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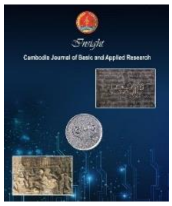

Improving local adaptive capacity to mitigate the negative impact of climate change: A case study of Tram Kak District, Takeo Province

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សង្ខិត្តន័យ

បម្រែបម្រួលអាកាសធាតុគឺជាការផ្លាស់ប្តូររយៈពេលវែងនៃសីតុណ្ហភាព និងលំនាំអាកាសធាតុ។ មួយក្នុងចំណោមគ្រោះធម្មជាតិធំៗទាំងពីរក្នុងប្រទេសកម្ពុជា នោះគឺគ្រោះរាំងស្ងួត។ គោលបំណងនៃការសិក្សានេះគឺចង់ស្វែងយល់ឱ្យបានស៊ីជម្រៅអំពីផលប៉ះពាល់អវិជ្ជមាននៃការប្រែប្រួលកាសធាតុ ដែលផ្តោតលើគ្រោះរាំងស្ងួត ឬកង្វះទឹកធ្វើស្រែរបស់កសិករខ្នាតតូចនៅឃុំចំនួនពីរ ក្នុងស្រុកត្រាំកក់ ខេត្តតាកែវ។ ការសិក្សាបានរកឃើញថា៖ (១) កសិករខ្នាតតូចក្នុងឃុំស្រែរនោង ភាគច្រើន ធ្វើស្រែដោយប្រើប្រាស់ពូជស្រូវធ្ងន់ ដែលធ្វើឱ្យពេលវេលាបញ្ចប់ការប្រមូលផលយឺតជាងឃុំញ៉ែងញ៉ង; (២) ក្នុងរយៈពេលមួយទសវត្ស កសិករខ្នាតតូចក្នុងឃុំញ៉ែងញ៉ងរងផលប៉ះពាល់ដោយគ្រោះរាំងស្ងួតខ្លាំងជាងឃុំស្រែរនោង លើកលែងតែនៅឆ្នាំ២០២១ គ្រោះរាំងស្ងួតបានប៉ះពាល់ប្រហាក់ប្រហែលគ្នាលើដំណាំស្រូវក្នុងឃុំទាំងពីរ។ នៅក្នុងតំបន់សិក្សា ប្រសិនបើកើតមានគ្រោះរាំងស្ងួតឬកង្វះទឹក កសិករខ្នាតតូចតែងមានជម្លោះក្នុងការទាញយកទឹកមកស្រោចស្រពដំណាំស្រូវពីប្រឡាយ ឬស្រះសហគមន៍; និង (៣) កសិករខ្នាតតូចក្នុងតំបន់សិក្សាមានសមត្ថភាពបន្សាំខ្ពស់។ ដើម្បីផ្គត់ផ្គង់ការធ្វើកសិកម្មដោយខ្លួនឯង ពួកគាត់ព្យាយាមបង្កើតប្រភពទឹកដូចជាការជីកស្រះជាដើម។ ប៉ុន្តែប្រភពទឹកទាំងនេះ ចំពោះដំណាំស្រូវ គ្រាន់តែអាចស្រោចស្រពបានតិចតួច ដើម្បីកាត់បន្ថយការខូចខាតប៉ុណ្ណោះ មិនអាចទប់ទល់នឹងគ្រោះរាំងស្ងួត ឬការខ្វះទឹករយៈពេលវែងបានទេ។ ពិតជាសំខាន់ណាស់ ប្រសិនបើស្ថាប័នពាក់ព័ន្ធសំខាន់ៗទាំងថ្នាក់ជាតិ និងទាំងថ្នាក់ក្រោមជាតិមានសកម្មភាពបន្ថែម ដើម្បីធានាឱ្យសហគមន៍ជនបទទាំងឡាយមានភាពធន់នឹងការប្រែប្រួលអាកាសធាតុ។ សកម្មភាពទាំងនោះគួរយកចិត្តទុកដាក់លើការអភិវឌ្ឍកសិកម្មប្រកបដោយនិរន្តរភាព ដោយផ្តោតលើ៖ ការអភិវឌ្ឍប្រព័ន្ធធារាស្ត្រដែលមានគុណភាពខ្ពស់, ផ្តល់ការបណ្តុះបណ្តាលបច្ចេកទេសកសិកម្មបន្ថែម, ការលក់ស្រូវពូជធន់នឹងភាពរាំងស្ងួតក្នុងតម្លៃទាប, ពង្រឹងកសិករខ្នាតតូចឱ្យចេះផលិតពូជមានគុណភាពដោយខ្លួនឯង, និងផ្តល់ឱកាសជូនប្រជាពលរដ្ឋក្នុងសហគមន៍ចូលរួមនិងកំណត់គម្រោងអភិវឌ្ឍន៍នានាក្នុងមូលដ្ឋាន។

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ABSTRACT

Climate change is a long-term change in temperature and weather patterns. Drought is one of the two major natural disasters in Cambodia. The study aims to better understand the negative impact of climate change on the rice production of small-scale farmers in two communes in Tram Kak district, Takeo province, by focusing on droughts or water shortages. It was found that (i) the small-scale farmers of Sraeronorng commune mostly cultivated late-cycle rice, and the harvest was completed later than small-scale farmers in the Nhaenghorng commune, and (ii) the impact of drought over a decade affected small-scale farmers in the Nhaenghorng commune more than the Sraeronorng commune, except in 2021 when the impact on rice production in the two communes was similarly high. If a drought or water shortage came, most small-scale farmers would have a dispute over access to water from canals or community ponds to irrigate their rice fields. However, (iii) the small-scale farmers were found to have a high adaptive capacity to droughts or water shortages. The study also found that most small-scale farmers tried to construct their water sources to supply their agricultural cultivation, such as digging their ponds. However, these water sources can only provide small amounts of irrigation to reduce rice damage in the event of a long-term drought or water shortage. In addition, it was very important that all key stakeholders, both at the national and local levels, take more action to ensure the resilience of rural communities. These actions should focus on developing high-quality irrigation systems, training on agricultural techniques, selling drought-resistant rice seeds at a low price, and strengthening small-scale farmers' capacity to produce their quality seeds. Local development projects must include planning and participation of community members.

1. Introduction

Climate change is a global environmental challenge, but the degree of effects is often felt locally (BUI et al., 2022). The impacts of climate change are increasingly threatening to the well-being of the people, the success of poverty reduction, and the ambitions of the southern hemisphere countries (Agrawal & Carmen, 2015; Hoegh-Guldberg et al., 2018). Climate change represents one of the biggest environmental, social, and economic threats the world is currently facing (Dhar & Mazumdar, 2009). As a result of climate change, developing countries face immediate concerns related to land degradation, a shortage of fresh water, food insecurity, and air and water pollution (Wright et al., 2015). At the end of the 21st century, temperatures in Southeast Asia are expected to rise from 0.8℃ in the lowest emissions scenario to 3.2℃ in the highest emissions scenario (IPCC, 2013).

If the temperature rises just 2℃, the Southeast Asia region will experience additional effects, such as tropical cyclones, rising sea levels, saltwater intrusion, floods and droughts, pests, and diseases. These phenomena are predicted to significantly impact agricultural production (Wassmann et al., 2009). Cambodia is a small Southeast Asian country with a total population of 16,524,482. Designated as an agricultural economy, the rural people in Cambodia depend on farming and horticulture as the main source of their livelihood and the backbone of the rural economy (Chhinh & Cheb, 2013). As of 2020, 35.5% of the population was employed in agricultural work (RGC, 2022). An estimated 1,726,000 households, approximately 50% of the total number of households in Cambodia, were involved in some agricultural activities on their household lot. Another 12% were engaged on separate household lot land parcels, and the remaining 35% were on separate parcels (MoP, 2019).

Cambodia is one of the countries in Asia most vulnerable to the impacts of climate change (Yusuf & Francisco, 2009). In 2019, 76% of the 16.5 million people living in Cambodia resided in rural areas, and most of them were small-scale farmers (Chhun et al., 2020; World Bank, 2021). Rice production contributes significantly to Cambodia's GDP, making up 4.5% and accounting for 20% of total family income (Sokcheng et al., 2017). In 2018, rice was exported to 61 countries by 87 rice-export companies, in an amount of 626,255 tons (ADB, 2021). However, the livelihoods of most farmers in Cambodia remain at the subsistence level, making their livelihoods highly susceptible to the effects of climate change on environmental conditions (Sary et al., 2020; Thangrak et al., 2020).

Cambodia has proven to periodically suffer from two types of major natural disasters: floods and droughts. These are likely to increase in the future due to climate change (Nguyen & Shaw, 2010). This study focuses on drought. The farmers in Cambodia face three challenges: (1) extreme drought, which detrimentally affects rice production; (2) lack of water storage to provide for sufficient irrigation; and (3) low level of local adaptation to the impacts of drought. Drought has caused significant damage to crop production and reduced agricultural productivity over the last decade, affecting domestic food prices, threatening food security, and escalating poverty, particularly in developing countries (Hameed et al., 2020). Drought affects many aspects of farming activities, making the community vulnerable. In Cambodia, drought is linked to decreased crop production because most of the agricultural production depends on rainfall. Cambodia was reported to have food shortages due to prolonged drought, with prolonged droughts occurring in 2001, 2002, 2004, 2005, 2011, and 2012 (Seng, 2020). Between 1994 and 2006, drought damaged more than 1,000 hectares of rice production, and drought is a significant livelihood hazard in Cambodia (Chhinh & Millington, 2015). In Cambodia in 2016, 31.3% of the rice-growing area was affected by severe drought during the dry season, compared to 26.1% in 2017 (Son & Thanh, 2022).

During the 2014–2016 El Nino, Cambodia experienced severe drought. In 2016, water levels in Cambodia's rivers fell 50–70% below the interannual average (Sutton et al., 2019). This made 2016 the driest year in the country's history, with one of the worst droughts in 50 years. Over the past 30 years, drought has affected the Tonle Sap region, which is highly vulnerable, and the lack of water severely impacts paddy rice cultivation (Sok et al., 2021). Approximately 35% of Cambodia's people did not have access to safe water during the drought (WHO, 2016). Water is also an indispensable ingredient for agricultural production, and supply is strongly influenced by changing hydrological cycles (Furuya & Meyer, 2008). In general, dry-season irrigation does not benefit people with low incomes because they are less able to afford access to water and less willing to take risks. Full irrigation of dry-season rice crops provides high yields, and returns from irrigation are much higher than in the wet season. Still, dry-season cultivation requires high levels of inputs (improved seeds, fertilizer, and pesticides) (He et al., 2020).

In Cambodia, scholars have associated their studies of climate change with (Manohar et al., 2023), adaptation, resilience, and sustainable livelihoods (Sok and Yu, 2015). The effects of climate change and the adaptability of local people vary with geography, but climate change generally increases existing vulnerabilities. Adaptation measures and options vary by sector, particularly areas of adaptive capacity and severity of impacts (Nuorteva et al., 2010). The ability of local communities to respond to or adapt to the effects of climate change remains limited. At the same time, communication systems and coordination mechanisms for effective multi-disaster warning systems are still lacking, and the preparedness capacity of local communities at risk of natural disasters remains low (RGC, 2012). The aim of this research is to achieve a better understanding of the negative impact of climate change, focusing on drought or water shortages for rice production of small-scale farmers, to achieve three objectives: (1) examine the characteristics of paddy rice cultivation practices; (2) understand the negative impacts of water shortages on dry-season and wet-season rice crops; and, (3) explore local adaptation strategies related to water shortages in support of livelihoods dependent on rice production.

2. Theoretical Framework

Drought is classified into a wide range of impacts, such as economic, environmental, and social (Bachmair et al., 2016). The existing studies about the effects of drought on rice framers in Cambodia cover the role of agricultural cooperatives (ACs) in drought risk management (Chhinh et al., 2022; Chhinh et al., 2023). In societies where agriculture is the main economic activity, the most direct effect of drought is observed as a decrease in food production through the reduced area farmed and crop yields (Zarafshani et al., 2016). The development community is becoming more aware of how their interventions and investments can enhance communities' capacity to cope with climate variability and change (De Bettencourt et al., 2013; Mitchell, 2013). As a result, both the development and research communities have shifted toward the promotion of integrated concepts such as resilience, Disaster Risk Reduction (DRR), and Climate Change Adaptation (CCA) (Schipper & Langston, 2015). Researchers from different disciplines (Tinch et al., 2015; Juhola & Kruse, 2015; Yusuf & St. John, 2017) have conceptualized adaptive capacity differently based on their objectives and the methods employed within their respective contexts.

This study not only relies on theories, frameworks, and the application of the relevant concepts but also focuses on practical solutions to problems in the context of the study area. The study makes use of the theory of dependency (Adger, 2006; IPCC, 2007; Goldman & Riosmena, 2013; Horlings & Marschke, 2020; Mesfin et al., 2020); adaptive capacity framework (de Boon et al., 2022); agricultural innovation (Redwood, 2012; Sah, 2002; Xu et al., 2015); sustainable livelihood frameworks (Dai et al., 2020; Skakun et al., 2016); and, agricultural adaptation and risk impacts. The main framework of the research is adopted from the Intergovernmental Panel on Climate Change (2007), which establishes that improving rural and household adaptation capacity and climate activity response will importantly reduce the negative impacts of climate change and help build resilience and reduce the vulnerability of rural people. Sano et al. (2011) applied this framework to integrate the results of outcomes from "Future Coastlines" and the "Southeast Queensland Climate Adaptation Research Initiative."

Human and natural systems are always interacting, causing impacts on the climate system (Liu et al., 2020). Human use of land, water, and forests has drastically altered land cover, hydrological cycles, ecology, and climate. Furthermore, natural processes can negatively impact human systems through environmental damage and disasters such as floods, droughts, hurricanes, diseases, etc. To address the study's objectives and research questions, the framework demonstrates that livelihood improvement depends on small-scale farmers' capacity to adapt to climate change impacts. It is based on the following assumptions: (a) farmers adapt by utilizing local resources and assets; (b) asset utilization results in adaptive capacity; and (c) farmers innovate to adapt and overcome challenges in their context to improve their livelihoods.

This framework sees livelihoods as an aid to or a constraint on the adaptive capacity to the effects of climate change of small-scale farmers. In this study, adaptive capacity is defined as the ability of a system to modify or alter its behavior or actions to moderate potential damage, take advantage of opportunities, or cope with the consequences of trauma or stress. The livelihood outcome in the framework of this study will be the adaptive capacity of small-scale farmers, treated as the dependent variable. The framework also assesses mechanisms to strengthen adaptive capacities to reduce risks, such as agricultural technology, integrated pest management, skills, and knowledge. In the context of agriculture, innovation is necessary for adaptation and response to problems. Farmers can improve their livelihood by strengthening adaptive capacity, increasing productivity, selling at a suitable price, and maintaining or increasing income.

3. Study Area and Methodology

Tram Kak district in Takeo province was selected as the research site as it is located in an area that is highly vulnerable to drought. Within this district, two communes were selected through stratified sampling for a comparative study focusing on different contexts and varying agricultural practices and capacity to respond to the impacts of climate change. The selected communes were Nhaengnhorng and Sraeronorng. In line with Yamane's (1967) calculations, with an acceptable sampling error of 9%, 120 respondents across 12 villages were selected for interviews (Fig. 1).

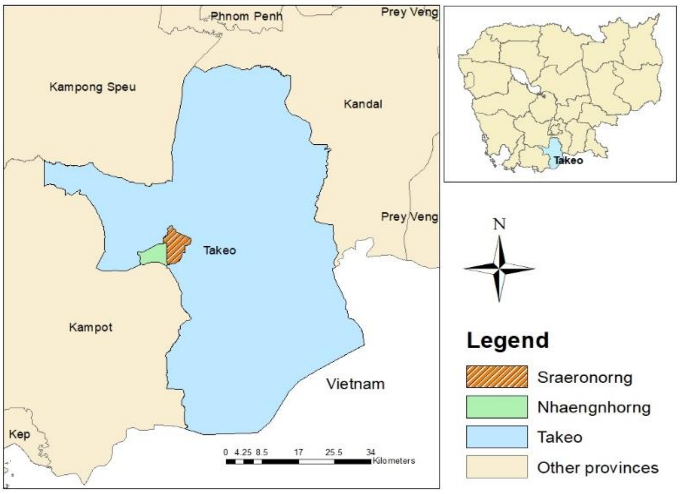

Fig. 1. Maps of Takeo province highlighting the study commune.

According to the commune database 2021, Nhaengnhorng is a rural commune with a population of 6,717 (3,523 females) and 1651 households. A sample of 54 respondents was selected from six of the eleven villages in this commune. The majority of villagers were mainly engaged in agriculture (75.4%). In the commune, there were 1860 hectares of farmland, and the total farmland that received water from the irrigation system amounted to 34 hectares pertaining to 43 households. Sraeronorng commune had a total population of 9,579 people (4,819 females), comprising 1,960 households (DoP, 2021). In total, 66 respondents were selected from six of the seventeen villages in this commune. The villagers depended on agriculture (78.2%); this commune had 3,039 hectares of farmland, and 12 canals with a length of 89,500 meters. 1,100 hectares of farmland (36.3%) obtained water from the parallel irrigation system and a community lake with an area of 17 hectares. For both communes, the sources of income were rice farming, home gardening, animal husbandry, factory work, and overseas migrant work.

Government agencies, non-governmental organization (NGO) staff, and local authorities were consulted as key informants. Secondary data was collected from web databases, journal articles, research reports, and official government reports. Primary data was collected from respondents via a field survey, participant observation, and focus group discussions. For quantitative analysis, statistical techniques were used to calculate the mean, standard deviation, and gain coefficient of daily income across three sources (agriculture, non-agriculture, and other). This information resulted in a calculation of inequalities across each of the communes studied, and a correlation was used to test the relationship between agricultural land and sources of income. Further, a weighted average index (WAI) with a five-point scale was used to assess the degree of satisfaction with available support mechanisms, institutional arrangements, and degree of dependency.

4. Results and Findings

4.1 Socio-economic characteristics of small-scale farmers

Cambodia is a highly rural and agricultural society. Agricultural practices have improved farming production, contributing to economic growth and rural household income. The difference was very significant when comparing the size of agricultural land between the two communes by *t*-test analysis (*p*-value=0.001). This means the size of agricultural land for farming in the two communes differed greatly. As a result, villagers in Sraeronorng had more opportunities for agriculture based on the ground they had access to. Overall, the average land use for both study areas was 1.13 hectares per household—1.34 hectares in Sraeronorng and 0.87 hectares in Nhaengnhorng. The standard deviation of agricultural land between both communes were 0.85 hectares (Fig. 2). For decades, the trend has been where a single occupation could no longer support a rural household. Moreover, excessive household spending can lead to an increase in the poverty rate in rural areas. As a result, almost all the villagers engaged in more than one occupation to obtain their household income in the two study areas. Agriculture has contributed to creating jobs, providing food, and expanding the household income of the rural population. In the communities studied, the residents undertook various types of occupations in the agricultural and non-agricultural sectors.

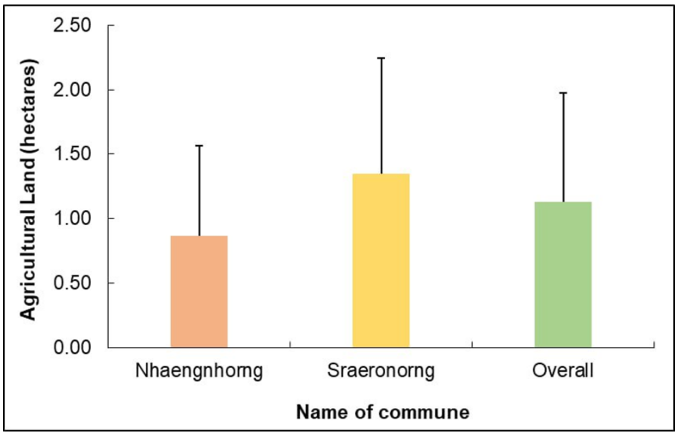

Fig. 2. Agricultural land size of respondents. ***p*-value=0.001 is very significant.

Most residents work predominantly in the agricultural sector, including 92.5% in rice production. In the sample survey, there were no respondents whose primary agricultural occupations were vegetable farming, fishing, or animal husbandry. They were mainly employed workers, self-employed individuals, and employees; this accounted for 7.5% of non-agriculture sources of income in the target areas.

Furthermore, the results also found that 94.2% of the respondents had secondary occupations. These were in the agricultural sector (rice cultivation, gardening, and livestock), which accounted for 73.2%, and in the non-agricultural sector (self-employed worker, employed worker, and self-owned business), which accounted for 27.2% (Table 1).

Table 1. Types of primary occupation of the respondents.

Attributes	Nhaengnhorng (n=54)	Sraeronorng (n=66)	Overall (n=120)
Agricultural sector			
Rice farming	92.6	92.4	92.5
Vegetable farming	0.0	0.0	0.0
Fishing	0.0	0.0	0.0
Raising Livestock	0.0	0.0	0.0
Sub-total	92.6	92.4	92.5
Non-agricultural			
Self-employment	0.0	0.0	0.0
Wage labor	5.6	5.6	5.1
Self-owned business	0.0	0.0	0.0
Employee	1.9	3.0	2.4
Sub-total	7.4	7.6	7.5

Note: The percentages of households engaged in more than one occupation in the two communes were 92.4% in Nhaengnhorng and 92.6% in Sraeronorng.

Overall, there was a difference between the average monthly household income of both communes (1,389.86 thousand riels) and the rural poverty line (1,637 thousand riels). One Sample *t*-test found this significantly different (*p*-value = 0.014). This meant that the overall income of households was lower than the rural poverty line. However, the *t*-test also enabled a comparison of the various sources of income of the households in the study area. The average monthly income in Nhaengnhorng (1,564.03 thousand riels) was compared with Sraeronorng (1,215.69 thousand riels), and the difference was found to be not significant (*p*-value = 0.105). The residents obtained their monthly income from three main sources: agriculture (rice farming, gardening, animal husbandry, and fishing), non-agriculture (physical labor, self-employed work, and employee). Sources of income for the two study areas were compared: agricultural source of income (*p*-value = 0.679) was insignificant, and non-agricultural or employee source of income (*p*-value = 0.020) was very significant. This meant the incomes of households from non-agricultural sources in Nhaengnhorng were significantly higher than those in Sraeronorng. Still, the incomes from self-employment sources (*p*-value = 0.712) were not significantly different (Fig. 3).

There were other sources of income besides rice farming, according to key data collected from respondents interviewed in the target areas. Rice farming inputs, such as fertilizer and gas-powered plows, cost a lot of money, and some families have small plots of land. There were often animals to raise in each family, such as cows, chickens, ducks, and a few extra vegetables to grow to earn more money. The income from

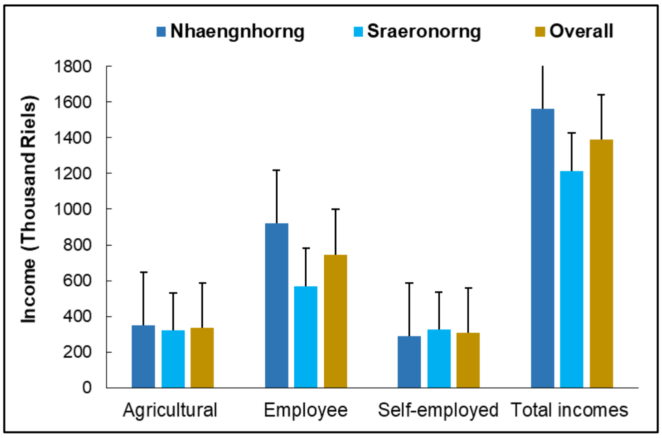

Fig. 3. Average household monthly income by source 2021.

raising animals and growing vegetables was substantial, depending on how diligent or lazy the family was. Most family members worked in companies, garment factories, NGOs (less), MFIs, or Banks. Furthermore, in addition to these extra income-generating jobs, some families migrated to work in the city and overseas. Below is a direct communication with Ms. Samouern, a woman farmer from Tropeangroboem, Sraeronorng, from May 2022.

“Because relying on a previous farm cannot support the family, I had two daughters working in a factory who could earn some extra income. I also have a son with his wife, who worked at a coconut factory in Thailand before the explosion of COVID-19. They regularly sent me monthly money to buy food and milk for their two children, for whom I was responsible. But now, sometimes every two months, the money is dropped only once. However, a small sum was earned by my two daughters to help support my son’s two children.”

The Pearson correlation is the best-fit line through two variables of data and the Pearson correlation coefficient. It indicates the distance between these data points of the most suitable line. In the study areas (Fig. 4), the relationship was analyzed between agricultural land and various sources of income. Agricultural land was correlated with agricultural income, with a Pearson correlation = 0.36 and *p*-value = 0.000, which was perfectly significant. This meant that farmland and agricultural income were more perfectly correlated. If the size of agricultural land were larger, the people’s incomes from paddy rice, animal husbandry, and vegetable growing would increase. Furthermore, agricultural land was closely associated with non-agricultural or employment income sources, with a Pearson correlation = 0.89 and *p*-value = 0.013, indicating a highly significant relationship. This result can be explained by the fact that if a farming family has a larger agricultural area, they do not rely on income from agriculture alone; instead, they try to find more work to increase additional income in the family, regardless of the type of work. Agricultural land was not correlated with self-employed income sources, as (*p*-value > 0.05) a significant association was not found. The last correlation analysis was used to investigate if there is an association between total household income and agricultural land. The result showed no correlation, as (*p*-value > 0.05) a significant association was not found.

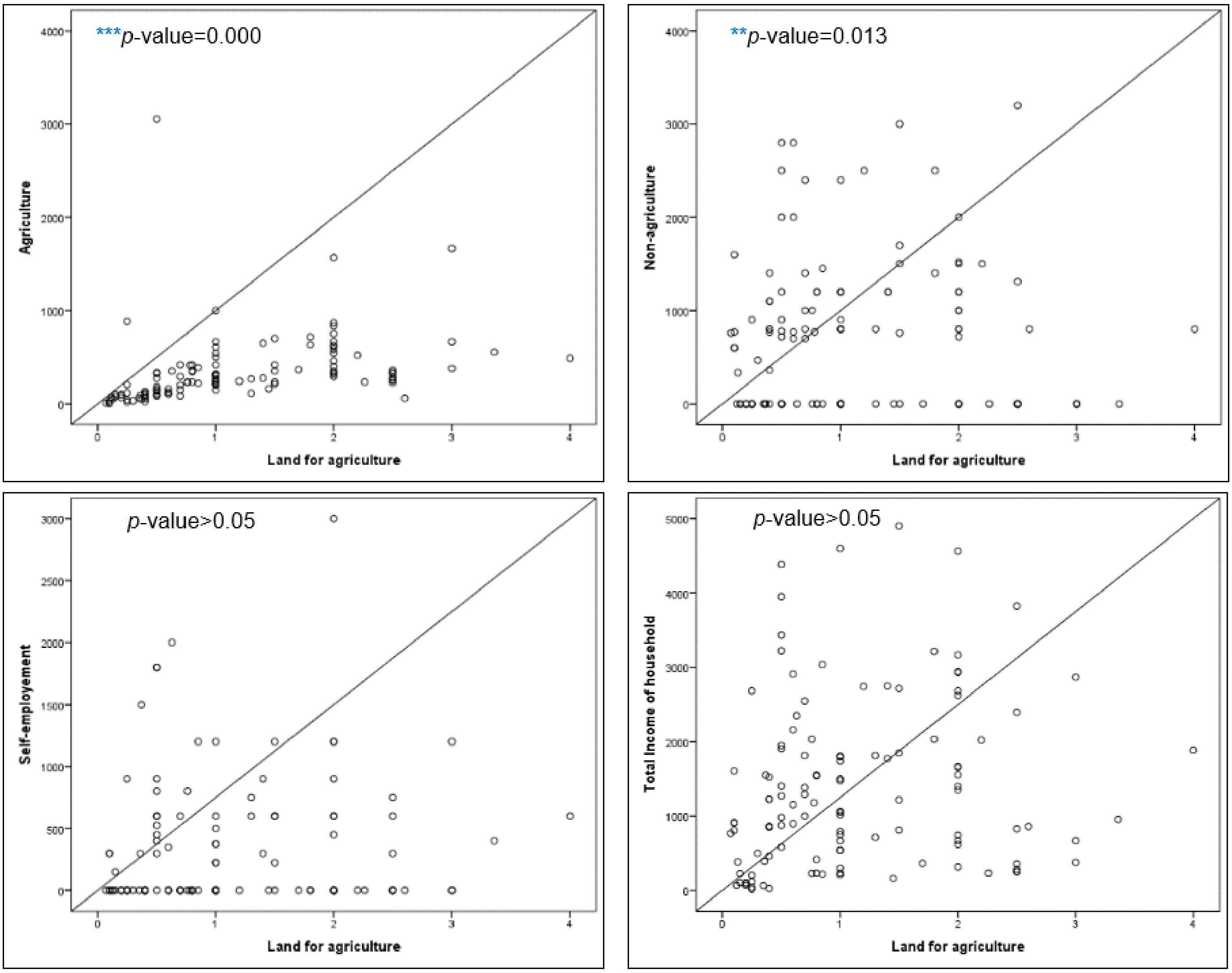

Fig. 4. Correlation between agricultural land and various sources of income.

4.2 The rice farming practices of small-scale farmers

In Cambodia, some ecological areas, such as parts of Sray Rieng, Prey Veng, Takeo, etc., could be farmed more than once yearly. In this study presented in Nhaengnhorng commune, the number of farmers who could cultivate only once per year was 81.8%, less than the figure of 89.4% found for Sraeronorng commune. The overall average for the two communes was 85.4%. When farming two rice crops yearly, the villagers planted early-cycle and late-cycle rice. In Nhaengnorng commune, the percentage of farmers who cultivated twice was 16.7%. This was more than the 10.6% percent found in Sraeronorng. The overall average for both communes was 13.6%. The villagers in both studied communes cultivated water-receding rice and early-cycle rice. Additionally, 1.9% of farmers in Nhaengnhorng commune farmed three times a year, but in Sraeronorng, farmers did not farm three times per year. The overall average for the two communes was 0.8% (Table 2). One respondent stated:

"Most farmers only farmed rice once a year. In the deep fields, most farmers cultivated late-cycle rice. Some of them also grow rice twice a year. Water-receding rice usually starts in April and May and is harvested in July and August. After harvesting, the farmers begin to plant the early-cycle rice. Water-receding rice was sometimes cultivated by farmers after harvesting early-cycle rice, starting between November and December. Most farmers who grow water-receding rice are close to water sources such as canals and ponds. (Mr. MAE Sor, Komsey village leader, personal communication, April 2022)."

Table 2. Number of times of rice cultivation.

Attributes (%)	Nhaengnhorng (n=54)	Sraeronorng (n=66)	Overall (n=120)
One time	81.5	89.4	85.4
Two times	16.7	10.6	13.6
Three times	1.9	0.0	0.9
Total	100.0	100.0	100.0

Farmers know how much rice yield they will get during the harvest stage from their efforts. In the study area, a minority of farmers farmed twice a year, most of whom were residents of the Nhaengnhorng commune. In Nhaengnhorng commune, a few farmers collected their first rice in August and September (Fig. 5). 86.4% of farmers in the Sraeronorng commune and 66.7% of farmers in the Nhaengnhorng commune completely harvested their rice crops in December. A very significant difference was found when comparing the two communes by *t*-test (*p*-value = 0.005). Through face-to-face interviews, the agroecosystems of the two communes were found to be slightly different.

The farmers in Sraeronorng commune cultivated a deep rice field called "Srae Veal Boeng." The rice field stored rainwater from the highlands between November and December every year. Most villagers grow long-term late-cycle rice known as "Phka Rompeak" or "Srov Krohom" by the local farmers. The completion of the harvest in Nhaengnhorng was faster than in Sraeronorng. At the end of the year, there was less of a problem with rainwater storage in rice fields. The farmers in this commune used a variety of early-cycle rice seeds called Pkarumdul and Pongrolok. For this reason, most farmers in Nhaengnhorng finished harvesting before Sraeronorng.

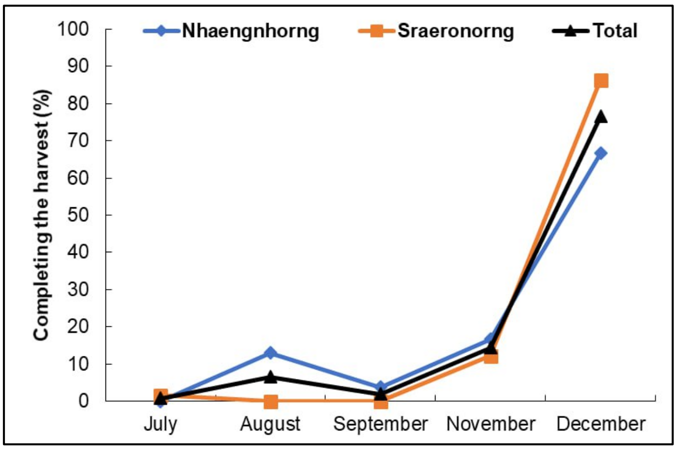

Fig. 5. The month respondents ended harvesting the first rice crop. ***p*-value=0.005 is very significant.

The research analyzed farmers' access to water sources for rice production (Table 3). One question pertained to the percentage of the 120 households that can access water from rivers, lakes, ponds, canals, and reservoirs for farming rice. In the areas studied, villagers have no reservoirs to use for agriculture. The results showed that 9.3% of the farmers in Nhaengnhorng commune drew water from the river, while those in Sraeronorng commune did not. Some farmers in Nhaengnhorng seemed to be farming near waterways, where they could get water by using pumps and machines to divert water to supply rice paddies. The number of farmers who received water resources from lakes was small in both communes. The average was 1.7%, based on 1.9% for Nhaengnhorng and 1.5% for Sraeronorng. According to the interviews with farmers and personal observations, few lakes in the area studied could provide a water source.

Overall, villagers in both communes could take (an average of 23.3%) water from ponds: 18.5% in Nhaengnhorng and 27.5% in Sraeronorng. People mostly dug ponds to irrigate rice to obtain dirt to fill the residential land, build houses, plant crops, or sell soil. The analysis of results showed that, overall, the number of target villagers who had access to canals for water supply to farm rice was 47.5%. Nhangnhorng had 31.5%, less than Sraeronorng, which had 60.6%. These results demonstrated that the rice farmers in Sraeronorng had greater access to canal water to irrigate rice than those in Nhaengnhorng. This suggests that in Sraeronorng, it would be easier to deal with droughts if farmers were diligent in extracting water for agricultural purposes, particularly rice.

Table 3. Water resources for rice production.

Attributes (%)	**Nhaengnhorng** (n=54)	**Sraeronorng** (n=66)	**Overall** (n=120)
River	9.3	0.0	4.2
Lake	1.9	1.5	1.7
Pond	18.5	27.3	23.3
Canal	31.5	60.6	47.5

In ancient times, cattle were an important source of energy for farmers because of their use in tasks such as plowing and hauling carts and transporting rice and seedlings. Traditional farming was less expensive because it used no pesticides or chemical fertilizers. Nowadays, cattle are no longer important for farmers, and the animals are raised for sale only. However, as a result, farming is more expensive due to factors such as the cost of plowing, fallowing land, pesticides, fertilizers, and harvesting.

Farmers borrowed money from various sources to grow rice in the area studied. Averaging findings for both communes, respondents borrowed from banks/microfinance (7.8%), agricultural material sellers (22.3%), agricultural product buyers (5.4%), agricultural skill supporters (0.8%), and private lenders (15%). It was also found that (Table 4) the amounts borrowed by those in the Nhaengnhorng commune to facilitate rice cultivation were higher than those borrowed in the Sraeronorng commune. The *t*-test comparison showed the difference to be not significant. This result meant that although the amount of money borrowed by the people in Nhaengnhorng was much higher than in Sraeronorng, the amount borrowed to invest in rice production was not significantly different between the two communes.

Table 4. Types of lenders for borrowing by small-scale farmers.

Attributes (%)	Nhaengnhorng (n=54)	Sraeronorng (n=66)	Overall (n=120)
Loans (Bank/MFI)	11.1	4.5	7.8
Agricultural material	20.4	24.2	22.3
Agriculture product buyer	9.3	1.5	5.4
Support Agriculture Skill	0.0	1.5	0.8
Lenders	14.8	15.2	15.0
The average amount borrowed (Khmer Riel)	792,592.7	1224,410.9	662,205.4

p-value > 0.05 is not very significant.

4.3 The impact of climate change on small-scale farmers

The people in both communes strongly agree that drought has caused food scarcity. The farmers in Nhaengnhorng felt more strongly that this issue was significant than the farmers in Sraeronorng. Drought also caused conflict among the villagers over scarce water supplies, which was very significant. When drought spread in the areas, farmers accessing canals and community ponds competed to transfer water to their rice fields, which affected other fields. In the areas studied, people engaged in rice farming were frequently in conflict over water distribution during the growing season and often came to complain to commune leaders. Ponds, lakes, and canals belong to the community, but when there was a drought, farmers near the water source were the first to pump water. Water storage in this area was limited when some farmers pumped water several times, causing the water to run out even though other farmers still needed it (Mr. Chan Sarith, deputy leader in Kork Ro Vieng village, Sraeronorng commune, personal communication, December 2021). One farmer asserted:

"Conflicts over water use in this village were related to community ponds, and some farmers who benefited from these ponds received more water than others. Another problem in this area was holding irrigation water from the canals between the upper and lower rice fields during drought or periods of water scarcity" (Mr. Chol, a farmer living in Krornhoung village, Naengnhorng commune, personal communication, May 2022)."

Respondents in both study areas agreed that the drought affected food choices. They strongly agreed that drought had a negative impact on human health (which was found to be perfectly significant when comparing the two communes). These results indicate that drought made it difficult for people in both communities to find suitable food to support their daily lives.

It wasn't easy to find the food needed in Sraeronorng, which was at a higher altitude than Nhaengnhorng. Respondents' perception of the impact of drought on human health was higher in Sraeronorng than in Nhaengnhorng. Furthermore, both respondents in both areas strongly indicated that drought hurts livestock health. One respondent indicated:

"I bred and raised many cows. In 2021, the weather was very hot, and there was not enough rain for the rice crop, but it was not a problem because I only cultivated a small amount to support annual food consumption. I had spent much money on cattle raising and was also in debt to the bank. In the summers, cattle were at high risk for Lumpy Skin Disease (LSD), which was very difficult to treat for calves which had high mortality rates. Cattle that can be vaccinated were easier to treat than cattle under six months of age" (according to Mr. CHHUY Sopheak, a farmer who lived in O Sngeoun village, Nhaengnhorng commune, personal communication, May 2022)."

A farmer who lived in Chraiveng village of Sraeronorng commune also shared their insights on the impacts of drought. She said that:

"At the beginning of 2021, I spent about 4,000,000 riels to cut down palm trees and make chicken coops. I raised more than 100 hens and 300 chickens. The first time procured a standard amount, resulting in a small profit. The second time, I also bought about 500 chicks at 2,800 riels per chick to raise. Between June and August 2021, hot weather with little rain warmed the ground, and 30 chickens died daily. Now I raise chickens for sale to pay for electricity and to give as wedding gifts when I don't have any money. She added that in 2021, the scary thing was COVID-19. My niece's children were young, and the hot weather had caused them to get diarrhea and acute pharyngitis, making it very difficult to find doctors for treatment. Before COVID-19, when the weather was hot, it was difficult for them to study at school, and sometimes the teachers were forced to leave class at 10 AM." (Ms. LOEM Khom, a farmer and resident of Chraiveng village, Sraeronorng commune, personal communication, May 2022).

Residents in both communes agreed that the drought had affected children's education, (p-value < 0.05), which was found to be significantly different. However, the results showed the Nhaengnhorng commune (WAI = 0.69) and Sraeronorng (WAI = 0.77) strongly agreed that drought caused malnutrition, which was a very significant difference. Residents in Sraeronorng agreed that drought affected migration, but residents in Nhaengnhorng were undecided, although the difference was not found to be significant (p-value > 0.05).

Table 5 also shows that the people in both communes strongly agreed that drought exacerbated food scarcity. The farmers in Nhaengnhorng opined that this issue was significantly more than those in Sraeronorng. Although the villagers in Nhaengnhorng were undecided, those in Saeronorng agreed that drought caused debt and unemployment, and the difference was significant. These results indicate that the people in the two communes had very different experiences. The study also measured the perception of people concerning water affected by climate change in a decade (Table 6). The results revealed that the difference in the rainwater patterns and temperatures over ten years corresponded to the respondents' perceptions of the two communes, with the people appearing to have experienced the same high level of change. Water evapotranspiration and groundwater changes were perceived to be moderate and not significantly different (p-value > 0.05).

In addition, the results also demonstrated that a high level of respondents perceived the impact of drought to have changed over ten years, and there was a significant difference (p-value = 0.040). This result meant that droughts affected the villagers of Nhaengnhorng more than Sraeronorng. The perception of the effect of drought over ten years differed between the two communes. The last question related to the water level in the water resources. The perception of the people that the water level in storage areas had changed was found to be at a moderate level. Still, the figure of Sraeronorng was higher than that of Nhaengnhorng, with a very significant difference (*p*-value = 0.010).

Table 5. Drought impacts on respondent households.

Attributes	Nhaengnhorng (n=54)		Sraeronorng (n=66)		Overall (n=120)		*p*-value
	WAI	OA	WAI	OA	WAI	OA	
Drought threatened household food scarcity	0.75	A	0.69	A	0.76	A	0.021*
Drought caused conflict for water scarcity	0.63	A	0.73	A	0.68	A	0.000***
Drought eliminated the choice of food	0.61	A	0.72	A	0.67	A	0.000***
Drought affects human health	0.78	A	0.89	SA	0.84	SA	0.000***
Drought caused malnutrition	0.69	A	0.77	A	0.73	A	0.002**
Drought affected animal health	0.82	SA	0.90	SA	0.86	SA	0.000***
Drought affected the schooling of children	0.65	A	0.70	A	0.68	A	0.024*
Drought caused population migration	0.59	U	0.64	A	0.62	A	0.067
Drought caused debt	0.58	U	0.69	A	0.64	A	0.000***
Drought caused unemployment	0.52	U	0.68	A	0.60	U	0.000***

Notes: WAI = Weighted Average Index measured on a five-point scale [Strongly disagree (SD) = 0.00-0.20, Disagree (D) = 0.21-0.40, Undecided (U) = 0.41-0.60, Agree (A) = 0.61-0.80, Strongly Agree (SA) = 0.81-1.00]; OA = Overall Assessment; *Significance at the 0.05 level; **Significance at the 0.01 level.

Table 6. Climate-induced changes to water availability over ten years.

Attributes	Nhaengnhorng (n=54)		Sraeronorng (n=66)		Overall (n=120)		*p*-value
	WAI	OA	WAI	OA	WAI	OA	
To what degree has the rainwater pattern changed in 10 years?	0.69	H	0.70	H	0.69	H	0.527
To what degree has the temperature changed in 10 years?	0.63	H	0.64	H	0.64	H	0.681
To what degree has water evapotranspiration changed in 10 years?	0.53	N	0.54	N	0.54	N	0.777
To what degree has drought changed in 10 years?	0.72	H	0.67	H	0.70	H	0.040*
To what degree has flooding changed in 10 years?	0.46	N	0.57	N	0.52	N	0.000***
To what degree has groundwater changed (ponds, wells…) in 10 years?	0.53	N	0.51	N	0.52	N	0.286
To what degree has the water level in the water storage facilities changed in 10 years?	0.53	N	0.57	N	0.55	N	0.010**

Notes: WAI = Weighted Average Index measured on a five-point scale [No change at all (N) = 0.00-0.20, Low change (L) = 0.21-0.40, Moderate (N) = 0.41-0.60, High change (H) = 0.61-0.80, Extreme change (E) = 0.81-1.00]; OA = Overall Assessment; *Significance at the 0.05 level; **Significance at the 0.01 level.

The results were analyzed to assess perceptions of the impact of a lack of water (Table 7). It was found that respondents perceived that people were highly affected by lack of water because water scarcity caused a moisture deficit in the soil of the rice fields, affected rice cultivation, affected the quality of rice, and increased expenses for rice farming. The respondents' perceptions in both communes were similar and were not found to be significantly different (*p*-value > 0.05). The perception that water scarcity caused a large reduction in soil fertilizer was found to be significantly different (*p*-value < 0.05).

Table 7. Sensitivity to water scarcity in rice production.

Attributes	Nhaengnhorng (n=54)		Sraeronorng (n=66)		Overall (n=120)		*p*-value
	WAI	OA	WAI	OA	WAI	OA	
To what degree has the rainwater pattern changed in 10 years?	0.69	H	0.70	H	0.69	H	0.527
Water scarcity caused a moisture deficit in the soil	0.68	H	0.70	H	0.69	H	0.555
Water scarcity effected rice cultivation	0.76	H	0.77	H	0.77	H	0.601
Water scarcity affected the quality of rice	0.74	H	0.77	H	0.75	H	0.336
Water scarcity caused a reduction in soil fertilizers	0.66	H	0.75	H	0.70	H	0.002**
Water scarcity caused increased expenses for rice farming	0.78	H	0.78	H	0.78	H	0.761

Notes: WAI = Weighted Average Index measured on a five-point scale [Not change at all (N) = 0.00-0.20, Low change (L) = 0.21-0.40, Moderate (N) = 0.41-0.60, High change (H) = 0.61-0.80, Extreme change (E) = 0.81-1.00]; OA = Overall Assessment; *Significance at the 0.05 level; **Significance at the 0.01 level.

The perception of villagers that water scarcity caused a decrease in soil fertilizer in Sraeronorng was more than in Nhaengnhorng. As one farmer in the Nhaengnhorng commune pointed out:

"I noticed that the weather was changing, especially the drought, which made growing rice difficult. It was very hard to determine the planting month, as some years, I have to wait until August to plant rice. For example, rice was grown for a month, replenishment began without rain, and the rice was damaged by increased heat. Not only did I suffer from drought and water shortages for my rice cultivation in 2021, but so did the villagers" (Mr. SOM Tha, personal communication, May 2022).

4.4 Drought and its impact on rice production

People in both communes perceived the need to reduce the level of water consumption. The people of both studied areas were found to understand that need at a moderate level. As for the reduction of rice cultivation size in response to the drought in both communes, the villagers' perception was low regarding the reduction in rice cultivation in response to drought, and the figures were similar for the two areas studied. The perception of the change in the rice planting calendar was high, which meant that respondents perceived that changing the farming calendar made it easier to grow rice while adapting to drought or water shortages. Farmers have needed to be innovative and flexible in their response to the situation because they have observed it intensifying yearly. When rice farming adaptation actions were compared, there was no significant difference. The ability of the two communities to adapt to the drought was not found to be different.

Secondly, the analysis showed the need for change in the variety of rice and an increase in chemical fertilizer were highly perceived as important by the villagers in both study areas. It was determined that the villagers understood the value of changing the variety of rice seed (such as non-seasonal rice seed) so that cultivated rice was resistant to climate change and perceived the critical importance of adapting to the current weather conditions. The findings indicated that an increase in chemical fertilizer was necessary for rice cultivation because, when the rice encountered drought, some of the rice died. The dead rice needed to be replaced. Therefore, using chemical fertilizers was a method to help rice grow well quickly when there was rainfall available or water could be pumped into the rice fields. A *t*-test was used to compare the two communes, and the result found that they were not significantly different (p-value > 0.05).

Thirdly, as for an increase in pesticide use, more time spent on rice farming, and the use of pumps, the villagers' perceptions in both studied communes were similarly high. This result meant that increasing the use of pesticides was understood to be important to solving problems exacerbated by drought. When drought resulted in less water in the fields, weeds, pests, and insects proliferated. Eliminating pesticides was a good option for farmers to address these issues. When there was a drought, the rice died, and so it took more time to remove weeds such as peacock tails, wolf tails, etc., which were difficult to manage, and more time was needed for farming. Pumping water could help rice survive, and watering and applying fertilizer were considered extremely effective. On the other hand, water pumps were also used to limit the growth of weeds as well as the use of pesticides. The results for the related perceptions were found to be slightly different, but when compared using a *t*-test, there was no significant difference between the two communes.

Fourthly, the perception of the importance of efforts to learn more about farming methods and increase organic fertilizer use. In contrast, the perception of diversification of rice cultivation practices was low in both communes. Although the figures were at the same level, the result was significantly different for the two communes. Sraeronorng commune found it more necessary than Nhaengnhorng commune to learn about other farming practices. This knowledge could help farmers have an understanding of new techniques to apply in the field of agroecosystems in their actual area. There was a reported increase in the use of organic fertilizer for farmers in Sraeronorng, who believed in using organic fertilizer more strongly than farmers in Nhaengnhorng commune. Using organic fertilizers such as animal litter reduced costs, resulting in long-lasting rice without damaging the soil, produced flavorful white rice, and made rice more resistant to drought than chemical fertilizers.

Farmers in Sraeronorng had more positive views on diversifying farming practices than farmers in the Nhaengnhorng commune. As shown in the table, the people in Nhaengnhorng commune had a moderate perception of increasing irrigation systems, while those in Saeronorng had a high perception. When the two communities' perceptions were compared, they were completely different—meaning that the respondents from Sraeronorng commune found that increasing the irrigation systems made it easier to farm, reduced the damaging impacts of drought, and enabled cultivation in both the rainy and dry seasons (Table 8).

Table 8. Rice cultivation adaptations to the impact of drought.

Attributes	Nhaengnhorng (n=54)		Sraeronorng (n=66)		Overall (n=120)		*p*-value
	WAI	OA	WAI	OA	WAI	OA	
Change to less water consumption for rice	0.59	M	0.59	M	0.59	M	0.970
Reduce Rice field size	0.39	L	0.40	L	0.39	L	0.818
Change rice variety	0.66	H	0.67	H	0.66	H	0.644
Improve planting calendar	0.61	H	0.61	H	0.61	H	0.945
Diversification practices	0.31	L	0.39	L	0.35	L	0.044*
Increase organic fertilizer	0.64	H	0.71	H	0.67	H	0.028*
Increase chemical fertilizer	0.65	H	0.60	M	0.62	H	0.058
Increase Pesticide and Herbicide	0.67	H	0.70	H	0.68	H	0.385
Spend more time planting	0.73	H	0.71	H	0.72	H	0.383
Make an effort to learn more about cultivation	0.61	H	0.68	H	0.64	H	0.027*
Increase irrigation maintenance	0.53	M	0.72	H	0.62	H	0.000***
Use the water pump machine	0.76	H	0.79	H	0.77	H	0.302

Notes: WAI = Weighted Average Index measured on a five-point scale [Very low (VL) = 0.00-0.20, Low (L) = 0.21-0.40, Moderate (M) = 0.41-0.60, High (H) = 0.61-0.80, Very high (VH) = 0.81-1.00]; OA = Overall Assessment; *Significance at the 0.05 level; **Significance at the 0.01 level.

In summary, the results confirm that the villagers in the target areas were aware of how to adapt to drought and that the farmers were capable enough to adapt to drought. Only the government or other sponsors, however, can construct the irrigation system and provide more training on farming techniques. According to one respondent:

"In 2021, there was little rain in my area between June and September, and parts of the rice crop died. While having such problems, the rice fields were treated with chemical fertilizers, but the rice soon died due to water scarcity, some rice paddies used resistant organic fertilizers. There was enough rain in each field at the beginning of September, but there was a lot of dead rice, and it always took several hours of rice transplanting. When there was enough rain, the grass in the rice fields sprouted abundantly. Spending time farming was not harmful to other work because of COVID-19; I did not go anywhere far away to earn money" (a woman farmer from

Tropeang Snor village, Nhaengnhorng commune, personal communication, May 2022).

According to the findings, seed selection and quality levels were extremely important for farmers in the two communes. The results showed that seed quality was necessary for rice cultivation because good seed care, pure seed separation, and resistant seed varieties made it easier for farmers to grow and maintain rice. The rice yield was higher, and the price also increased. Water management was very important because if water was managed properly, good-quality rice could reduce the use of chemical fertilizers and pesticides. When comparing the above methods, the respondents in the two communes were not in disagreement, and perceptions were not found to be significantly different (p-value > 0.05).

The villagers' perception was that pest and disease control was very important in the Nhaengnhorng commune, while the villagers perceived it to be extremely important in the Sraeronorng commune. The comparison was perfectly different. This result meant the farmers in the Sraenornong commune were more attentive to controlling pests and diseases during rice production. In the last analysis of the perceptions of land preparation, the Nhaengnhorng commune (WAI = 0.72) and the Sraeronorng commune (WAI = 0.78) had high levels, which were very significantly different (p-value < 0.05). Suitable soil preparation was understood to be important for rice to grow well, making it easier to control water and weeds (Table 9).

Table 9. The perception of paddy rice farming adaptations to drought.

Attributes	Nhaengnhorng (n=54)		Sraeronorng (n=66)		Overall (n=120)		p-value
	WAI	OA	WAI	OA	WAI	OA	
Seed selection	0.72	V	0.77	V	0.75	V	0.066
Water management	0.78	V	0.82	E	0.80	V	0.097
Pest and disease management	0.69	V	0.81	E	0.75	V	0.000***
Land Preparation	0.72	V	0.78	V	0.75	V	0.035*

Notes: WAI = Weighted Average Index measured on a five-point scale [Not at all important (N) = 0.00-0.20, Slightly important (S) = 0.21-0.40, Moderately important (M) = 0.41-0.60, Very important (V) = 0.61-0.80, Extremely important (E) = 0.81-1.00]; OA = Overall Assessment; *Significance at the 0.05 level; **Significance at the 0.01 level.

5. Conclusion

The findings of two communes in Tram Kak district on the negative impact of climate change, focusing on problems stemming from droughts or water shortages for rice production of small-scale farmers, entailed the following: (i) Small-scale farmers of Sraeronorng commune mostly cultivated late-cycle rice, and the harvest was completed later than the small-scale farmers in the Nhaengnhorng commune. At the same time, the resulting income was not significantly different. (ii) In the past decade, droughts or water shortages have affected the Nhaengnhorng commune more than the Sraeronorng commune; both communes were similarly affected at a high level in 2021. In addition, drought had a negative impact not only on rice production but also on children's education, human and animal health, and conflicts over access to water for irrigation. (iii) The adaptive capacity of small-scale farmers in both study areas was similarly high, while the farmers in Nhaengnhorng commune were found to be slightly more adaptable. Farmers have changed rice seed varieties, changed the planting calendar, used more chemical and organic fertilizers, and used mechanical water pumps to adapt to the constraints imposed by drought. Farmers practiced Integrated Pest Management (IPM) to control pests and diseases, using both chemical and mechanical measures. Through observation and case studies, the research found that most small-scale farmers tried to construct their water sources to supply their agricultural cultivation, such as digging ponds. However, these water sources can only be used for a small amount of irrigation in the event of a long-term drought or water shortage. Drought has severely affected rural farmers in Cambodia. It is very important that all key stakeholders, both at the national and local levels, take more action to ensure the resilience of rural communities. These actions should focus on developing high-quality irrigation systems, training on agricultural techniques, providing the sale of drought-resistant rice seeds at a low price, and strengthening the capacity of small-scale farmers to produce their high-quality seeds. Moreover, local development projects must include the participation and decision-making of community members. To successfully implement these actions, the Royal Government of Cambodia will need an improved approach to selecting civil servants, effective civil servant management systems, and checks and balances in policy implementation. The policymakers, planners, and implementers should have high responsibility without conflicts of interest. NGOs should work according to their vision, mission, goals, objectives, and action plans to improve livelihoods rather than to attract donor funding. In this connection, the study suggests that future research in the field anticipates various topics to promote insightful and inclusive understanding. Firstly, future research should study the adaptive capacity of people to deal with drought, focusing on rice production by comparing locations beyond the study area and including locations along the sea, in the central lowlands, and the highlands. Secondly, the adaptive capacity of agricultural community members (AC) and non-agricultural community members to respond to the effects of droughts or floods on rice production should be studied. Thirdly, studies should examine farmers' ability to adapt to floods and droughts in the areas where cassava is grown.

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Declaration of competing interest

The author has no competing interests to declare. The author has read and approved the final, published version of the manuscript.

Credit authorship contribution statement

PRIN Sovandavy: Experimental design, conceptualization, data collection, data analysis and interpretation, visualization, writing-original draft, reviewing and editing.

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