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Evaluating the Economic Efficiency of Crop Production in the Floodplain During the Dry Season in Chulkiri District, Kampong Chhnang Province

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ABSTRACT

Purpose of the study: This study aims to assess the status of crop production and evaluate the costs, benefits, opportunities, and challenges along Tonle Sap Lake during the dry season.

Methodology: Data were collected from 47 farmers, 10 vendors, and four local authorities through random interviews followed by questionnaires. The cost-benefit ratio, net present value (NPV), and sensitivity analyses were conducted, assuming a 9% cost overrun and a 5% yield decrease for analysis data.

Main Findings: The study found, that farmers employ crop rotation and expertise from nearby farmers to grow beans, corn, sweet chilli, and melon from December to August. Floodplain crop production is moderately profitable, despite a 10% increase in total costs, with labor, irrigation, fertilizer, weeding, and pesticides being the high expenses. Challenges such as labor scarcity, financial literacy deficits, pest management issues, falling crop values, climate variability, and insufficient seed storage further complicate floodplain agriculture.

Novelty/Originality of this study: This research explores floodplain farming's financial efficiency, and sustainability, utilizing cost-benefit analysis, sensitivity analysis, and qualitative evaluations to address Cambodia's unique agricultural challenges in the floodplain area.

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1. INTRODUCTION

Crop production encompasses the cultivation and harvesting of crops for food, fiber, or other purposes, including soil preparation, planting, irrigation, fertilization, plant protection, harvesting, and storage [1]. Crop production requires an immense quantity of technical expertise and skills, as well as proficient comprehension and implementation of scientific knowledge. In addition to scientific prowess, extensive management and integration expertise is necessary for the successful execution of a crop production operation [2]. Soil preparation involves loading and turning the soil for root penetration, typically through tilling or plowing [3]. High-quality seeds are chosen for their higher yields, despite their higher cost, which can burden farmers and increase food prices [4]. Balanced nutrients are essential for crops to achieve their genetic potential and yield quality [5]. Fertilizer prices have surged by nearly 30% since early 2022, following an 80% increase in the previous year, due to higher input costs, supply disruptions, export restrictions, and the Ukraine war [6]. Water is vital for plant growth, enabling roots to absorb minerals and fertilizers, and ensuring consistent crop growth and food supply [7]. Weeds and pests significantly reduce global agricultural yields using pest control methods including biological, mechanical, and cultural approaches [8]. Efficient harvesting, whether manual or mechanized, is crucial for minimizing waste and maximizing returns, with machinery choice based on harvest area and cost-benefit analysis [9].

"Floodplain agriculture" refers to farming near rivers, lakes, or other water bodies prone to flooding. Unlike upland agriculture, floodplains are often fertile because of nutrient-rich silt deposits from floods [10], [11]. At Tonle Sap Lake, the Mekong River's rise during the rainy season inundates the surrounding lowlands, replenishing the soil with nutrient-rich silt, which is beneficial for farming [12]. However, floodplain farming around Tonle Sap Lake faces challenges, including water management, land ownership, and climate impacts. Upstream dam construction, deforestation, and overfishing alter water flow, threatening the ecosystem's balance and sustainability of riverbank farming.

In microeconomics, "economic efficiency" refers to the optimal market functioning for goods or services, minimizing production costs, maximizing output, and achieving the highest possible surplus. It combines static and dynamic efficiencies to reflect the overall effectiveness of a market system [13]. Economic survival is essential, and is the first and foremost in the management of farming operations. If a farm is unprofitable, it will not survive. A cost-benefit analysis [14] evaluates the economic feasibility, profitability, and sustainability of projects or investments. In agriculture, this entails considering costs such as land preparation, irrigation, seedlings, labor, and transportation against benefits, including increased crop yield, market demand, and higher selling prices [15]. Thus, increasing agricultural productivity significantly influences the pricing.

Net Present Value (NPV) is used in capital budgeting to assess a project's profitability by calculating the difference between the present value of cash inflows and outflows over a given period [16].

Sensitivity analysis reveals how changes in parameters impact the total costs and benefits of the proposed rule, highlighting the sensitivity of the estimated net benefits to varying assumptions and unknown variable values. It identifies critical assumptions and evaluates the importance of the uncertainty regarding specific variables. Conducting a systematic sensitivity analysis and presenting it is essential for decision-makers. Confidence in production efficiency impacts can be maintained if the net benefits remain positive or negative despite considering various possibilities [17].

Cambodia's agricultural sector is underdeveloped and processes only 10% of its domestic output. Challenges include limited private investment, price-taking by farmers, constrained markets, decelerating land productivity due to quality degradation, low yields, and climate change [18], [19]. Smallholder farms rely on traditional low-yield methods which exacerbate environmental vulnerabilities. Inadequate infrastructure and processing facilities increase costs and restrict market access [20], hindering regional competitiveness. Additionally, climate change causes droughts and floods, which affect crop production [21], [22]. The rising costs of agricultural inputs and unofficial payments for permits and electricity further aggravate the financial burden.

Kampong Chhnang, one of the five provinces with major flooded plains for agriculture adjacent to Tonle Sap Lake, has experienced a 40% increase in agricultural land use [23]. The Chulkiri District, situated near Tonle Sap Lake, floods during the rainy season and possesses nutrient-rich sediment that is conducive to cultivating vegetables, rice, and fisheries [24]. Flooding facilitates the release of mineralized nutrients, enabling farming during the dry season.

Due to their fertile soils and natural irrigation, the Tonle Sap River area has a long history of crop cultivation, especially in floodplains. The economic viability of these agricultural practices remains insufficiently explored, especially considering the area's susceptibility to climate-related events like droughts[25].This knowledge gap offers a chance to examine the financial performance of crop cultivation in floodplains during dry periods, potentially guiding approaches to improve the adaptability and yield of these farming methods. The objective of the study was to determine the current status of dry-season crop production practices by farmers along the lake, assess the costs and benefits of crop production, and identify opportunities and key challenges in crop production. This study equips farmers with essential knowledge about crop productivity in the Tonle Sap Lake region, enabling informed decision-making and strategic planning. It identifies opportunities and challenges for developing effective methods and supporting sustainable practices to protect the environment. Local authorities can use these findings to design programs and a 3-year rolling plan to aid farmers and promote sustainable development. The findings contribute to the existing knowledge on regional crop productivity and provide data for future research on fishing agriculture and water quality in Tonle Sap Lake.

2. RESEARCH METHOD

2.1. Research Approaches and Types

This research approach employs an interpretation of quantitative and qualitative research methods. Quantitative research aims to utilize statistical instruments, such as frequency, total cost, total benefit of production, net present value, cost-benefit ratio, and sensitivity analysis. Qualitative research aims to describe and analyze socioeconomic characteristics, crop schedules, opportunities, and key challenges, as well as individual perspectives.

2.2. Research Subjects

This research was conducted in Kampong Ous Village, Kampong Ous Commune, Peam Chhkaok Village, Anlong Metrei Village, and Peam Chhkoak Commune, Chulkiri District, Kampong Chhnang Province (as shown in Figure 1). This area experiences flooding during the rainy season from June to November and a dry season from December to August, which marks the commencement of crop cultivation.

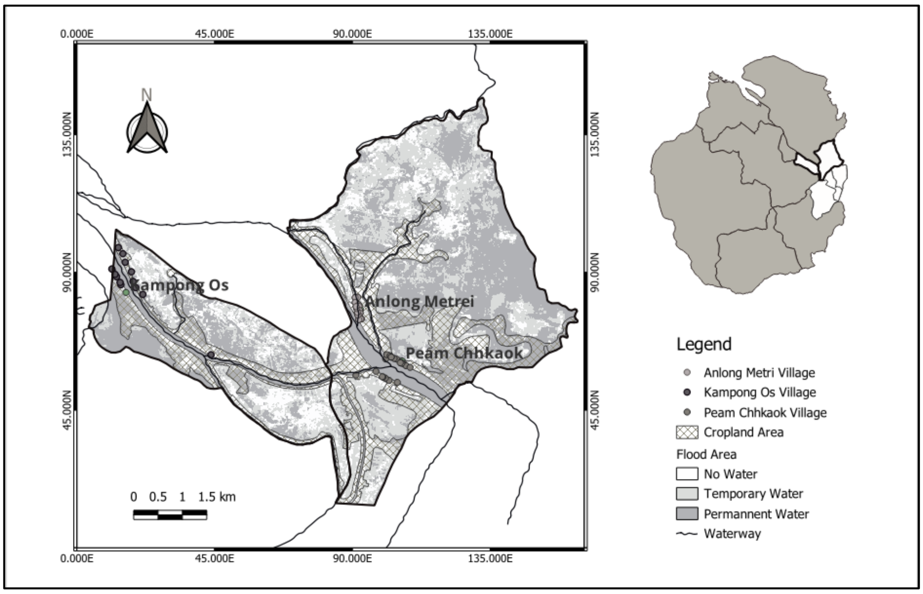

Figure 1. Research locations with flood areas (no water, temporary water, and permanent water by OCD (2018) and cropland.

2.3. Data collection technique

Data were collected through questionnaires and field observations, including structured questionnaires, random sampling, and observations of farmers, vendors, and consumers. Cost-benefit analysis tools were employed, and sampling followed Taro Yamane's (1967) method. Interviews were conducted with local authorities in Kampong Os Village, Kampong Os Commune, Chulkiri District. In Peam Chhkaok Village, 23 families and in Anlong Metrei Village, 17 families participated, all involved in crop production. In total, 53 crop-producing families from two communes in Chulkiri District, Kampong Chhnang Province, were sampled, along with 10 vendors and 4 local authorities. Moreover, data included existing literature and readily available information from the sources.

The research tools included surveys, questionnaires, interviews, and telephone methods for selecting longitude and latitude, ensuring reliability, validity, and accuracy. Researchers engaged with farmers, authorities, vendors, and customers to align with the objectives of the study and build on previous research through a collaborative approach.

2.4. Data analysis

These finding qualitative data analysis was performed using R programming 4.4.1. for the mean, standard deviation, average, and linear regression respectively to estimate the linear relationship between total cost and total revenue. The software QGIS 3.32.3 was utilized to generate maps of specific regions and data maps of Cambodia's flood-prone areas, which were obtained from Open Development Cambodia (ODC) [26]. The equation was used to estimate these parameters:

Cost Analysis includes expenses for land preparation, labor, seeds, fertilizer, watering, weeding, chemical spraying, and harvest per hectare:

$$TC_i = VC + FC \;\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Labor cost: The minimum hourly wage is set at 204 USD per month according to Prakas No. 283 for 2024 [27]. Article 137 of the Labor Law states that full working hours should not exceed 8 hours per day or 48 hours per week. Interest rate: 1 USD = 4043 KHR [28].

Benefit Analysis estimates potential revenue from vegetable sales based on market prices and expected yields:

$$TR_i = P_i * Q_i \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where:
TRi = Profit of crop production,
Qi = Quantity of the ith crops (Kg)
Pi= Average price of ith crops (Riel. /Kg)

The Cost-Benefit Ratio (CBR), which can be expressed using the equation of Gittinger (1982) [29], is computed as follows:

$$\text{Cost} - \text{Benefit ratio} = \frac{\text{Gross profit}}{\text{Gross cost}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The NPV can be expressed using the equation of Gittinger (1982) [29]. The decision rule for NPV is that if NPV > 0, crop production is considered financially viable, If NPV < 0, crop production is not financially viable. The net present value (NPV) is computed as:

$$\text{NPV} = \sum_{t=0}^{n} \frac{\text{Bt} - \text{Ct}}{(1+r)^t} \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where:
Bt = Total benefits in year t
Ct = Total costs in year t
r = Discount rate (1+r)
t = Discount factor for year t

Sensitivity analysis must be conducted methodically and presented understandably for decision-makers to find value. There may be trust in the efficiency impacts of production if, after considering the range of possibilities, the sign (positive or negative) of the net benefits does not change [17]. Costs and benefits are discounted at a 9.66% bank lending rate [30], with a discount factor of 0.508. The inflation rate in 2024 is 3%. The sensitivity analysis assumes a cost overrun of 9% and a 5% decrease in yield.

3. RESULTS AND DISCUSSION

Socioeconomic Characteristics of Farmers

This result indicates limited knowledge about the responses to socioeconomic variation (Table 1). Most respondents were male, with 63.83% male and 36.17% female, reflecting traditional gender roles in farming. Of the 47 respondents, 44.68% were aged 31-40, with an average age of 44.27 years (SD = 10.06). Respondents aged 51-60 comprised 21.28%, those aged 41-50 comprised 29.79%, and only 4.26% were under 30. This suggests a predominantly middle-aged, experienced farming community. The mean family size was 4.72 members (SD = 1.31), with 76.60% having 3-5 members and 27.66% having five or more. This suggests potential for family labor in farming, common in rural agricultural areas. The survey found 48.94% of respondents had two family members involved in agriculture, with an average of 2.67 labor members per household (SD = 0.76). Additionally, 34.04% had three family laborers, and 17.02% had four (Table 1). Despite having three to four family members, only 2.67 laborers, including parents and a son, contribute to crop production, while others work in non-agricultural fields.

Knowledge enables individuals to make informed decisions, grasp complex ideas, and solve problems. Farmers need knowledge to perform their duties, boost productivity, and manage resources effectively. The financial literacy of farmers in Cambodia is a complex matter, shaped by many socio-economic elements and educational qualifications [31]. Table 1 shows that 80.85% of respondents completed secondary education, while 19.15% completed only elementary education. The high number of farmers with secondary education suggests they have the formal education necessary to adopt modern farming techniques and efficiently manage crop production. Table 1 also indicates that 53.19% of respondents managed farms smaller than one hectare, 31.91% managed farms between one and five hectares, and 14.89% managed farms larger than five hectares. Regarding land ownership, 57.45% rented land, and 42.55% owned land. Most participants had 1-5 years of experience (39.08%), followed by 5-10 years (27.66%), 10-20 years (25.53%), and over 20 years (8.51%). The varying levels of experience influenced the adoption of innovative practices and farm productivity, with an average experience of 11.7 years.

Table 1. Socioeconomic characteristics of respondents

Characteristic	Frequency (n = 47)	Percentage(%)	Mean	SD
Age group (year)				
<30	2	4.26	44.27	10.06
31-40	21	44.68		
41-50	14	29.79		
51-60	10	21.28		
Gender				
Male	30	63.83		
Female	17	36.17		
Member Family (people)				
3-5	36	76.60	4.72	1.31
>5	13	27.66		
Member Labor (people)				
2	23	48.94	2.67	0.76
3	16	34.04		
4	8	17.02		
Educational Qualification				
Primary school	9	19.15		
Secondary	38	80.85		
Farm size (ha)				
<1ha	25	53.19	2.29	2.89
1-5ha	15	31.91		
>5ha	7	14.89		
Owner land				
Owner	20	42.55		
Rent	27	57.45		
Farming experience (year)				
1-5 Years	18	38.30	11.7	9.29
6-10 years	13	27.66		
11-20years	12	25.53		
>20 years	4	8.51		

The study found that during the dry season starting in December, farmers in the floodplain region began farming crops, continuing until the Mekong River flooded the area in August. In Kampong Os Commune, crops like white corn (Zea mays) and beans (legumes) were grown. Legumes were cultivated from December until their harvest in April, after which white corn was planted and harvested in August (Table 2). In Pheam Chhkaok Commune, various crops such as sweet chilli (Capsicum annuum), winter melon (Benincasa hispida), Cambodian melon (Cucumis melo), and white chilli (Capsicum annuum) were grown. Sweet chilli was planted in December and harvested in April, followed by winter melon cultivation in June and July, Cambodian melon in April and July, and white corn in May and August. In Anlong Metrei Commune, sweet chilli, white chilli, and white corn were cultivated. White chilli was grown from December to August, while sweet chilli was planted from December to May. After the sweet chilli harvest, white corn was sown and grown from June to August.

Table 2. Monthly cultivation schedule for crops grown in floodplain areas

Monthly / Crop	Dec				Jan				Feb				Mar				Apr				May				Jun				Jul				Aug			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Sweet Chilli		<	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	>														
White Chilli		<	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	>		
Bean				<	*	*	*	*	*	*	*	*	*	*	*	>																				
White Corn																	<	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	>		
Winter Melon																									<	*	*	*	*	*	*	*	*	>		
Cambodia Melon																							<	*	*	*	*	*	*	*	*	*	>			

Costs of crop production

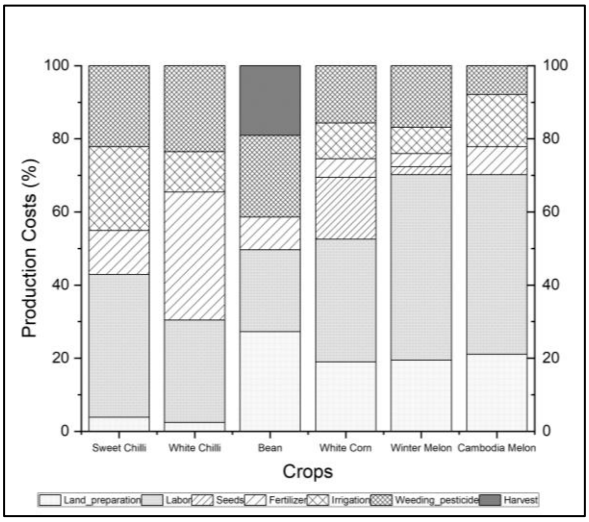

Figure 2. Comparing elemental costs of crop production as a percentage of each crop.

The significant findings of this study include the following: For sweet chilli (Figure 6), labor was the highest cost (39.07%), followed by irrigation (22.9%) and weeding and pesticide application (22.17%). Land Preparation (3.85%) was the lowest expense, while fertilizers were a notable cost (11.98%). For white chilli, fertilizer was the primary expense (35.03%), with labor (28%) and weeding and pesticide application (23.54%) also being significant. Irrigation (11.02%) and land preparation (2.4%) were minimal costs. In bean cultivation, the largest expenses were land preparation (27.23%), irrigation (22.41%), and weeding and pesticide application (22.33%), with reduced fertilizer costs (8.94%) but substantial harvest costs (19.06%). Seed costs were negligible (0%) due to using stored seeds. For white corn, the highest cost was manual labor (33.52%). Field preparation cost 18.98%, water management 16.93%, weeding and pesticide application 15.67%, fertilizer 5.09%, and seeds from suppliers 9.80%. Winter melons had higher labor expenses (50.71%), with field preparation at 19.46%.

Table 3. Average costs of production in each crop per hectare in floodplain.

Crops	Total cost of each crop (riel/ha)
Sweet Chilli	6,492,896.69៛
White Chilli	10,407,527.73៛
Bean	1,835,701.39៛
White Corn	2,633,727.59៛
Winter Melon	1,284,558.16៛
Cambodia Melon	1,186,505.55៛
Total Cost	3,973,486.19៛

*Exchange rate 1USD = 4043 KHR or riel

Irrigation needs were low, with nutrient application costs at 3.63% and water management at 7.16%. Crop protection and weed control costs were high (16.86%), while seed costs were minimal (2.15%). For Cambodia melon, labor was the highest expense (49.12%), with field preparation costs at 21.07%. Nutrient application costs were low (7.61%), but water management was significant (14.32%). Weed and pest management costs were moderate (7.86%).

Benefits of crop production

This study examined the production and market value of crops listed in Table 4, including white chilli, sweet chilli, bean, white corn, winter melon, and Cambodian melon. Sweet Chilli generated the highest income at 8.75 million Riels, with a mean yield of 7,000 kg/ha and a range of 6,000–8,000 kg/ha. Bean production averaged 900 kg/ha, ranging from 600 to 1,200 kg/ha. White corn's production varied from 3,000 to 5,000 kg/ha, averaging 4,000 kg/ha and generating 4 million Riels. Winter Melon yields ranged from 8,000 to 10,000 kg/ha, averaging 6,000 kg/ha. Cambodian Melon harvests ranged from 4,000 to 5,500 kg/ha, averaging 4,750 kg/ha and generating 3.8 million Riels. White chilli, despite lower yields, was the most lucrative due to its high unit price, while bean had the lowest yield and income, indicating a lower market value.

Table 4. Average yields and prices of crops output

Vegetable items	Sales Revenue				
	Yield Range kg/ha	Mean Yield kg/ha	Price Range riel/kg	Mean Price riels/kg	Revenue riels/ha
Sweet Chilli	6,000-8,000	7,000	1,000-1,300	1,250	8,750,000.00
White Chilli	3,500-4,000	3,750	3,500-4,000	3,750	14,062,500.00
Bean	600-1,200	900	2,300-3,300	2,800	2,520,000.00
White Corn	3,000-5,000	4,000	800-1,200	1,000	4,000,000.00
Winter Melon	8,000-10,000	6,000	500-600	550	3,300,000.00
Cambodia Melon	4,000-5,500	4,750	600-1,000	800	3,800,000.00
Total					6,072,083.33

*Exchange rate 1USD = 4043 KHR or riel

The impact of farmers' education on total crop yield was statistically significant as determined by t-test ($p < 0.009$), primarily through enhanced skills, improved resource management, and increased adoption of modern agricultural practices.

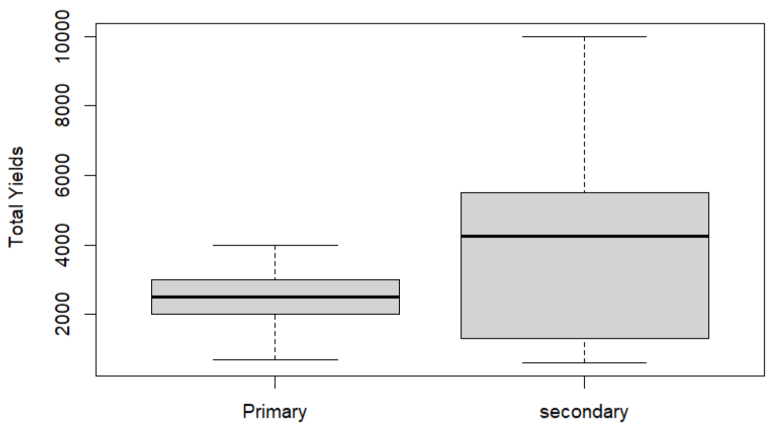

Figure 3. Impact of farmers' education on total crop yield

Detailed analyses were needed to determine cash flow by inflow (crop sales). The average income from crop sales was 6.07 million riels, with a high standard deviation indicating unsustainable income likely due to variations in yields, market prices, or crop types. Cash outflow (production costs) averaged 3.97 million riels, also with significant deviation due to fluctuations in labor costs, input expenses, and operational expenditures across harvest cycles. The net cash flow, as the difference between revenue and expenditure, averaged 2.09 million riels. Though a positive cash flow suggests profitability, volatility indicates profit levels may vary significantly due to various factors. The net present value (NPV) averaged 1.06 million riels, indicating the financial viability of agricultural cultivation in floodplains. A positive NPV of 1.06 million riels suggests that, on average, investment in crop production would yield positive returns after accounting for capital costs (loan interest), indicating potential financial success.

Table 5. Cash Flow Summary: Cost-Benefit Analysis for Crop Production

Cash flow	Mean (Riels/ha)	Std. Deviation
Cash inflow (sales)	6,072,083.33៛	4,098,284.81
Cash outflow(cost)	3,973,486.19៛	3,393,793.15
Net cash flow	2,098,597.15៛	935,948.86
Discount factor @ 9.66%	0.508	
Net present value	1,066,087.35៛	
Cost-benefit ratio	1.53	

*Exchange rate 1USD = 4043 KHR or riel

The cost-benefit ratio indicated a return of 1.53 for every unit invested in the manufacturing process, suggesting that benefits exceeded costs, confirming the profitability of floodplain crop growth. Linear regression analysis examined agricultural output in the Tonle Sap River floodplain. A significant linear relationship was found between total costs and income, illustrated in Figure 8. The linear regression equation between total cost and total revenue for crop production is as follows:

$$Y = (-9.862e + 05) + 0.8168 * X \ldots\ldots\ldots\ldots\ldots\ldots. (5)$$

The regression equation shows that the total cost rose by about 81.68% for every unit increase in total income, explaining 97.29% of the cost fluctuation. The R-squared value of 0.9729 confirms this accuracy. With a p-value of 0.000278, the cost-income relationship is statistically significant. The positive gradient suggests that costs rise with income growth, typical in crop production. The negative y-intercept may imply fixed expenses or initial investments not fully recouped at lower income levels.

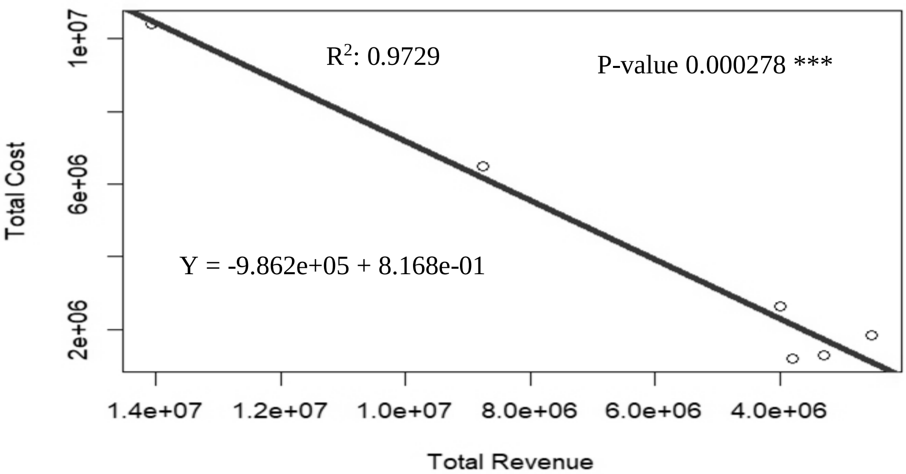

Figure 4. Linear regression analysis of the relationship between total cost and total revenue in crop production within floodplain areas.

In the floodplain area, a study found that a 9% increase in inflation-induced cash outflow and a 5% decrease in cash inflow negatively impacted crop production finances. The initial cash inflow of 6.07 million Riels dropped to about 5.76 million Riels, while cash outflow rose from 3.97 million Riels to around 4.33 million Riels. Consequently, net cash flow decreased by 0.66 million Riels, from 2.09 million Riels to 1.43 million Riels, causing the net present value (NPV) to fall from 1.06 million Riels to 0.73 million Riels. The cost-benefit ratio also dropped from 1.53 to about 1.33, indicating a lower return on investment. This situation exposed the financial sustainability of crop production to unsustainable income and costs, resulting in reduced profitability. These findings highlight the importance of favorable market conditions and effective cost management for sustained profitability in floodplain agriculture. The return on investment (ROI) significantly decreased from 52.83% to 33.19%, underscoring the need for revenue maximization and cost control in agricultural operations.

Table 6. Sensitivity analysis for the crop production

Cash flow	Mean (riels/ha)	Std. Deviation
Cash inflow (sales)	6,072,083.33៛	4,489,446.07
Reduction (5%)	303,604.17៛	224,472.30
Cash outflow(cost)	3,973,486.19៛	3,717,714.13
Cost over-run (9%)	357,613.76៛	334,594.27
Net cash flow	1,437,379.22៛	
Discount factor @ 9.66%	0.508	
Net present value	730,188.65៛	
Cost-benefit ratio	1.33	

*Exchange rate 1USD = 4043 KHR or riel

Opportunities and challenges accompany any endeavor. According to Figure 5, 27 farmers expressed significant concern about climate change, while 21 viewed soil fertility as a moderate issue. The agricultural market is a major obstacle, with 21 farmers rating it as a "strong" issue. Twenty-three farmers considered agricultural practices an average problem, and the harvest process is seen as moderate. The labor force is a moderate concern, with 35 farmers perceiving it as a "little" problem. For irrigation, 26 farmers see it as a "little" issue, while 34 view pest and weed management as "average." Fertilizer application is seen as an "average" issue by 25 farmers, and seed quality or availability by 30 farmers. Land preparation is a minor difficulty, with only 7 farmers considering it a significant concern, aligning with the administrative community's response.

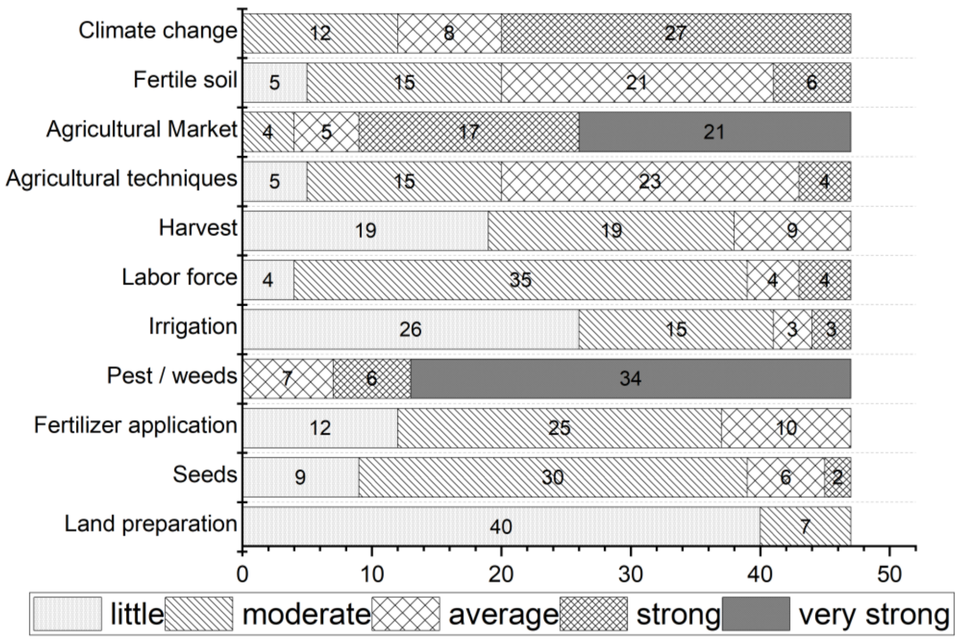

Figure 5. Factors contributing to reduced crop yields as reported by farmers.

3.1. Evaluate the costs and benefits of crop production

This study aimed to assess the economic viability of cultivating crops in floodplains during the dry season, with a specific focus on Chulkiri District in Kampong Chhnang Province. The findings indicate considerable differences in expenses and revenues among various crops, demonstrating the complex nature of agriculture in floodplain areas. A notable discovery was that workforce costs and field preparation represented the main expenditures for most crops, primarily because of the labor-intensive nature of the work and the extensive land preparation required. This observation aligns with previous research, such as studies by [32], and [33] which emphasizes the significant role of labor costs in overall agricultural production expenses. It was apparent that the farmers involved in this study employed traditional farming methods, encompassing all stages from sowing seeds to harvesting, relying solely on manual labor without using any efficiency-boosting technologies. In addition, many farmers are forced to rent land from other individuals to practice agriculture. Moreover, fertilizer expenses varied significantly among crops, with white chilli incurring the highest costs. This observation does not align with previous research such as studies by [34], in which fertilizer costs were minimal for riverbank farming. At the study sites, the cost of fertilizer varied depending on the crop type. White Chilli, cultivated from December of the previous year until the first week of August in the following year, required a higher fertilizer expenditure. In contrast, in the bean crop, grown in the last week of December and harvested in March, only a few farmers require fertilizer application. The study also revealed that while sweet chilli was the most profitable crop due to its high yield and market price, bean production was the least lucrative, primarily because of its lower yield and market value.

While floodplain farming benefits from natural flood and dry cycles that boost soil nutrients, it requires greater investment in resources such as fertilizers, pest management, and workforce [10];[12]. Research conducted by [35] and [23] demonstrated that agricultural yield in floodplains is linked to water flow patterns, with yearly flooding enhancing soil fertility but posing management issues, necessitating increased resource inputs and effective water and soil administration in more affluent regions. Farming in floodplains demands substantial upfront costs for infrastructure such as irrigation systems and flood defenses, which can be burdensome without adequate income [36]. The high R-squared value of 0.9729 in this study, corroborated by [37], indicates that income explains most of the variation in overall expenses, underscoring the need for careful financial planning and tactics to reduce instability in floodplain settings.

The assertion that the Net Present Value (NPV) is positive and the cost-benefit ratio (CBR) is 1.53 for crop production in floodplain areas aligns with the findings of [38]. This indicates that the NPV of floodplain agriculture can indeed be positive when considering both the costs of potential flood damage and the benefits of agricultural utilization.

The sensitivity analysis further emphasized the susceptibility of crop production to fluctuations in costs and market conditions, indicating that even minor changes can significantly impact profitability. This finding is crucial for farmers and policymakers, as it underscores the importance of managing input costs and securing favorable market conditions to ensure sustainable agricultural practices.

3.2. Opportunities and Key Challenges

Furthermore, the study highlighted several challenges faced by farmers, agricultural productivity and economic returns are significantly diminished by moderate stress from crop-damaging insects, as noted by [39], which also impacts labor costs. Fungal diseases and insect pests thrive in humid and moist environments. This study's survey participants reported using chemical pesticides, which have sensitive ecosystems, and the risk of water contamination. Integrated pest management (IPM) combines cultural and biological methods, such as employing natural pest enemies (e.g., birds, ladybugs, spiders, praying mantis), and mitigates environmental impacts through practices such as crop rotation and intercropping.

Agriculture faces substantial challenges owing to climate change, which affects growing conditions, crop distribution, and yields, while also increasing the occurrence of severe weather events. Additionally, it creates difficulties in water resource management and animal husbandry. Rising temperatures lead to heat stress, water shortages, and soil degradation, while extreme weather damages crops, accelerates soil erosion, and ruins the infrastructure. To address these issues and ensure global food security and sustainable agricultural growth, it is crucial to implement effective water management strategies[40].

Limited financial literacy and market volatility were consistently identified as major challenges in this study. Farmers in the region often lack essential financial knowledge, which impedes their ability to make informed investment decisions and effectively manage debt. Market volatility, exacerbated by fluctuations in global food prices and supply chain disruptions, also significantly impacts revenue, potentially jeopardizing livelihoods [41]. Addressing these challenges requires targeted interventions, such as financial training for farmers and improved access to agricultural inputs.

This study found it to have a positive and significant impact on factors affecting farmers' crop production in floodplain areas. This indicates that crop production efficiency is profitable in floodplain areas. This positive effect was consistent with the studied by Kailali (2020) and Sarkar et al. (2023) [42], which demonstrate that floodplain areas enhance crop production efficiency, with the costs of land planning, irrigation, weeding, chemical spraying, and fertilizer application being lower in these regions. However, labor costs and farmer education present significant challenges, as identified by Sarkar et al. (2023). This was probably because the farmers continued utilization of traditional agricultural methods, which employed manual labor from seedling to harvest, thereby resulting in elevated labor costs. The findings have implications for optimizing crop production management and production techniques for smallholder farmers in Chulkiri District, Kampong Chhnang Province. However, the study exhibits limitations, such as the data collection period, and the constraint of not fully representing other floodplain regions with only crop cultivation except for paddy crops.

4. CONCLUSION

This study investigates agricultural practices in floodplain regions, focusing on crop cultivation during the arid season, primarily during the Mekong River inundation. In the floodplain, farmers start cultivation in December as water levels recede, continuing until August when they rise. Farmers used rotation cropping, combining beans with white corn and sweet chilli with Cambodian or winter melon, and mono-crop white chilli. Their farming methods are shaped by their education, primarily by gaining technical knowledge from neighboring farmers. Financial literacy is crucial for informed decision-making and resource management. The majority of farmers have attained secondary education, and their experience levels influence innovative practices and productivity.

Crop production in floodplain areas exhibits moderate profitability, as evidenced by the Net Present Value (NPV) and cost-benefit ratio, despite a 10% increase in total costs. Labor costs constitute the primary expense for cultivation, followed by irrigation, fertilizer, weeding, and pesticide application. Notwithstanding the nutrient-rich soil, fertilizer costs remain significant due to prolonged crop growth. Although floodplain agriculture benefits from nutrient-rich soils and diverse farming systems, it faces challenges such as labor availability, limited financial literacy, pest control, falling crop prices, climate change, and inadequate seed storage. The findings indicate economic benefits but highlight the need for measures to overcome challenges and ensure long-term viability, including enhancing financial education, broadening farming resources, and stabilizing market conditions.

This evaluation acknowledges several limitations in our study, including only considering costs over one year. Future research should consider long-term analysis to examine accounting and economic costs using data over five years or compare the same crop production in floodplains and uplands.

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