a drought year for the 129.1 ha in ST.

Table 9. Costs of yield reduction in Sopor Tep

Cultivated area	Area (ha)	Yield (ton/ha)	Total production (tons)	Total value in USD (* USD 275/ton)
Non-affected area	98.12	3.01	295.34	81,218.50
Affected area (24%) Yield reduction (35%)	30.98	1.95	60.41	16,612.75
Total	**129.10**		**355.75**	**97,831.25**

Damage costs. Based on Table 5, the total harvested area in ST in the drought year was 123.3 ha with a total production of 272.5 tons. During the drought year, the farmers could only produce USD 74,937.50 worth of rice while in the non-drought year, they could produce up to the value of USD 106,862.25. Thus, the damage to the harvested area was estimated at USD-31,924.75.

Table 10 shows the risks of irrigated agriculture calculated as a loss-frequency function. The loss from drought in supplementary irrigated paddy production was found to be USD 2,970.90 per annum for the 129.1 ha in ST or USD 23.01 per hectare. This was based on recurrent periods of different drought intensities associated with damage during the four stages of rice cultivation.

Table 10. Risks of supplementary irrigation agriculture in Sopor Tep Commune

Recurrent period (years)	Annual probability	Damage (USD)	Risk = Probability * Damage (USD)
5	0.20	2,357.78	471.56
10	0.10	9,031.00	903.10
20	0.05	31,924.75	1,596.24
		Annual expected damages	**2,970.90**

The difference in expected loss per hectare from drought events in rain-fed (USD 53.47) and irrigation-supplemented (USD 23.01) areas is USD 30.46. The difference in expected losses is relatively large because PL is much more sensitive to drought than ST. Also, there are big differences in the productivity levels between the two communes; ST's production volume is double that of PL and the harvested area reduced by drought is far smaller.

3.8 The Restoration of Kvit Reservoir

3.8.1 Cost analysis

Attempts have been made by the Department of Meteorology and Water Resource of KPS to supply farmers in the province with water, especially in PL commune. We did a small feasibility study on the prospect of restoring an old reservoir (Kvit Reservoir) which had been built between 1975 and 1979 in PL[10]. This reservoir had been completely damaged and was unusable and some farmers cultivated rice in it.

The primary costs of the restoration of the reservoir will be for the repair of the 1,150-meter dike and the 4,000-meter long canal, the removal and reconstruction of one large water gate, and the construction of one 80 cm-diameter culvert and one 100 cm-diameter culvert with gates. The water from the reservoir flows to the paddy fields via gravity. The costs associated with the proposed renovation of the reservoir are given in Table 11.

Table 11. Cost breakdown for the restoration of Kvit Reservoir in Peang Lvea

Description	Estimated costs (USD)
Engineering costs (only in Year 1)	343,680.00
Opportunity cost of stopping rice cultivation in the reservoir (only in Year 1)	19,081.00
Operation and maintenance costs per year from Year 2-20	21,204.00
Agricultural extension services per year from Year 2-20	15,547.00

The estimated total engineering cost is USD 343,680. It is estimated that USD 21,204 will be spent annually for operation and management (USD 36 per hectare). To increase the skills of farmers in PL to be on par with those in ST, agricultural extension services will be provided to them at the cost of USD 26.40 per hectare or USD 15,547 in total.

In addition, the restoration of Kvit Reservoir will incur an opportunity cost for farmers who currently cultivate the paddy in the reservoir. The reservoir occupies 49.56 ha of land. Using the productivity level of 1.4 tons of rice per hectare in PL, the total production volume of the current cultivated land in the reservoir would be USD 19,081 annually.

As indicated in Table 11, the cost of restoring Kvit Reservoir in Year 1 is USD 362,761 while the cost in Years 2 to 20 is USD 36,751 per year.

3.8.2 Benefit analysis

According to the feasibility study, the Kvit Reservoir can supply water to 324 ha of cultivated land in the wet season, 75 ha in the dry season, and 190 ha for early-season rice. This would benefit 640 households.

Table 12 shows that if PL Commune were to be provided with irrigation water as a result of reservoir restoration, it can double its rice production in a non-drought year using ST's yield. In a drought year, it can produce more than 600 tons of rice compared to only about 80 tons at its current productivity level with drought.

If there is a reservoir in PL, the expected loss during drought events in ST would apply here for the 324 ha. This means that if the 324 ha of paddy area in PL were irrigated like in ST, the farmers will lose only USD 7,455.24[11] instead of USD 17,324.28[12]. This value is treated as the avoided damage cost provided by the facility.

[10] A feasibility study on the restoration of Kvit Reservoir was done by Mr. Chea Bora, one of the researchers of this study, as part of this research project.
[11] This value (USD 7,455.24) is from 324 ha * USD 23.01 (expected drought damage cost in ST).
[12] This value (USD 17,324.28) is from 324 ha * USD 53.47 (expected drought damage cost in PL).

Table 12. Rice production in converting from a rain-fed to an irrigation-supplemented system in Peang Lvea

		Rain-fed	Supplementary irrigation
Non-drought year	Area cultivated (ha)	324	324
	Area harvested (ha)	324	324
	Yield (ton/ha)	1.40	3.01
	Total Production (tons)	**453.60**	**975.24**
Drought year	Area cultivated (ha)	324	324
	Area harvested (ha)	89.29	309.44
	Yield (ton/ha)	0.89	2.21
	Total Production (tons)	**79.47**	**683.86**

Note: The area harvested is based on ST's drought damage area in 2004 which was 4.49% of total area.

At the same time, the productivity of wet season rice is expected to increase from 1.4 to 3.01 tons per hectare. In other words, the net revenue of wet season rice will increase to USD 392.59 per hectare (from USD -361.33/ha in PL to USD 31.26/ha in ST for 324 ha of wet season rice), which amounts to USD 127,199.16 for a normal year (Table 13).

According to the feasibility study, the reservoir can supply 75 ha of dry season rice and 190 ha of early season rice. Assuming that droughts will not impact dry season and early season rice, the net revenue in PL will be the same as ST for dry season rice and wet season rice which is USD 70.18 and 31.26 per hectare, respectively. Thus, the dry season rice and early season rice will enable farmers to make USD 5,263.50 and USD 5,939.40, respectively (Table 13).

Table 13. Avoided damage costs and additional benefits from the restoration of Kvit Reservoir in Peang Lvea

	Area (ha)	Annual net benefit per hectare	Annual net revenue (USD)
Avoided damage costs	324	30.46	9,869.04
Increased productivity	324	392.59	127,199.16
Dry season rice	75	70.18	5,263.50
Early season rice	190	31.26	5,939.40
		Total	**148,271.10**

3.8.3 Cost-benefit analysis

The reservoir restoration project was planned to start in 2014 subject to the availability of funds[13] and expected to yield benefits for the following year. Table 14 shows the projected costs. For the first year, construction and opportunity costs will be USD 362,761 and from the second year until Year 20, operation and maintenance, and agricultural extension services total USD 36,751 yearly. Satrting in Year 2, the yearly benefit from the avoided damage costs increased yield due to supplementary irrigation, and double cropping amounts to USD 148,271 (Table 14).

Table 14 also shows the results of the cost-benefit analysis (CBA) of the restoration of Kvit Reservoir. The discount rate was set at 6% and the expected completion time of the project was estimated to be 20 years. It can be seen that except for Year 1, the project will generate a profit each year. The CBA shows that the project can earn a profit of USD 914,834.94 over 20 years and provide a benefit 2.18 times higher than the cost (Benefit-Cost Ratio = 2.18). It can provide an internal return rate of 30.6% to investors.

[13] We are still in the process of seeking a grant to support the reservoir restoration project.

Table 14. The costs and benefits of the reservoir restoration project in Peang Lvea

Year	Total costs (USD)	Total benefits (USD)	Discount factor	PV of future net benefits (USD)
1	362,761	0	0.00	-362,761.00
2	36,751	148,271	0.94	105,207.64
3	36,751	148,271	0.89	99,252.49
4	36,751	148,271	0.84	93,634.43
5	36,751	148,271	0.79	88,334.36
6	36,751	148,271	0.75	83,334.31
7	36,751	148,271	0.70	78,617.27
8	36,751	148,271	0.67	74,167.24
9	36,751	148,271	0.63	69,969.09
10	36,751	148,271	0.59	66,008.58
11	36,751	148,271	0.56	62,272.24
12	36,751	148,271	0.53	58,747.40
13	36,751	148,271	0.50	55,422.07
14	36,751	148,271	0.47	52,284.97
15	36,751	148,271	0.44	49,325.45
16	36,751	148,271	0.42	46,533.44
17	36,751	148,271	0.39	43,899.47
18	36,751	148,271	0.37	41,414.60
19	36,751	148,271	0.35	39,070.37
20	36,751	248,829	0.33	70,100.52
			Net Present Value (NPV)	**USD 914,834.94**
			Benefit-Cost Ratio (BCR)	**2.18**
			Internal Rate of Return (IRR)	**30.6%**

3.9 Sensitivity Analysis

Table 15 shows the results of the sensitivity analysis conducted. Four scenarios were generated for this: good scenario, bad scenario, worse-case scenario, and worst-case scenario.

Scenario 1 is the good scenario based on the assumption that the project was perfectly estimated. In other words, there is no change from the base case CBA. According to Table 15, the project could generate a NPV of USD 941,834.94 for 20 years whereby the benefits are 2.18 times higher than the costs. Figure 4 illustrates that even if the discount rate increases to 14%, the project could generate USD 376,079 for the 20 years.

The bad scenario (Scenario 2) was formulated by assuming that the costs of the project would be underestimated by 15%, or the project would face an increase of 15% of total costs. Under this scenario, the project will only earn a NPV of USD 798,910 with a BCR of 1.9 and an IRR of 25.13% (Table 15). If the discount rate increases to 14%, the project would only earn USD 285,555 (Figure 4).

Scenario 3 (worse-case scenario) was based on the assumption that drought will take away 15% of the total benefit. If the costs remained constant, but 15% of the benefits were to be reduced by drought, the project would deliver a NPV of USD 661,684.76. The IRR would be 24.3% with a BCR of 1.86 (Table 15). If the discount rate increased to 15%, the project would still generate USD 229,143 (Figure 4).

Scenario 4 is the worst-case scenario where it was assumed that the project costs were underestimated by 15% or 15% of the benefits will be lost through drought. Even in this worst case, the project does not lose under the discount rate of 6% (Table 15). The project could earn USD 545,759.82 with a BCR of 1.61 and an IRR of 19.53%. At a discount rate of 14%, the project would still bring in a benefit of USD 138,619 (Figure 4).

Assuming the discount rate of 6% is correct, and the benefits are constant, the profits will remain positive even if the costs are underestimated by 15%. On the other hand, if the costs of the project remain constant at a 6% discount rate, the project will still bring in a profit even if the benefits decrease by 15%. In all four scenarios, the project will bring in benefits for rice cultivation.

Table 15. Sensitivity analysis results

Year	Present value of future net benefits (USD)			
	Scenario 1	Scenario 2	Scenario 3	Scenario 4
1	-362,761.00	-417,175.15	-362,761.00	-417,175.15
2	105,207.64	100,007.03	84,225.88	79,025.27
3	99,252.49	94,346.25	79,458.38	74,552.14
4	93,634.42	89,005.90	74,960.73	70,332.21
5	88,334.36	83,967.83	70,717.67	66,351.14
6	83,334.30	79,214.93	66,714.79	62,595.41
7	78,617.27	74,731.07	62,938.48	59,052.28
8	74,167.23	70,501.00	59,375.92	55,709.70
9	69,969.10	66,510.38	56,015.02	52,556.32
10	66,008.57	62,745.65	52,844.36	49,581.43
11	62,272.24	59,194.01	49,853.17	46,774.93
12	58,747.40	55,843.40	47,031.29	44,127.30
13	55,422.10	52,682.45	44,369.14	41,629.52
14	52,284.97	49,700.43	41,857.68	39,273.14
15	49,325.45	46,887.20	39,488.38	37,050.13
16	46,533.44	44,233.20	37,253.19	34,952.95
17	43,899.47	41,729.44	35,144.51	32,974.48
18	41,414.60	39,367.39	33,155.20	31,108.00
19	39,070.37	37,139.05	31,278.50	29,347.18
20	70,100.52	68,278.52	57,763.44	55,941.44
NPV	**USD 914,834.94**	**USD 798,910.00**	**USD 661,684.76**	**USD 545,759.82**
BCR	**2.18**	**1.90**	**1.86**	**1.61**
IRR	**30.60%**	**25.13%**	**24.30%**	**19.53%**

Notes: Scenario 1: No change from the base case
Scenario 2: The costs are underestimated by 15%
Scenario 3: Drought reduces the benefits by 15%
Scenario 4: The costs are underestimated by 15% and drought reduces the benefits by 15%

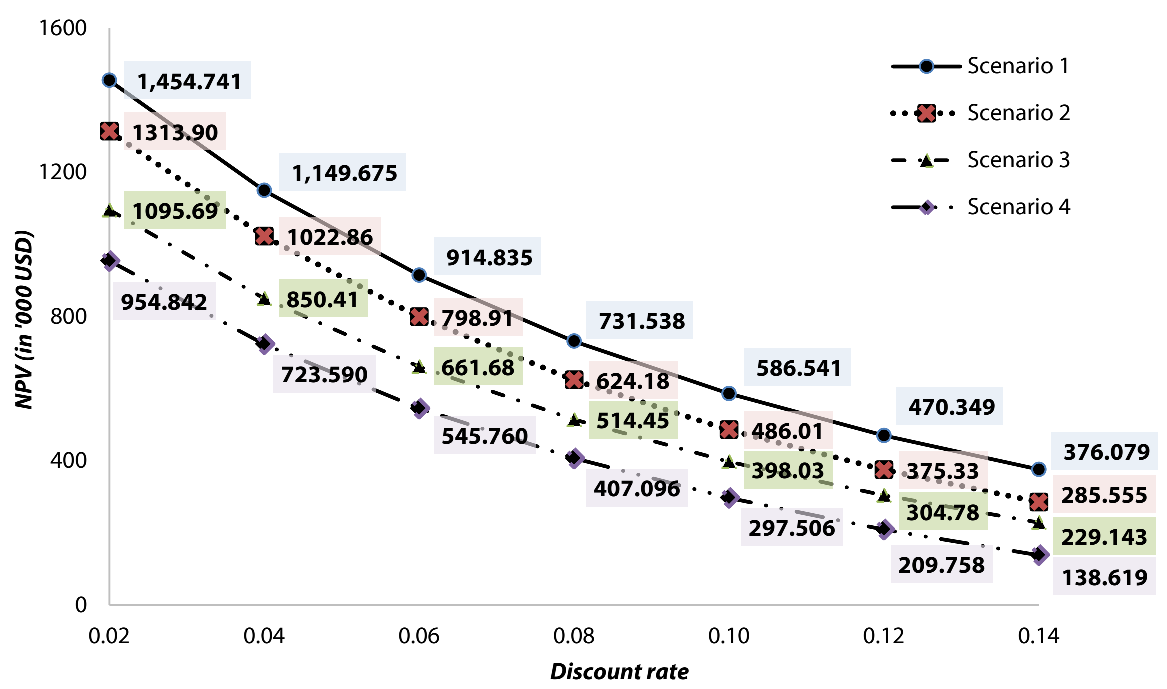

Figure 4. Sensitivity analysis of the Kvit Reservoir project

3.10 Discussion

The Stern Review estimates that the cost of climate change impacts is approximately 5% of the world's annual Gross Domestic Product and in the worst case, could jump to 20% or higher (Stern 2006). In this study, we found that the expected loss to a rain-fed farmer during a drought year was USD 53.47 per hectare. With a 6% discount rate, the restoration of Kvit Reservoir will yield a NPV of USD 941,834.94 (Table 14). The BCR is high at 2.18. The benefits calculated here, however, do not take into account co-benefits, such as protecting non-rice crops like watermelon.

Repairing the reservoir will help to secure the livelihoods of smallholder farmers in rural Cambodia and is likely the most effective project proposed to date. For example, a study by Barker and Molle (2004) found that the BCR trends for irrigation investments in the Philippines and Sri Lanka went downwards between the 1970s and the 1990s from the highest ratio (more than 3.5) to the lowest (less than 0.5) towards the end of the study period.

While irrigation in Cambodia is often viewed as providing water security and is closely linked with food security, the CBA in this study mainly focused on quantitative profits which will be useful to policymakers. Having said this, the benefits of improved social welfare and the survival of smallholder farmers are equally important to consider.

By default, farmers will do everything in their capacity to maintain their yields. They may not be recording rice yields or production costs. Therefore, they may not associate yield fluctuations with drought, but other factors such as lack of labor or an increase in the price of fertilizers (which may also happen during years with good rainfall). Since drought is an insidious kind of phenomenon, farmers may experience additional hardships due to it before they identify it as the cause and take action to address it.

4.0 CONCLUSIONS

The biggest climate change impacts in Cambodia relate to floods and droughts. Droughts occur frequently in Cambodia, especially in Kampong Speu Province. Recognizing that agriculture is a key economic sector for the country, the Royal Government of Cambodia is attempting to mitigate drought impacts using many methods, especially through improvements in physical infrastructure like reservoirs. Included in the government's climate change projects are nine projects aimed at mitigating drought and five focusing on mitigating the effects of floods. The drought projects all involve irrigation.

Rain-fed farmers are highly vulnerable to climate variability. Cambodia is expected to experience more droughts in the future; therefore securing water is vital to avoid widespread crop failure. In this study, we found that farmers in the study sites experienced droughts up to four times between 1990 and 2012. Drought was defined based on the farmers' experiences of periods when they experienced water shortages in their paddy fields which resulted in damage to their rice seedlings, yield reductions, or destruction of their crops. Comparing farmers who had access to supplementary irrigation with those who were totally reliant on rain in the same province, we found that drought occurrences and the degree of impacts from droughts were higher in the rain-fed rice area, Pean Lvea Commune. Without supplementary irrigation, droughts resulted in a reduction of at least 73% of paddy production compared to a normal year in Peang Lvea. It was estimated that the farmers in Peang Lvea faced an annual expected loss of USD 53.47 for every hectare of paddy field.

Based on our feasibility study on restoring the old Kvit Reservoir in Peang Lvea, we found that the projected costs were low compared to the significant benefits such a project could yield. If restored, the reservoir will play a very significant role in strengthening food security for the majority of households in the commune, which own very small parcels of land and rely on subsistence farming. Just one crop failure would spell disaster for these households. Therefore, it is imperative that the restoration of the reservoir be carried out as soon as possible before more adverse consequences befall the community.

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Appendix 1. Focus group discussion questions on the socioeconomic impacts of drought on Kampong Speu Province communities

1. Do you think there is more domestic violence in families during drought years?
2. Are there any villagers producing charcoal in the villages?
3. Do you think charcoal producers increase or decrease during drought years?
4. What is the source of water for consumption by the villagers during drought years?
5. Do you think more groundwater is consumed during drought years?
6. What do you think about drought? And how do you think your crops and animals have been affected by droughts?
7. Do you think that more people get sick during a drought or non-drought year?
8. In order to increase rice yields in your villages, what should you do?
9. What years were non-drought years from 1990-2012?
10. Now, these are the drought years: 19xx, 19zx, 19ab, 20xz, 20ac, and 20dc. If we were to divide them into 2 years for low intensity drought, 2 years for medium intensity drought, and 2 years for high intensity drought, what would they be?
11. *Beginning of rice seasons:* In a normal year, when should be the latest date for transplanting? In a drought year, what should be the latest date for transplanting? What crop variety (genotype) did (will) you use?
12. *Dry period during wet seasons:* In a normal year, how many days did this last? In a drought year, how many days did it last?
13. *End of rice seasons:* In a normal year, when will the rains stop? In a drought year, when will the cessation of rain cause damage to the crops and affect harvest and yield?

Appendix 2. Semi-structured key informant interview questions relating to small-scale irrigation development and rice cultivation in Kampong Speu Province

Small-scale irrigation project
1. Why did you build this dam? Or why do you want this dam?
2. What will be the impacts from restoring the dam here? Who will gain or/and lose?
3. What will you gain from restoring the dam? What will you lose from the dam restoration?

Changing crop calendar
1. Why did you change your crop calendar?
2. What are the costs of changing your crop calendar?
3. What are the benefits of changing your crop calendar?
4. If you can avoid changing your crop calendar, what are your alternatives? What will be your costs and benefits?

Changing seeds
1. What varieties/seeds did you use in the past?
2. What is the most preferred crop variety that you use now and will use in the future?
3. Why do you change seeds?
4. What are the costs of changing seeds?
5. What are the benefits of changing seeds?
6. If you can avoid changing seeds, what are your alternatives? What will be your costs and benefits?

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