Synthesis Report for the CTCN Project:

Market Assessment of Climate Technologies for Rural Development

Country: The Kingdom of Cambodia

Reference number: CTCN 23-012

National Designated Entity: Ministry of Environment

Climate Technology Center Network (CTCN)

Sustainable Solutions for Africa (SSA)

June 2024

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Acronyms and Abbreviations

AE	Accredited Entity by the Green Climate Fund
AEZ	Agro-Ecological Zone
ARDB	Agricultural and Rural Development Bank
BAU	Business as usual
CARDI	Cambodia Agriculture Research and Development Institute
CASIC	Cambodia Conservation Agriculture and Sustainable Intensification Consortium
CAVAC	Cambodia Agriculture Value Chain Program
CCCA3	Cambodia Climate Change Alliance-Phase 3
CCFF	Cambodian Climate Financing Facility
CCPAP	Climate Change Priority Action Plan
CE SAIN	Center of Excellence on Sustainable Agricultural Intensification and Nutrition
CERF	Clean Energy Revolving Fund
CHAIN	Cambodia Horticulture Advancing Income and Nutrition
COP	Conference of the Parties
CTC	Climate Technology Centre
CTCN	Climate Technology Centre and Network
FIs	Financial Institutions
FWUC	Farmer Water User Committees
GCF	Green Climate Fund
GMB	Greater Mekong Basin
ICT	Information and Communication Technologies
LDC	Least-Developing Country
MAFF	Ministry of Agriculture, Forestry and Fisheries
MoE	Ministry of Environment
MOWRAM	Ministry of Water Resources and Meteorology
MRD	Ministry of Rural Development
NAMAs	Nationally Appropriate Mitigation Actions
NAPA	National Adaptation Programme of Action to Climate Change
NAPs	National Adaptation Plans
NBC	National Bank of Cambodia
NCDD	National Committee for Sub-national Democratic Development
NCSD	National Council for Sustainable Development
NDAs	National Designated Authorities
NDC	Nationally Determined Contribution
NDE	National Designated Entity
Nexus	Nexus for Development

RE	Renewable Energy
SDGs	Sustainable Development Goals
SMAs	Small and Medium Agri-businesses
SMEs	Small and medium enterprises
SOGE	Solar Green Energy Cambodia
SSA	Sustainable Solutions for Africa
TAPs	Technology Action Plans
TNAs	Technology Needs Assessments
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change

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Introduction: CTCN mandate and project background

As the operational arm of the United Nations Framework Convention on Climate Change (UNFCCC)'s Technology Mechanism, the Climate Technology Center Network (CTCN) has the mandate from the UNFCCC to promote the accelerated transfer of environmentally sound technologies for low carbon and climate-resilient development at the request of developing countries (cf. COP decisions 1/CP.16, 2/CP.17, 14/CP.18, and 25/CP.19). To achieve this, the CTCN provides technology solutions, capacity building and technical advice on policy, legal and regulatory frameworks tailored to the needs of individual countries and based on specific country requests submitted by a National Designated Entity (NDE). The CTCN is, therefore, a demand-driven mechanism; as its services are offered upon request by developing countries, the volume and specific nature of activities ultimately depend on countries' requirements and needs.

The CTCN is composed of a Climate Technology Centre (CTC) and a Network (cf. COP decision 2/CP.17). The CTCN is hosted by the United Nations Environment Programme (UNEP). As a CTC Network member, Sustainable Solutions for Africa (SSA) was awarded to lead this research assisting the NDE office in mobilising resources and funding, as well as identifying technological solutions.

This project contributes to the Climate Action Sub-programme of the UNEP Results Framework for 2022-2023, including Indicators:

(i) "Number of national, subnational and private-sector actors that adopt climate change mitigation and/or adaptation and disaster risk reduction strategies and policies with UNEP support", indicator

(iv) "Positive shift in public opinion, attitudes and actions in support of climate action as a result of UNEP action", and indicator

(v) "Positive shift among private sector actors in support of climate action as a result of UNEP engagement".

The objective of the project is to implement a market assessment for the application of climate technologies in agricultural operations for rural development. This is expected to support Cambodia in implementing its NDCs. The proposed project aims to analyze the market concerning the use of climate technologies in the agricultural sector. This includes technologies in irrigation, water harvesting, and agro-food processing such as solar cooling, solar pumping, and food product preservation and packaging and other digital applications. It is anticipated that the project will identify climate technologies requiring technical assistance for rural development. This assistance is expected to enhance production efficiency and climate resilience in the agriculture and water sectors of rural areas.

This synthesis report is a critical component of the market assessment for the application of climate technologies in rural development, aligning with Cambodia's NDCs. The report establishes a baseline understanding of climate change impacts within the agriculture and water sectors. It identifies appropriate climate technologies requiring technical assistance and climate financing to enhance their climate impact. Additionally, the report offers strategic recommendations for overcoming barriers that impede the adoption of climate technologies, thereby aiming to boost agricultural productivity in rural areas in line with the NDCs.

Furthermore, the report underscores the roles of key stakeholders and business models, which are instrumental in driving the application of climate technologies for rural development. Consequently, this report represents a significant milestone in formulating a strategy for low-emission and climate-resilient agricultural production, supporting the realization of Cambodia's NDC objectives.

1. Country and climate risk profile

Cambodia, located in mainland Southeast Asia, is bordered by Laos, Thailand, Vietnam, and has a coastal area along the Gulf of Thailand. It spans 181,035 square kilometers and features a landscape dominated by the Mekong River's low-lying central plains, surrounded by mountainous and highland regions, and a 435-kilometer coastline. As of 2022, Cambodia's population stood at 16.8 million, with 75% residing in rural areas. This marked a decline of 5% since 2010 due to rapid urbanization (WB, 2024; WB Data, 2024).

While Cambodia is categorized as the Least Developed Country (LDCs) in Asia as of 2018 (UNDESA, 2018), the country was considered for graduation in the 2021 Report[i]. Cambodia has achieved consistent growth, with a 5.2% increase in GDP in 2022. The GDP per capita reached US$ 1,760, a significant rise from US$ 410 in 2004 (WB, 2024). The country has the ambition and high development aspirations, aiming to become an upper-middle-income country by 2030 and a high-income country by 2050 (EAST ASIA PACIFIC, 2023), which will require a more inclusive, diversified, low emission and climate resilient economy.

Climate change could amplify existing development challenges, with potentially sizable impacts on growth, trade, debt, and poverty reduction, as Cambodia faces one of the world's highest levels of exposure to floods and extreme heat. However, building climate resilience also offers an opportunity, not only to mitigate climate risks, but also to concurrently further development outcomes, as this report finds that adaptation measures in Cambodia have large development co-benefits. Moreover, Cambodia has made ambitious pledges in its updated NDC and in the Long-term Strategy for Carbon Neutrality (LTS4CN). Delivering these commitments will require careful policy choices to mitigate transition risks and seize development opportunities. Finally, as a small, open economy highly dependent on trade and foreign direct investment (FDI), Cambodia will be highly affected by the accelerated decarbonization and changing consumption and production patterns in the rest of the world. With the right policy choices and a vibrant private sector, this could offer opportunities for export diversification, job creation, and growth.

Cambodia's population relies heavily on agriculture, forestry, and fisheries, providing 22% of GDP in 2022 and employing 49% of the country's labor force[ii]. The economic growth in the agricultural sector has been fueled by effective macroeconomic policies, increased lending, investments, and a surge in exports (CIB & CSEZB, no date; WB, 2015; Cramb, Sareth, and Vuthy, 2020). Rice stands as the most vital crop in Cambodia, fulfilling nearly 70% of the country's nutritional requirements and constituting about 80% of its crop production. Other significant crops include cassava, maize, soybean, mung bean, among others (MoE, 2015; MAFF, 2017). The agricultural sector is dominated by smallholder farmers and engages around 45% of the labor force, predominantly in rural regions where poverty rates exceed 20%, in contrast to around 10% in urban areas like Phnom Penh (RGC, 2014, 2018b).

Concurrently, Cambodia observes a rise in its annual net greenhouse gas (GHG) emissions due to ongoing development activities. This trend underscores the critical need to focus on economic development and enhancing the social and economic well-being of its population, including the most vulnerable, by adopting sustainable, low-carbon pathways. The most significant source of emissions was the Forest and Other Land Use (FOLU) sector, largely due to deforestation impacting carbon stocks. This was particularly noticeable from 2010, coinciding with a notable rise in economic land concessions starting in 2009. The expansion of agriculture has led to environmental degradation, particularly noticeable in the form of widespread deforestation for crop cultivation. This has reduced the forest area to 45% in 2021, a decline of 15% from 2010, as reported by the World Bank in 2024. The Figure 1 shows FOLU / LULUCF (land-use, land-use change and forestry) as the largest contributor to Cambodia's gross GHG emissions, while electricity and heat has the highest growth rate[iii].

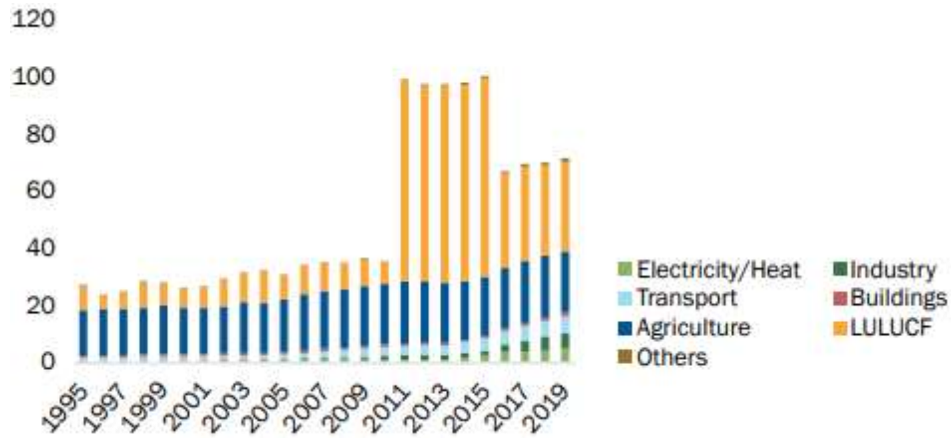


Figure 1. GHG emissions by sector (mtCO2e) in Cambodia
Sources: CAIT emissions data.

Agriculture is the country's second-highest source of emissions. While the GHG emission increase by agricultural sector is directly correlated with sector's substantial contribution to Cambodia's GDP, rice cultivation extensive development has been its primary driver.

Despite the economic growth overall, the country remains vulnerable to climate change, affecting key sectors like agriculture, infrastructure, forestry, and human health. Cambodia's climate vulnerability is highlighted by its ranking as the 12th most climate risk-prone country globally (Global Climate Risk Index)[iv].

Ranked 140th out of 181 countries on the ND-GAIN Index[v], Cambodia's vulnerability is compounded by its Cambodia's vulnerability to climate challenges is heightened due to its low readiness and the tropical monsoon climate it experiences, characterized by a rainy season from May to October and a dry season from November to April. Across the country, average temperatures remain relatively uniform, but annual average rainfall exhibits significant variability influenced by the Monsoon and the El Niño Southern Oscillation (ENSO).

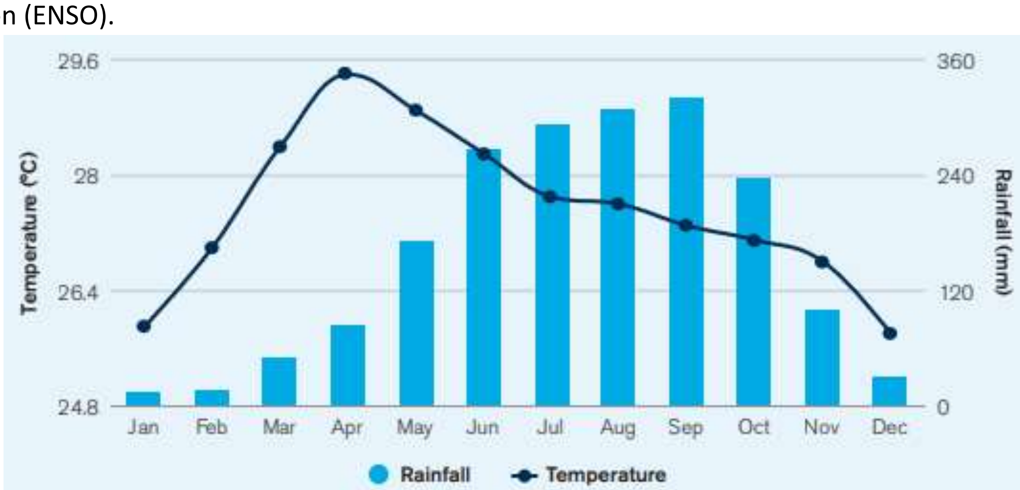
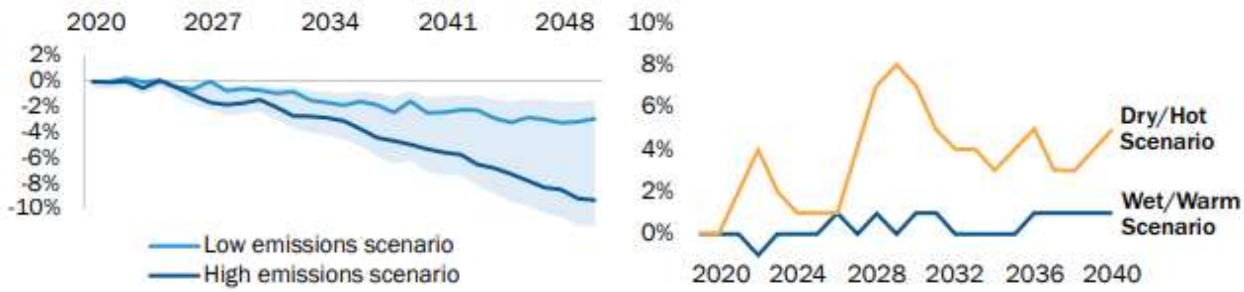


Figure 2. Average monthly temperature and rainfall in Cambodia (1991–2020)

Source: (CCKP, 2021)

The nation's varied topography, encompassing mountainous areas, central plains, and a coastal zone, is largely defined by the Mekong River and the Tonle Sap Lake. These geographical characteristics, along with the monsoon dynamics and climate variability, make Cambodia particularly susceptible to weather-related extremes like floods, storms, and droughts, leading to substantial economic losses estimated at 9 percent by 2050 and increase the poverty rate by 6 percentage points by 2040[1] (Figure 3) or USD 1.4 billion over two decades, with annual damages of USD 100 to 250 million (EM-DAT, 2021; DESINVENTAR, 2021; UNDRR, 2019).



1) Impacts of climate change on GDP 2) Impact of climate change on poverty rate

Figure 3. Impact of climate change on GDP and poverty rate in Cambodia relative to a baseline scenario without climate change (%)

Source: Source: Panel a) CGE Box model estimates of the combined impacts of floods on asset losses, climate change on labor productivity, climate change impacts on the labor supply from health impacts and climate change impacts on crop yields, without any adaptation measures. Low emissions scenario=SSP1-1.9, high emissions scenario=SSP3-7.0. The baseline is a business-as-usual scenario without explicitly modeling climate change. Panel b) Roy et al. (2023) combines Cambodia's socioeconomic surveys with satellite-based measures from ERA, TerraClimate, and CHIRPS to estimate the impact of weather shocks, including drought, on consumption, and in turn, the impact of consumption on poverty.

Cambodia confronts a tangible risk of droughts, both meteorological (related to a lack of precipitation) and hydrological (stemming from deficits in surface and subsurface water flow). Seasonal flooding, crucial for agriculture and fisheries, often results in significant losses through river and flash floods, positioning Cambodia as one of the most flood-exposed countries globally. Droughts, notably the 2015-16 El Nino event[vi], have had severe impacts, affecting millions and significantly reducing rice production (World Bank, 2017). Analyzing the past two decades, it has been observed that agricultural production losses predominantly arose from flooding (accounting for approximately 62%) and drought (about 36%). The primary cause of these floods has been the rising water levels in the Mekong River and Tonle Sap Lake, occurring mainly between early July and early October. Such flooding events significantly disrupt agricultural supply chains, impacting both local markets and international trade.

Under the most extreme emissions scenario (RCP8.5), Cambodia is expected to experience temperature increases of as much as 3.6°C by the 2090s, relative to the 1986–2005 baseline (Figure 4). A significant increase in the number of hot days is anticipated by the 2060s.Therefore, in the upcoming years, the impact of higher temperatures, particularly for Cambodia's increasingly fragmented forests is likely to increase forest fires, reduce water retention capacity and further reduce the essential services from ecosystems. By 2050, the majority of Cambodia's agricultural regions are expected to confront an escalated risk of drought.

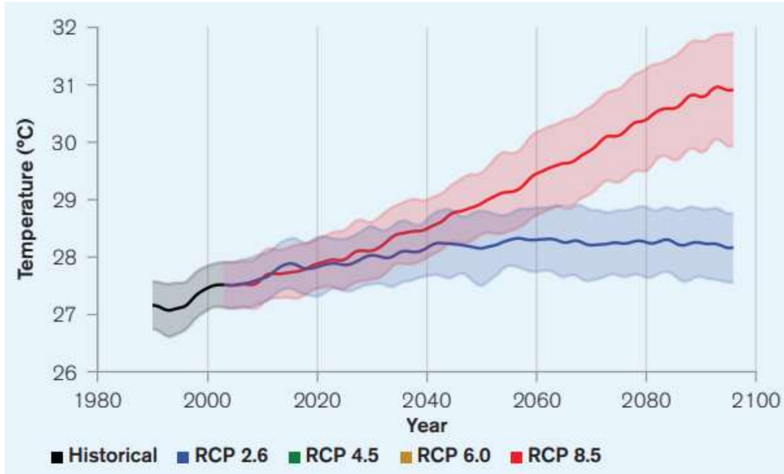


Figure 4. Historic and projected average annual temperature in Cambodia under RCP2.6 (blue) and RCP8.5 (red) estimated by the model ensemble. Shading represents the standard deviation of the model ensemble.

Cambodia has 64 days in average annually with the maximum temperature reaches 35°C (Figure 5). Presently, the median likelihood of experiencing a heatwave (defined as a stretch of three or more days with temperatures exceeding the historical 95th percentile of daily mean temperatures) stands at about 3%. Under all emissions scenarios, the risk of heat stress is expected to rise markedly in Cambodia. This risk can be quantified nationally by the number of days with a Heat Index exceeding 35°C, an index that combines temperature and humidity to indicate conditions potentially hazardous to human health and critical for food production.

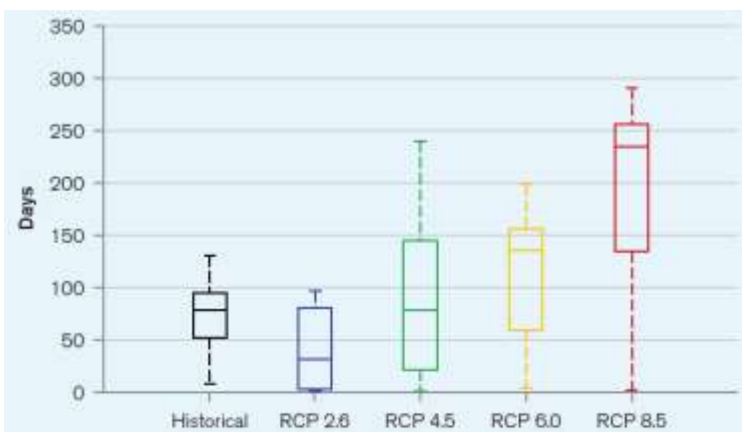


Figure 5. Historical (1986–2005) and projected (2080–2099) average annual frequency of days with Heat Index >35°C

There is a general trend of intensifying sub-daily extreme rainfall events with rising temperatures, a pattern observed across various Asian regions. Specific research in Cambodia tentatively supports this trend, but further study is needed. Predictions suggest an increase in seasonal rainfall from June to August in Cambodia's northwest, contrasted with a decrease in the northeast. Most models predict higher annual precipitation rates, especially under higher emissions scenarios (Figure 6), but the range of model estimates indicates substantial uncertainty. This uncertainty is compounded by the limited application of downscaling techniques in studying precipitation changes and the inconsistent performance of global climate models, particularly in simulating the El Niño phenomenon.

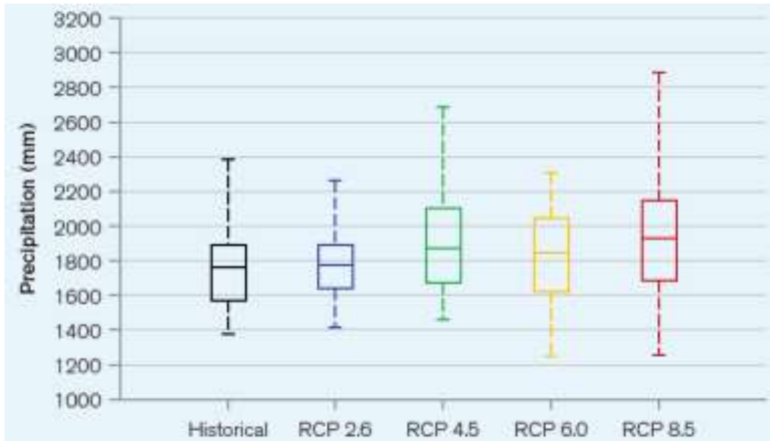


Figure 6. Projected average annual precipitation for Cambodia in the period 2080–2099

The effect of climate change on agricultural yields is considerable. According to projections under a high emission scenario, there is an expectation of a continuous decrease in wet season rice yield (rain-fed) until 2080, potentially dropping to as low as 70% of the current yields. In contrast, rice yields during the dry season (irrigated), particularly for crops planted in November and December, are anticipated to reduce by about 40%. This decline in agricultural productivity could lead to a disruption in food systems, and in the context of extreme climate events, vulnerable populations are at an increased risk of food and nutrition crises.

Furthermore, climate change is set to affect food production through both direct and indirect impacts on crop growth processes. Direct effects include changes in carbon dioxide levels, precipitation, and temperatures. Indirectly, climate change influences water resources, soil health, pest and disease dynamics, and can lead to a reduction in arable land due to coastal submergence and desertification. Studies indicate that Cambodia's agricultural output is hindered by the absence of advanced irrigation systems, which could also be increasing the country's susceptibility to extreme weather conditions[vii]. Additionally, Cambodia's reliance on the natural flow and flood regimes of rivers plays a significant role in its agricultural and environmental stability.

These changes are expected to negatively affect key global staple crop yields, even under lower emissions pathways. For example, Tebaldi and Lobell (2018) predict a decline of 5% and 6% in global wheat and maize yields, respectively, even if global warming is limited to 1.5°C as per the Paris Climate Agreement. Additionally, Li et al. (2017) report that Cambodia is facing one of the highest net rice yield losses in Southeast Asia due to climate change, with expected yield losses of 10–15% by the 2040s under both RCPs4.5 and RCP8.5.

The susceptibility of Cambodian farmers to climate variability presents a substantial risk to the nation's sustainable development, as it affects not just the economy but also food security and social stability. The COVID-19 pandemic has highlighted the fragile nature of agricultural supply chains and the socioeconomic vulnerabilities of Cambodian farmers, particularly affecting the poor, women, and socially marginalized groups (MAFF, CARD, and FAO, 2020). The pandemic underscored the importance of building resilient and sustainable agricultural markets to withstand both economic and natural disruptions.

Moreover, the distribution of climate-related risks across Cambodia varies geographically, with the poorest regions and communities being the most vulnerable. An in-depth geographic analysis of current climate hazards shows that areas along the Mekong, in the Tonle Sap River valley, and in northwest Cambodia, are already facing a high number of poor households dealing with compounded risks from floods, droughts, and heatwaves. Flooding has particularly adverse effects on agriculture in the northwestern parts of the country. High poverty rates in the northern and western provinces coincide with significant exposure to heatwaves. Central regions around the Mekong River and Tonle Sap are frequently affected by droughts. Women and individuals with disabilities in the northeastern and southwestern rural areas are among those most affected by climate change. These findings emphasize the importance of developing geographically and socioeconomically tailored strategies to support people living in these climate-vulnerable areas (WB, 2023).

Studies have projected significant reductions in rice yields, making Cambodia one of the most affected countries in Southeast Asia in this regard (Chun et al., 2016). Additionally, increased heat and humidity are expected to reduce labor productivity, and there will be heightened health risks due to an increase in vector-borne diseases (WHO, 2015). Sea-level rise and storm surges along the coastal belt are also anticipated.

Therefore, climate adaptation of the agricultural sector is essential for mitigation of the dire effects of climate change on both poverty and food security. According to the Country Climate Development report (CCDR), modernizing the irrigation infrastructure can avert 90–95 percent of the potential yield losses in rainfed rice cultivation. Similarly, improving irrigation can significantly reduce the yield losses of maize and cassava, potentially by more than half. Current limitations in irrigation efficiency include high costs associated with water pumping, subpar canal systems, outdated designs unaligned with evolving rainfall trends, and the insufficient capability of maintenance groups. Furthermore, climate change is expected to adversely affect both livestock and fisheries, thereby compounding food security issues. Implementing climate-smart methodologies in agriculture, as well as in livestock and fisheries sectors, offers a vital chance to overhaul production methods, resulting in enhanced efficiency, greater yields, and improved income for farmers in Cambodia. Additionally, the involvement of the private sector is key in strengthening the resilience of agricultural supply chains, improving distribution systems, investing in eco-friendly agricultural technologies, and providing funds for agro-industrial processing to increase the value of agricultural products[viii].

2. Cambodia’s commitment to climate action in agricultural production

Cambodia is committed to address the urgent challenges posed by climate change and is determined to accelerate its transition towards a climate-resilient and low-carbon sustainable development pathway. The country has demonstrated commendable progress in integrating climate change policies into its national and sub-national planning processes.

Since 1995, the Royal Government of Cambodia has demonstrated a remarkable commitment to climate action, evidenced through a series of pivotal steps and institutional developments. Key milestones include Cambodia's ratification of the United Nations Framework Convention on Climate Change (UNFCCC) in 1995 and joining the Kyoto Protocol in 2002, followed by the establishment of the Climate Change Office in 2003 and its evolution to the Climate Change Department in 2010. In 2006, Cambodia formed the National Climate Change Committee (NCCC) and developed the National Adaptation Programme of Action to Climate Change (NAPA). NAPA outlines prioritized measures to address the immediate and forecasted consequences of climate variability and change. It focuses on the nation's most susceptible sectors, including agriculture, forestry, water resources, health, and coastal areas.

The integration of climate change into the National Strategic Development Plan (NSDP) began in 2009, marking a significant policy shift. Continuing this trajectory, the Cambodia Climate Change Strategic Plan 2014-2023 was approved in 2013, catalyzing the development of Climate Change Action Plans by 14 ministries. The nation's dedication to climate response was further solidified with the ratification of the Paris Agreement in 2016 and the integration of climate change into sub-national planning processes in 2017. By 2018, climate change became a cornerstone of the Rectangular Strategy phase IV, and in 2019, the draft Environment and Natural Resource Code introduced a dedicated section on climate change, laying a legal foundation for future regulations. These actions collectively demonstrate Cambodia's proactive and evolving approach to climate change mitigation and adaptation.

Cambodia has developed updated National Determined Contribution 2020[ix] (updated NDC) to set the target and improve several important approaches to mitigating greenhouse gas emissions and adapting to climate change impacts especially through forestry and land use, agricultural production, and improving energy efficiency. In pursuit of comprehensive climate action, Cambodia has identified priority areas for climate change adaptation and mitigation, emphasizing the need for innovative financing mechanisms to support the widespread adoption of environmentally sound technologies and the increased utilization of renewable energy sources.

The updated NDC established the increased target for GHG emission reduction in the agricultural sector, accounting for of 6.2 MtCO2e, which 23% reduction to the BAU scenario. Cambodia updated NDC is goal is to reduce the Energy sector emissions for 13.7 MtCO2e, which is 40% to the BAU scenario. According to the updated NDC, Cambodia government identified the following priority adaptation and mitigation actions in Agriculture and Water sectors:

Table 1. Priority adaptation actions in Agriculture and Water sectors related to agricultural production

No	**Adaptation action**	**Sector, subsector**	**Ministry in charge**
1	Towards an Agroecological transition in the uplands of Battambang	Agriculture	NCDD
2	Development of Rice crops for increase production, improved quality-safety; harvesting and post harvesting technique and agro-business enhancement	Agriculture	MAFF
3	Development of Horticulture and other food crops for increase production, improved quality-safety; harvesting and post harvesting technique and agro-business enhancement	Agriculture	MAFF
4	Development of Industry crops for increase in production, improved quality-safety; harvesting and post harvesting technique and agro-business enhancement	Agriculture	MAFF
5	Improvement of support services and capacity building to crop production resilient to climate change by promoting research, trials, and up-scaling climate-smart farming systems that increase resilience to CC and extreme weather events	Agriculture	MAFF
6	Building climate change resilience on cassava production and processing	Agriculture	MAFF
7	Research for the development and enhancement of agricultural productivity, quality, and transfer through strengthening of crop variety conservation and new crop variety release responding to the	Agriculture	MAFF

	impacts of climate change		
8	Development of new technologies and increased yields by using new crop varieties which adapt to climate change	Agriculture	MAFF
9	Development of rubber clone varieties suitable for AEZ and resilient to climate change	Agriculture	MAFF
10	Enhancing institutional and capacity development on climate change impact, vulnerability assessment, adaption measures	Agriculture	MAFF
11	Improvement of animal breeding technology in Cambodia through AI which can adapt to climate change	Agriculture	MAFF
12	Promotion of research capacities on animal genetic, animal breeding, and animal feed is strengthened to adapt to climate change	Agriculture	MAFF
13	Strengthening capacities for risk prevention and reduction, effective emergency preparedness and response at all levels; enhancing livestock and disease-related early warning system, and integrating disaster risk reduction and climate change adaptation measures into recovery and rehabilitation initiatives in the livestock sector	Agriculture	MAFF
14	Promoting aquaculture production systems and practices that are more adaptive to climate change	Agriculture	MAFF
15	Promoting climate resilience in the capture fisheries sector	Agriculture	MAFF
16	Scaled up climate-resilient agricultural production through increased access to solar irrigation systems and other climate-resilient practices	Agriculture	NCDD
17	Developing a training manual and providing training on approaches for development of climate-smart and sustainable livelihood to rural poor people	Agriculture	MRD
18	Establish nationally standardized best-practice systems for irrigation	Water resources	MOWRAM

Source: Cambodia First NDC (Updated submission) https://unfccc.int/documents/499051

Table 2. Priority mitigation actions in Agriculture and Water sectors related to agricultural production

No	**Mitigation Projects/Activities**	**Sector, subsector**	**Ministry in charge**
1	Bio-digesters construction Target: 85% reduction compared to 2000 Small size (2-3-4m3) Medium size(6-8-10m3) Large size(>10m3)	Energy generation / Agriculture land related / Waste -MSW	MAFF
2	Increasing the effectiveness and sustainability of agricultural land management techniques (Conservation Agriculture)	Agriculture land- related	MAFF
3	Organic input agriculture and bio-slurry; and deep placement fertilizer technology Target: 10 Provinces by 2030	Agriculture land- related	MAFF
4	Promote manure management through compost making process to reduce carbon emission Target: 25 provinces and cities by 2030	Agriculture land- related	MAFF

Source: Cambodia First NDC (Updated submission) https://unfccc.int/documents/499051

The Updated National Determined Contributions (NDC) highlights Cambodia's significant achievements in addressing climate change, particularly in integrating climate considerations into both national and regional planning. The Cambodian Government has adopted a strategy that primarily emphasizes adaptation to climate change, while progressively incorporating mitigation measures in line with its economic development objectives. To support this approach, Cambodia has formulated and is executing the Cambodia Climate Change Strategic Plan 2014 – 2023 (CCCSP) (2015). Additionally, relevant ministries have established their own specific action plans (CCAPs) to contribute to this overarching strategy.

The Cambodia Climate Change Strategic Plan 2014-2023 (CCCSP 2014-2023), officially launched by the Royal Government of Cambodia in November 2013, is a comprehensive framework aimed at guiding the nation towards climate-smart development over a ten-year period. This strategic plan is designed to integrate with existing government policies, creating a cohesive approach to tackling a broad spectrum of climate change challenges. These challenges include adaptation, greenhouse gas (GHG) mitigation, and fostering low-carbon development. The CCCSP outlines eight key strategic objectives: enhancing climate resilience by improving food, water, and energy security; reducing vulnerability across various sectors and demographics to climate change; ensuring the resilience of crucial ecosystems, biodiversity, and cultural heritage sites; promoting low-carbon technologies and planning for sustainable development; enhancing knowledge, capacities, and awareness for responding to climate change; advocating adaptive social protection and participatory methods to minimize loss and damage; strengthening institutional frameworks and coordination for national climate response; and bolstering active involvement in regional and global climate change initiatives.

3. Agriculture and Water Sectors for Agricultural Production in Cambodia

3.1 Climate change vulnerabilities in agriculture, forestry, and fisheries

Agricultural sector is acknowledged in the RGC's National Strategic Development Plan (NSDP) as a priority sector and fundamental to accelerate the economic growth and poverty reduction of the Cambodian population[1]. The country's agricultural resources consist primarily of around 3.7 million hectares of cultivated land, of which 75 percent is devoted to rice, a primary commodity and source of income for the majority of farmers and 25 percent to other food and industrial crops, primarily rubber, and freshwater and marine fisheries and aquatic resources provide employment to over three million people[2]. This natural-resource-based sector contributed around a quarter to the gross domestic products (GDP), 26.3% in 2016 and 24.9% in 2017, and within this sector in the later year, crop productions accounted for 13%, followed by 5.5% of fisheries, 2.6% of livestock and poultry, and 1.6% of forestry and logging productions[3].

It was stated in the recent MAFF's annual report that rice production has been gradually increased from 3.163 tons/ha in 2013 to 3.298 tons/ha in 2017[6], due to the strong support from the Royal Government of Cambodia, concerned ministries, various development partners, national and international organizations, sub-national authorities, and active participation by farmers, especially the change from subsistent to commercial oriented production[5]. Such achievement as claimed in the report was associated with the application of high-yielding seeds, proper farming technology, soil & water management, extension and demonstration farm trials, and research enhancement.

[1] National Strategic Development Plan 2014-2018
[2] FAO (2014) Country factsheet on food and agriculture policy trends (http://www.fao.org/3/a-i3761e.pdf)
[3] MAFF annual report 2018 (http://oads.or.kr/upload_file/bbs/56-1.MAFF-2017-2018%20(EN)-Final-Binder.pdf)

In pursuit of implementing the NSDP, the Ministry of Agriculture, Forestry and Fisheries (MAFF) focuses on improving agricultural productivity, diversification and commercialization by accelerating the implementation of necessary measures, including building and improving infrastructures support to agricultural production, increasing the provision of technical services to farmers, strengthening the agricultural research and development capacity to increase crop yields and climate change adaptation, improving soil fertility, and strengthening the capacity of agricultural communities and the institutional capacity to promote agricultural development[6]. MAFF has also accelerated the promotion of livestock and aquaculture through vigorously strengthening the application of rules and regulations to manage the use of natural resources, such as forests, fisheries, agricultural land, to ensure the sustainability of these resources and environment. These concerted efforts are implemented with a focus to increase the value of agricultural products, as well as income for the farmers, to promote agribusiness and increase national revenue.

The main focused and vulnerable sub-sectors of agriculture to the impacts of climate change found in this study are primarily rice and crop productions, livestock, and fisheries and aquaculture. The next sections give a synthetic review on the impacts and vulnerability, and the adaption practices and measures in these sub-sectors.

Agriculture

Cambodia agriculture is reported to be highly reliant on rainfall due to the insufficient irrigation systems that could not cover the cultivated land of the whole country. There is no consensus on the areas of total cultivation under fully irrigation scheme. This study found that by 2017, the areas of cultivation particularly rice paddy with irrigated schemes were between 15% and 25% of the total cultivated land, but it was reported that some of these irrigation schemes still faced water shortage especially during the years of prolong drought. This signifies that rice plantations are highly susceptible to water deficiency especially under the pressing effects of climate change these days and the years to come.

There are a number of reports and scientific research in respect to the impacts of climate change on agriculture. FAO (2008) states that climate change is expected to significantly affect the productivity of rice systems, thereby worsening the nutrition and livelihoods of millions of people. Furuya et al., (2014) studied about the impacts of climate change on rice market and production capacity found that the impacts will depress the production of wet season rice especially in Cambodia. In addition, Mainuddin et al., (2012) figure out that there will be a significant increase in water productivity of rainfed rice in the lower Mekong basin in Cambodia. In particular, the droughts in 2005 had more intense impacts than those in 2010, reducing NPP by 14.7% and 8.4% respectively, because of the longer drought period and larger precipitation deficit in 2005 than in 2010. The study also confirms a significant variation in the types of vegetation: less variation in NPP is found for croplands, even under drought conditions, compared to forests, woodlands and shrub lands. The result of that study emphasised that under drought conditions there are wider uses of irrigation and the exploitation of water sources for farming systems, which means more efforts and costs are required for the production process. Such finding is very consistent with that of Furuya et al., (2014), who conclude that climate change impacts will raise production costs of rice farming in Cambodia, Lao and Vietnam.

The critical concerns of extreme climate events as the effects of climate change impacting the agriculture sector are mainly floods, droughts and pest and disease outbreaks for crop plantation and other agricultural systems. The section to come is a description of vulnerability status in three key sub-sectors namely rice and crop productions, livestock, and fisheries and aquaculture.

Rice and crop production

In Cambodia, rice which is the dominant crop accounted for over 75% of the country's total crop productions is mainly cultivated in the floodplain regions of the Mekong and the Tonle Sap great lake. Rice and other certain crop production systems are consequently extremely sensitive to large year-to-year climate variability.

It was highlighted that with a 1°C increase in temperature would cause the annual mean crop loss by around ten percent, which essentially indicates that for an average farm, climate change may render cropping agriculture an unprofitable activity[4]. However, the agricultural impact of climate change may be felt evenly across the country. Increased wet-season rainfall in drier areas can be beneficial, especially if this coincides with a reduction in frequency and duration of drought in the wet season[5]. In wet areas, potential increase in flooding tends make rice plantation unviable in low-lying areas if they are too frequently inundated; in turn, this will likely require a more transformational shift to production systems such as through changing rice cropping into the dry season through irrigation.

The projected impacts of climate change on crop productions was emphasised in the MAFF's Climate Change Priority Action Plan 2014-2018. Table 2 gives a summary of these projected impacts. In addition, a recent research carried out by ICEM on the vulnerability of main crop productions using climate-crops modelling was published in the *Mekong ARCC Climate Change Impact and Adaptation Study on Agriculture* report[6]. In Cambodia, the study that included the V&A assessment in Mondul Kiri (upland and mountainous areas) and Kampong Thom (Tonle Sap flood plains), focusing on rice and particular commercial, cash crops namely soybean, cassava and rubber, found that these crop plantations are *Highly* vulnerable in Kampong Thom and *Medium* to *Highly* vulnerable in Mondul Kiri – see Tables 3 and 4 for a summary of the results.

Table 3. Projected climate change impacts on crops productions highlighted in MAFF's climate change strategic action plan 2014-2018

Climate Change Effects/Threats	Impacts Summary	Source
Increased temperature	Reducing the crop yields. The yield of rice decreases by 10% for every 1°C increase in the minimum temperature during growing season.	Peng et al., 2004
Pest and diseases outbreak	Higher growth rate of pathogens due to the long growth cycle and warmer season, and increase in weeds due to the increased atmostparic CO_2 concentration	MAFF (2014)
Sea level rise and saline water intrusion	Reduce vegetable crop area at the coastal zones with flooding in the tidally influenced areas and increased are affected by saline water	MAFF (2014)
Increased extreme weather events	Causing frequent droughts and floods devastating crop plantations. The more floods and droughts – more intense and frequent – will make the onset of growing seasons less predictable, thereby affecting productivity especially rice which is sensitive to	MAFF (2014)

[4] MAFF (2014) Climate change priority action plan for agriculture, forestry and fisheries 2014-2018.
[5] http://hdr.undp.org/sites/default/files/cambodia_2011_nhdr.pdf
[6] https://www.usaid.gov/documents/1861/usaid-mekong-arcc-climate-change-impact-and-adaptation-study-agriculture-report

	timing of first rains. Mini droughts in wet season and unexpected rain in dried season, all of which further affect productivity and the livelihoods of farmers.	
Changes in rainfall patterns	Wet seasons would be shorter but with higher levels of rainfall, while dry season will be longer and drier. This will result in shifts in the distribution of rainfall between areas. The changes to the length of seasons, combined with the delayed onset of the wet season after a long dry season, will affect traditional cropping practices	MAFF (2014)

Source: MAFF (2014)[7]

Table 4. Main threats and vulnerability for crops in Kampong Thom province

Vulnerable crops	Threats	Impact Summary	Vulnerability
Lowland rainfed rice **Irrigated rice** **Soybean**	Increased temperature	More than 75% of the maximum daily temperature above the optimal zone for lowland rainfed rice. More than 50% of maximum daily for irrigated rice. High Extreme maximum temperature (<25% of frequency) higher than 35°C during soybean crop High growth.	High
Lowland rainfed rice **Cassava** **Soybean**	Flooding	Flood prone area around the Mekong and Tonle Sap High lake in the southwestern part of the province. Precipitation above 500 mm per month in October and total precipitation in the wet season above 1,700 mm.	High
Soybean	Decrease in water availability	Decrease in water availability will be between 10% and 4% during the crop growth period.	High

Source: ICEM (2013)

Table 5. Main threats and vulnerability for crops in Mondul Kiri province

Vulnerable crop	Threats	Impact Summary	Vulnerability
Cassava, Soybean, Lowland rainfed rice	Storm and increased rainfall	21 days with more than 100 mm, including 1 day above 160 mm per year. Rainfall above 500 mm per month in October and high frequency of storms, which may damage crops and create water logging in lowland areas that are more exposed.	Medium to High

[7] MAFF (2014) Climate Change Strategic Action Plan for Agriculture, Forestry and Fisheries 2014-2018

Soybean	Increased water availability	Decrease in water availability would be between 18% and 20% during crop season, creating water stress.	High
Rice	Increased temperature	Increase in maximum temperature will fall between 12% and 17% compared to baseline during growth period. More than 50% of the maximum daily temperatures will be above the optimal zone for rainfed rice.	Medium
Cassava	Increased temperature	Around 15% of the days will be above 35°C as during the growth cycle cassava.	Medium
Rubber	Increased temperature	Dry season (March to May) will have more days above 35°C as daily maximum temperatures, with temperature increases of 17% in May	Medium
Soybean	Increased temperature	Higher maximum temperature below 35°C in the rainy season will create a stress and limit yield. This might be a stress for soybean in the case of the early wet season crop, in April or May.	Medium

Source: ICEM (2014)

Livestock

Livestock is another priority sub-sector contributing to jobs creation, securing food nutrition, economic growth and poverty reduction. It has accounted for over 11% of the total agricultural productions for the last five years since 2014[8]. MAFF's 2019 annual report indicates that in 2018, livestock husbandry increased by 3.6% compared to the previous year. The main livestock commodities include cows, buffalo, pigs and poultry, of which gigs are predominantly raised in traditional system. Approximately 90-95% of farming households throughout the country have chickens, which are mainly local genotypes raised primarily for meat in scavenging, low-input, low-biosecurity backyard systems[9].

It has been recognized that small- and medium-scale commercial operations of livestock are most vulnerable due to the limited capacity to adapt to the effects of climate change. The presence of commercial livestock production units has increased dramatically in recent decades and this trend is highly likely to continue. The summary of the vulnerability to climate change of different livestock systems in Cambodia is shown in Table 5, emphasized in the MAFF's climate change strategic action plan. This result was also concluded from a synthesis of various information and from expert assessments.

Furthermore, livestock is very much sensitive to the increased temperature. *Bos indicus* sp. Cattle, for example, are comfortable in high temperatures, as high as 38°C before any notable effects on production, but the temperatures above 38°C may lead to heightened stress, reducing immunity and feed intake, and likely exacerbated by work[14]. The thermoneutral zone of this species is typically 0-20°C, and the individuals exhibit significant decline in milk yields at around 21-25°C[14]. This is important for the burgeoning dairy industry which largely employs Holstein-Friesians. However, relatively wide variation exists between breeds. For example, Brown Swiss milk production is not affected until 30-32°C, and again will depend on the animal's past experience[14].

[8] MAFF's Annual Report 2019
[9] ICEM (2013) USAID Mekong ARCC Climate Change Impact and Adaptation on Livestock; available at: https://www.usaid.gov/documents/1861/usaid-mekong-arcc-climate-change-impact-and-adaptation-study-livestock-report

In terms of pigs, the thresholds very dependent on systems of management and breed, but the optimal production typically can be achieved between 20°C and 30°C. Young pigs in their first few days are most susceptible to low temperatures. Bigger piglets are better able to cope; hence improved sow condition management is a possible means of building resilience to temperature changes.
For poultry, the optimal temperatures are approximately between 25°C and 30°C at all times until a week or so of age[14]. The importance is that the biggest production losses occur with sudden changes; they are better able to cope with temperature extremes if the change is gradual. As such sudden temperature shocks can be catastrophic, particularly the intensive units. Significantly, the likelihood of disease transmission will be affected by changes in temperature affecting pathogen ecology. However, given the capacity of bovines to adapt to different temperatures, minor temperature changes across the region will have impacts at scale but will be difficult to notice or measure in individual animals or herds.

Table 6. Vulnerability level of livestock to climate change threats highlighted in MAFF's climate change strategic action plan 2014-2018

Livestock System	Impact	Adaptive capacity	Vulnerability
Smallholder cattle/buffalo	Low	Low	Medium
Dairy/large commercial livestock farms	Very high	High	High
Small commercial pig	High	Medium	High
Smallholder low-input pig	Low	Low	Medium
Smallholder commercial chicken	Very low	Low	Very high
Scavenging chicken	Low	Low	Medium
Field running layer duck	Very low	Low	Low

Source: MAFF (2014)
Changes in rainfall patterns will substantially affect livestock units through feed and animal health issues. Also, changes in the availability, quality, and price of feeds are fundamental to all livestock production systems. For intensive monogastric units, feed costs typically account for 65 to 80 percent of production costs, while a key current constraint to most extensive smallholder systems in the region is under-nutrition[14]. Furthermore, pathogens will likely be affected in terms of viability outside hosts and rates of proliferation by humidity levels and, importantly, the quality and quantity of vector breeding sites. Wetter periods typically increase the likelihood of disease transmission through fomites, increasing the importance of employing effective biosecurity measures. Therefore, livestock sub-sector is highly vulnerable to the projected rising temperature and shifting rainfall patterns that are the effects of climate change. The result of the V&A assessment of climate change on livestock, conducted by ICEM under the USAID support (See Table 5).

Fisheries and aquaculture

This sub-sector includes freshwater and marine fisheries and aquaculture. The inland capture fisheries of Cambodia are among the most productive in the world, providing the main source of protein especially in rural diets, accounted for approximately 61% of household's animal protein intake[10]. Average annual fish consultation per person is estimated at 63 kg. According to MAFF, in 2018 the total annual productions of

[10] https://www.worldfishcenter.org/country-pages/cambodia

fisheries and aquaculture were 910,153 tones, comprising 535,005 tones freshwater fisheries, 121,100 tones marine fisheries and 254,048 tones aquaculture[11].

Capture fisheries production is highly sensitive to hydrology and land use changes – and thus to climate change. Any declines in natural productivity would have serious food security implications that could not be offset by other forms of food production. Short-term climate change impacts on aquaculture can include losses of production and infrastructure arising from extreme events such as floods, increased risks of diseases, parasites and harmful algal blooms. Long-term impacts can include reduced availability of wild seed as well as reduced precipitation leading to increasing competition for freshwater[12].

Furthermore, increased temperatures will have significant impacts on elements of the capture fisheries and aquaculture systems affecting food security and the livelihoods of the people living in these areas. Extreme weather events could further harm Cambodia fish production by causing loss of aquaculture stock and destroying fishing and aquaculture infrastructure[18]. Changes in fishery production are likely to have the greatest impact on people who depend on fishing as their primary livelihood activity. As these people are often poorer and more marginal than those who own land and have other primary sources of income, the effects of climate change on fisheries will harm those least equipped to cope[13].

Droughts and reduced water availability through decreased precipitation will be more manageable by some species and aquaculture farmers in some areas but will seriously impact others. Storms and flash flooding will likely affect the viability of aquaculture systems, more so than slow-paced flooding, which allows for greater adaptability. However, fisheries are not only affected by climate change, but the infrastructure developments of dams and irrigation systems on the upstream Mekong. By 2030, climate change may raise the wet season flood level of the Tonle Sap lake by 2.3 meters[14], extending feeding grounds and encouraging fish production. On the other hand, dams to be developed in the Mekong Basin will store water during the monsoon and thus will decrease wet season flood levels. Such hydrological changes to river flows and levels caused by the construction of mainstream and tributary dams will likely completely mask the changes in river hydrology caused by increased precipitation throughout the catchment.

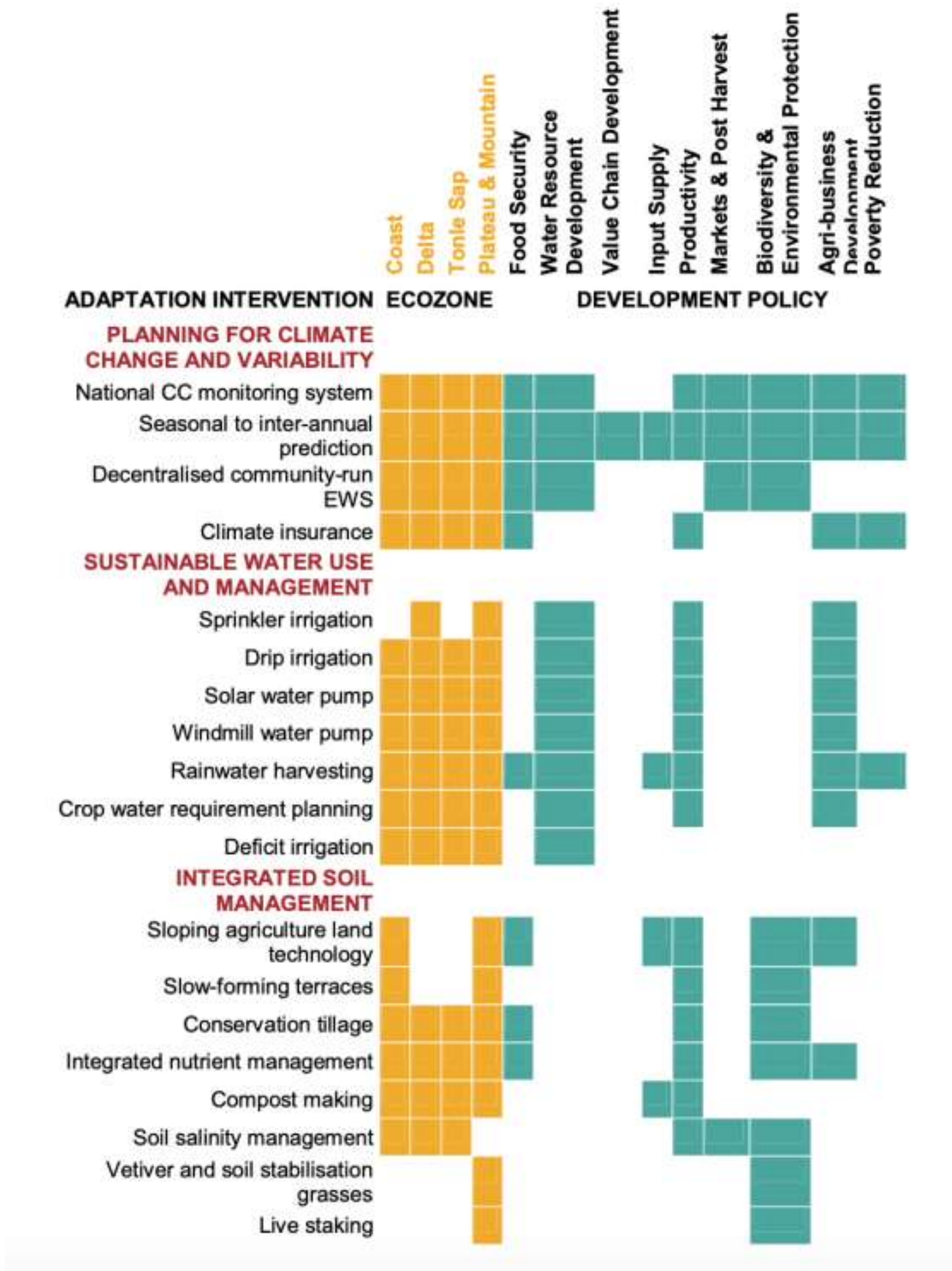
3.2 Adaptation practices and measures in agriculture, forestry, and fisheries

Cambodia's NDC focuses on adaptation, highlighting that climate change adaptation action requires an integrated, multi-sector approach to be effective and to be able to support national development objectives[15]. The country has made concerted efforts in adaptation to the impacts of climate change in various affected sectors, particularly the agriculture and its sub-sectors.

Adaptation in crop production systems

Adaptation practices in agriculture have been implemented substantially through various projects throughout the country coordinated by both the concerned ministries, research institutions, universities and NGOs including donor agencies. A significant number of farmers have been introduced with some agriculture practices/ technologies to adapt to the effects of climate change and these technologies are perceived somehow help the farmers' farming practices more climate resilient. A summary matrix of recommended adaptation interventions at different Cambodia's ecozones and the type of intervention policies (Figure 7).

[11] Annual report 2019 of the Ministry of Agriculture, Forestry and Fisheries
[12] http://www.fao.org/3/i9705en/i9705en.pdf
[13] http://publications.iwmi.org/pdf/H042414.pdf
[14] https://pdfs.semanticscholar.org/16d1/d955a0d11e229aeb733777a033395b27aa7d.pdf
[15] Cambodia NDC roadmap and stakeholder engagement plan 2019-2030 (https://ncsd.moe.gov.kh/resources/document/cambodia-ndc-roadmap-and-stakeholder-engagement-plan)



Coast
Delta
Tonle Sap
Plateau & Mountain
Food Security
Water Resource Development
Value Chain Development
Input Supply
Productivity
Markets & Post Harvest
Biodiversity & Environmental Protection
Agri-business
Poverty Reduction
ADAPTATION INTERVENTION
ECOZONE
DEVELOPMENT POLICY
PLANNING FOR CLIMATE CHANGE AND VARIABILITY
National CC monitoring system
Seasonal to inter-annual prediction
Decentralised community-run EWS
Climate insurance
SUSTAINABLE WATER USE AND MANAGEMENT
Sprinkler irrigation
Drip irrigation
Solar water pump
Windmill water pump
Rainwater harvesting
Crop water requirement planning
Deficit irrigation
INTEGRATED SOIL MANAGEMENT
Sloping agriculture land technology
Slow-forming terraces
Conservation tillage
Integrated nutrient management
Compost making
Soil salinity management
Vetiver and soil stabilisation grasses
Live staking

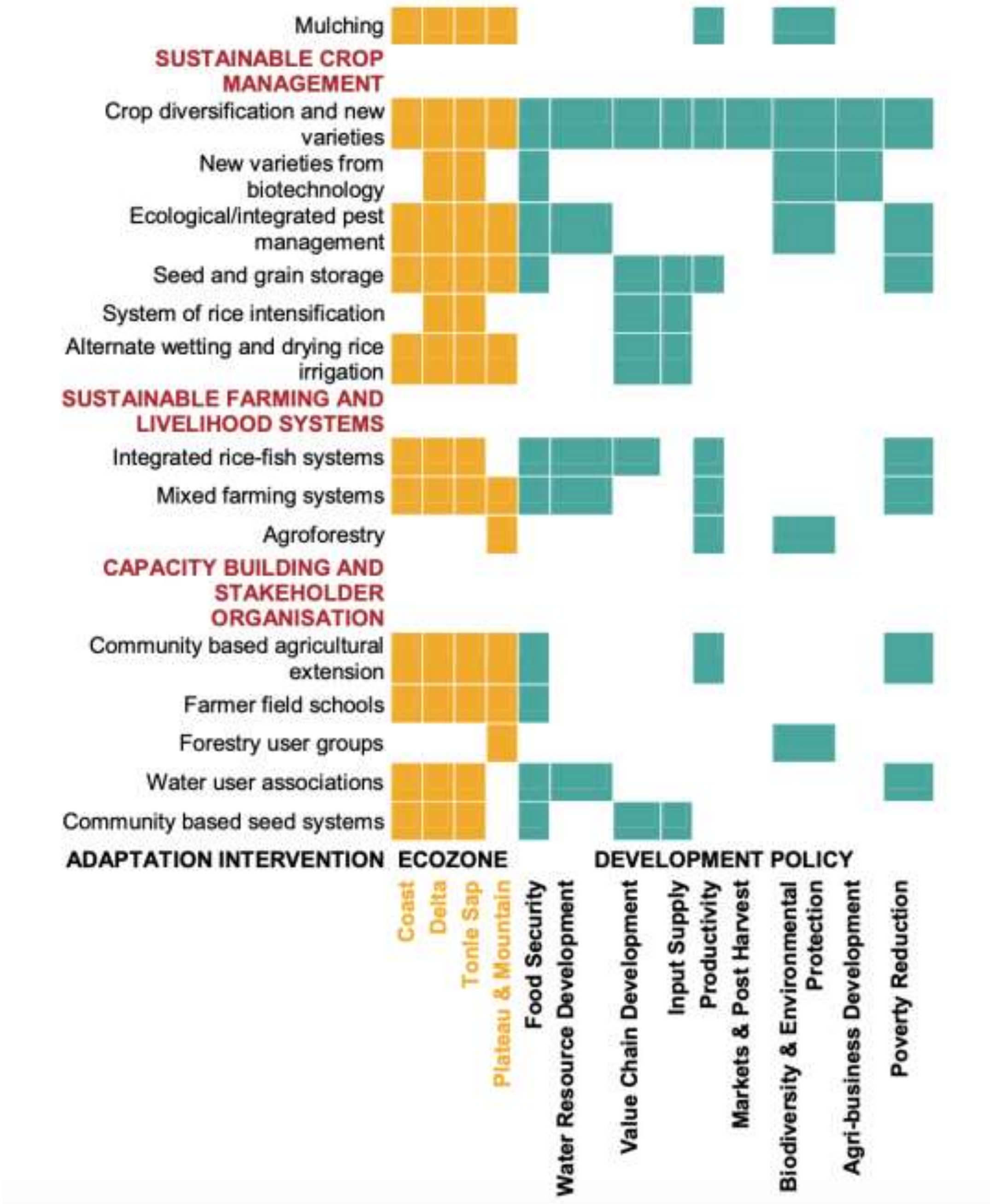


Figure 7. Selected adaptation measures and technologies in crop production systems at different ecozones and policy options for agriculture production systems

(Source: MAFF 2019)[16]

[16] Available at: https://ncsd.moe.gov.kh/resources/document/adaptation-technologies-guide-agriculturejune-2019en

Fisheries and aquaculture

FAO's report recognizes that the impacts of climate change on the fisheries and aquaculture sector will be determined by the sector's ability to adapt because each specific fishery or fishery/aquaculture enterprise exists within unique contexts, and climate change adaptations must start with a good understanding of a given fishery or aquaculture system and a reliable assessment of potential future climate change[17]. The suitable adaptation measures are as follows:

- Enhancing the productivity of rice field fisheries through protection of dry season habitats for fish
- Participatory action research in inland small-scale fisheries co-management and wetlands conservation
- Low input, cost effective, and nutrition sensitive small-scale and medium enterprise models for aquaculture production and business enterprise models
- Climate Smart Agriculture technologies and practices
- Adapt by making ponds for conservation, making conservation areas
- Aquaculture producers will have to avoid overfeeding and overstocking fish and to monitor water temperature.
- Build capacity for problem solving
- Create and improve livelihood options; diversify livelihoods
- Create/build self-help groups
- Extend/promote understanding of climate change
- Grow/re-grow forests and the flooded forest
- Dig ponds, rehabilitate canals, make conservation areas
- Select livelihoods option to adapt to climate change
- Build networks and provide information on climate change
- Species should be screened, and better-adapted species selected, or strains could be developed that are physiologically more tolerant to the changing environment

3.3 Climate change vulnerabilities of water sector

Cambodia's water resources are highly dependent upon the Mekong River Basin (LMB), which includes the Tonle Sap basin with 12 tributary sub-basins; the Sekong, Sesan and Srepok rivers of the northeast; the Cambodian Mekong delta; and a number of small river systems from the high-rainfall Cardamon and Elephant Mountains in the southwest[18]. Cambodian territory covered about 80% within the Mekong basin, which occurred due to have large fluctuations of water levels between the dry and wet seasons

This causes an annual cycle of droughts and floods, damaging agricultural production and livelihoods and constraining development and poverty alleviation. The 2014 World Risk Report puts Cambodia as the ninth most at risk country in the world.

The rivers and streams, lakes, aquifers and marine water are important sources for national economic development in many sectors including agriculture, manufacturing and small-scale industries, hydropower, navigation, tourism, environmental protection and the livelihoods of the population especially those living along the floodplain regions. The Mekong and Tonle Sap rivers and their systems play vital roles in maintaining aquatic ecosystems and provide natural resource bases for national

[17] http://www.fao.org/3/i9705en/i9705en.pdf

[18] MoE (2011) *Climate Change and Water Resources*, Cambodia Human Development Report 2011. (http://hdr.undp.org/sites/default/files/cambodia_2011_nhdr.pdf)

economic and social development, particularly for agriculture and fisheries which are the main sources of national and household incomes.

Albeit with plenty freshwater resources, the country has faced tremendous challenges of water resource management related to the availability and distribution at different periods of the year, across spatial regions and between users. These include floods in the rainy seasons and water shortages in the dry seasons, which not only affects agricultural and fisheries activities[19]. Importantly, the seasonal cycling of water levels at Phnom Penh causes the large water flow reversal to and from the Great Lake via the Tonle Sap, with the associated flooding and drying creating a rich ecology.

Cambodia's law on Water Resources Management was approved in 2007, building on the National Policy on Water Resources Management and the Strategic Plan on Water Resources Management and Development (2005-2008). The Law includes several articles that deal with rights, organization and participation of water users. It emphasizes the integration of farmer water user committees (FWUC) into water resources sustainable management as the most important and decentralized scheme of the RGC for poverty alleviation. The Law refers to the need to integrate environmental considerations into water management but does not address climate change issues specifically. It does highlight a recognition of the cross-sectoral nature of water management, and the need for inter-agency and ministerial cooperation, although realizing such cooperation is challenging in practice. This becomes particularly important including the transboundary coordination between the countries involving the Mekong due to the interconnected and inter influential nature.

Impacts and vulnerability

Climate change is known to exacerbate the existing challenges of the country's water resource management (Bach et al. 2014)[20]. It is also emphasised that climate change will increase water management challenges; less rainfall is anticipated during the dry season and more during the wet season, with more extreme weather events and potentially worse seasonal water shortages and floods[21]. The challenges are more threatening to a developing country like Cambodia, where meteorological systems are not yet able to forecast extreme weather, like flash floods and unpredicted drought, which have often happened in Cambodia.

According to MoE and UNDP (2011), the changing climate will shift the timing and intensity of rainfall patterns and seasons, change the hydrology of the major rivers and their tributaries, affect ground water aquifers, and increase the frequency and intensity of extreme events like floods and droughts. These changes affect the quantity, quality, availability and distribution of water. Climate change also alters the habitats of the Tonle Sap basin: increasing the open water by 2–21% and reducing rain-fed habitats by 2–5% and seasonally flooded habitats by 5–11%[22]. Such distortions are believed to affect key fishery habitats, thereby leading to substantial impacts on human development, as fish are the main source of protein in the local diet. Currently there are no viable substitutions to fish in local diets, so this would worsen the low nutrition levels across rural areas.

[19] MRC (2009) *Adaptation to climate change in the countries of the Lower Mekong Basin: Regional synthesis report. (http://www.mrcmekong.org/assets/Publications/report-management-develop/MRC-IM-No1-Adaptation-to-climate-change-in-LMB.pdf)*

[20] Bach, H, Glennie, P, Taylor, R, Clausen, TJ, Holzwarth, F, Jensen, KM, Meija, A & Schmeier, S 2014, *Cooperation for Water, Energy and Food Security in Transboundary Basins under Changing Climate*, Mekong River Commission, Vientiane.

[21] Climate change strategic plan for water resources and meteorology 2013-2017

[22] Arias, ME, Cochrane, TA, Piman, T, Kummu, M, Caruso, BS & Killeen, TJ 2012, 'Quantifying changes in flooding and habitats in the Tonle Sap Lake (Cambodia) caused by water infrastructure development and climate change in the Mekong Basin', *Journal of Environmental Management*, vol. 112, pp. 53-66.

The impacts of the present climatic change on natural resources and socio-economic systems is currently less clear but anticipated to become more visible and significant over time, particularly as projected future climate change across the Lower Mekong Basin is extreme under some scenarios[23]. However, according to MRC (2018) the impacts of climate change on the water resources especially the LMB are specified. At present, although there are certain phenomena like drought and floods occurred in certain years, yet it is unlikely to conclude that such phenomena are the results of the climate change effects.

However, in the future, models show that significant impacts are highly like to occur requiring particular attention. It is undeniable that the hydrologic conditions of the Mekong and water systems in Cambodia are not only affected by climate change, but also by the upstream infrastructure development. It is projected that the largest range of predicted impact at Kratie associated with climate change and 2060 infrastructure development scenarios are: the range of annual river flow change is estimated as -38% to +28%; water level -1.95m to +1.29m; flood season peak flow -30% to +43%; flood season peak level -2.83m to +2.96m, minimum 1-day flow -21% to +79% and minimum 1-day level -0.18m to +0.90m[24]. More importantly, the shift in hydrological level and flow will affect other sectors including agriculture, natural resources, socio-economic systems as a whole, particularly fisheries, and ultimately the people whose livelihoods depend entirely upon such activities.

Arias et al. (2014)[25] conclude that there will be a significant change and decline in ecosystem services that drive ecological productivity: habitat cover, net primary productivity and sedimentation, if mitigation and adaptation strategies are not implemented. They further demonstrate that climate change effects will link to a decline in ecosystem services attributing to lowering the ecological productivity such as NPP, sedimentations and habitats cover if mitigation and adaptation strategies are not appropriately implemented. Such hydrological distortions are expected to affect important fish habitats, thereby connecting to substantial impacts on nutrition supply since fish is the major protein source in the diet of local people in the region especially those of Cambodia, and this will exacerbate the current low nutrition levels across the rural areas (UNDP, 2011). Besides, more frequent and intense floods and droughts also adversely affect agricultural productions and livelihoods. For instance, Cambodia has already been tremendously affected by 12 major flood events between 1987 and 2007 (ICEM, 2013). Under the conditions of potentially more frequent and intense floods and droughts, it is likely that farmers will be more exposed to higher risks of crop failure and livelihood burdens.

3.4 Adaptation practices and measures for water sector

It has been acknowledged that climate change adaptation is necessary for water sector in Cambodia. In the context of the Mekong River Commission, adaptation measures to climate change can be classified into two main groups: *policy-based* and *vulnerability-based* adaptation measures[26]. The policy-based measures refer to the measures generally dealing with improving the 'enabling environment' or framework conditions for climate change adaptation, and they target the policy, legal and institutional settings as well as the financial and information systems and capacity building. The vulnerability-based

[23] MRC (2018) Mekong climate change adaptation strategy and action plan. (http://www.mrcmekong.org/assets/Publications/MASAP-book-28-Aug18.pdf)

[24] MRC CCAI, 2016. Basin-wide Assessment of Climate Change Impacts on Water and Water Related Resources and Sectors in the Lower Mekong Basin. Technical Report. Climate change impacts on hydrology of the Lower Mekong Basin – Volume 1: Water level, flow and salinity (http://www.mrcmekong.org/assets/Publications/Basin-wide-Assessment-of-Climate-Change-Impacts-on-Hydropower-Production_report-13May19.pdf)

[25] Ariasa et al. (2014) 'Impacts of hydropower and climate change on drivers of ecological productivity of Southeast Asia's most important wetland', *Ecological Modelling*, vol. 272, pp. 252-263.

[26] MRC (2018) Mekong climate change adaptation strategy and action plan. (http://www.mrcmekong.org/assets/Publications/MASAP-book-28-Aug18.pdf)

measures are associated with the technical and infrastructure measures generally dealing with the expected water resources and socio-economic vulnerability.

In addition to the MoE's NAPA and National Climate Change Strategic Plan 2014-2023, the Climate change strategic plan in water resources (CCSP-WR) 2013-2017 was published[27], specifying the adaptation policy in water resources of Cambodia. Below is a list of the adaptation measures that this policy highlighted.

- Build foundations for river water use and control
- Specific awareness raising for private companies in adapted climate change development
- Establish flood prevention measures in the riskier regions such as populated areas and potential agriculture sites
- Encourage private companies in low carbon development and sustainable development
- Deliver more mandates on water resources management to sub-national levels
- Capacity building in water resources management and uses of modern weather technologies at sub-national levels
- Develop a long-term plan of national water control to prepare for possible heavy rain casualties caused by abnormal climate variability
- Build flood warning system
- Take measures against negative impacts on water resources from urban development such as stream flow reduction, worse water quality, and drainage systems
- Prepare water use, considering drought
- Build stabilized irrigation systems addressing reduced precipitation caused by climate change
- Develop ground water preservation plans and restriction regulation
- Shore up functions of the river environment, including ecological system preservation and water-familiar functions
- Conduct research on what matters most in water resources, with regard to the impacts of climate change
- Prioritize climate change coping activities on sustainable water resources development and management
- Rehabilitation of canals along Cambodia-Vietnam borderlines

The mainstream-related activities, such as raising awareness through training, various forms of media and study tours to some places with successful adaptation practices are particularly important for Cambodia, where mainstreaming adaptation is still minima[28], and they can contribute, though probably insufficient, to behavioural changes required for adaptation. Similarly, staff capacity building within the ministries and among other stakeholders is essential for strengthening the institutions, which need to collaborate in the adaptation efforts. Additionally, ecosystem-based adaptation approaches, the good element that the strategy also has are considered cost-effective as they make use of local or existing ecosystem services to

[27] This policy document is available at: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=5&cad=rja&uact=8&ved=2ahUKEwju9YzyjP3mAhXPR30KHWp1D1YQFjAEegQIBhAC&url=http%3A%2F%2Fwww.camclimate.org.kh%2Fen%2Fdocuments-and-media%2Flibrary%2Fcategory%2F117-sectoral-ccsp.html%3Fdownload%3D531%3Asectoral-ccsp-for-water-resource&usg=AOvVaw3-HUW2wgA-D8PyXmMuWEi5

[28] Saito, N 2013, 'Mainstreaming climate change adaptation in least development countries in South and Southeast Asia', *Mitigation and Adaptation Strategies for Global Change*, vol. 18, no. 6, pp. 825-849.

build resilience[29], and to provide multiple benefits socially, economically, culturally and environmentally through biodiversity conservation[30].

4. Overview of agricultural climate technologies supporting Cambodia updated NDC

Market assessment for the application of climate technologies in agriculture, focusing on areas like irrigation, water harvesting, agro-food processing, solar cooling, and food product preservation.

Urgent adaptation measures are crucial to counteract the potential impact of climate change on Cambodia's developmental progress. The country has achieved remarkable results in reducing poverty, being nominated for graduation from the LDC status. However, its susceptibility to climate change threatens to negate these advancements, potentially increasing poverty levels by up to six percentage points by 2040 (WB, 2023) unless climate resilience and adaptation technologies are adequately enhanced. Furthermore, the revised National Determined Contributions (NDC) highlight that the agricultural sector has specified a comprehensive range of technological requirements for implementing climate-resilient practices. These include everything from cultivating varieties that can withstand environmental stresses to adopting more efficient rice cultivation methods, as well as comprehensive pest management and soil and nutrient management strategies.

Scaling up climate mitigation technologies is essential to fulfill climate pledges. Cambodia has pledged to achieve carbon neutrality by 2050, and achieving this goal will require a paradigm shift for decoupling GDP growth from emissions growth. It is especially crucial to divert GHG emissions in forest and other land use sectors.

Cambodia has already made commendable progress in integrating advanced adaptation and mitigation technologies and methodologies across various sectors. Innovative information platforms, such as CAMDI and DesInventar, alongside cutting-edge weather forecasting technologies from European meteorological institutes, are revolutionizing disaster risk management. In the energy sector, renewable and efficient energy solutions are being tailored to local needs. The health sector utilizes sophisticated surveillance systems to track diseases, while the infrastructure sector employs guidelines from international bodies for climate-resilient investments. Land use and water resources management benefit from high-tech surveys, detailed spatial analyses, and comprehensive risk assessment tools. Moreover, the sectors responsible for enabling these advancements effectively leverage media channels and monitoring manuals to disseminate information and track progress.

This market analysis is essential to ascertain which climate technologies for agricultural production supporting the updated NDC, have not yet been adequately scaled up to meet the countries goals. In the next part of the report, we will examine the status of NDC climate technologies in the agricultural sector and identify areas that demand immediate technical assistance and climate finance support, with the aim of developing a comprehensive roadmap. This roadmap will facilitate climate resilience and promote low-emission development pathways, essential for sustainable rural development.

ADAPTATION TECHNOLOGIES SUPPORTING UPDATED NDC:

1. Towards an Agroecological transition in the uplands of Battambang

[29] Kerkhoff, LV, Ahmad, IH, Pittock, J & Steffen, W 2011, 'Designing the Green Climate Fund: How to spend $100 billion sensibly', *Environment: Science and Policy for Sustainable Development*, vol. 53, no. 3, pp. 18-31.
[30] Colls, A, Ahs, N & Ikkala, N 2009, *Ecosystem-Based Adaptation: A natural response to climate change*, International Union for Conservation of Nature and Natural Resource (IUCN), Gland.

In line with the Cambodian government's strategic vision articulated in the CCCSP 2014-2023, an adaptation agricultural program is underway in the uplands of Battambang, spearheaded by the National Committee for Sub-National Democratic Development (NCDD). It focuses on leveraging the decentralization process to bolster local adaptation capabilities and mainstreaming climate change into both national and sub-national development strategies. This project endeavors to strengthen local agricultural practices by innovating with agroecological technology, where private sector within the supply chain will play a pivotal role for scaling up. The ambition is to impact 100,000 individuals by 2026, potentially scaling up to benefit 5 million people, representing about 30% of the population.

The program[x] has been submitted to the Green Climate Fund to access USD 10 million of climate finance. It will be implemented by NCDD in partnership with MAFF, MoE, Swisscontact, CIRAD, UNDP. The initiative aims to assist small-scale farmers in evolving towards a diverse agroecological landscape system through an innovative public-private agroecological extension model MetKasekor. This model is currently in its pilot phase by MAFF and will be enhanced to support market systems, knowledge management, education, and conducive policy frameworks. Additionally, the project will reinforce DeiMeas, a pioneering transition financing model under the Department of Land Resources Management (DALRM). This model is designed to be self-sustaining, offering incentives for adopting agroecology-based practices. These practices aim to boost smallholder incomes, foster landscape-level climate resilience, and reduce emissions through enhanced land cover, biodiversity, and soil carbon.

2. Early Warning System (EWS 1294) for risk prevention and reduction

Early Warning System 1294 is a Cambodia's multi-hazard system that provides timely notification to protect people from possible natural disasters that supported by Swiss Cooperation Mekong HEKS-EPER Cambodia Caritas Suisse. This system was strongly collaborating the National Committee for Disaster Management (NCDM) and the Ministry of Posts and Telecommunications (MPTC), international development agencies, international governments and donors, civil society, private companies, and local communities. This system also cooperated with SMART mobile sim-card that will be automatically receive SMS messages on the phone user when they live in risk geographical area. EWS 1294 is a straightforward technology that was created with the four elements required: 1. Awareness of disasters, 2. Monitoring of hazard, 3. Warnings, 4. Preparedness, respond, and evidence based yearly cycles of upgrade. In addition, the Interactive Voice Response (IVR) system also play a key role inclusively on vulnerable people with those low literacy. Moreover, this system also collaborating with radio broadcast (ABC radio channel) to widespread the agent information. With the expanding EWS1294, it has been slowly increased that is still low if compare the overall population. There are some challenges related to the operation and maintenance of the sensor with the nationwide expansion system, the connectivity issues, management issue and modality of changing SIM card of users. However, this system has been widespread to other agricultural digital platforms such as SESAME app, Tonlesap app, Chamkar app, etc. This initiative will be enhancing the mitigation and adaptation in climate resilience by focusing on increasing productivity, diversifying, producing livestock and other making profit in value chains and agro-industrial crops to achieve Cambodia's Agriculture Development Policy 2021-2030.3. Agricultural research, information and technique

With a focus on enhancing food and nutritional security in Cambodia, CE SAIN was founded to promote public sector and private sector collaborating in capacity building through sharing knowledge, innovation, agricultural research, education, training and extension to sustainable agriculture intensification and nutrition (SAIN). This project organizes and makes the future innovation of agricultural lab and establish Agricultural Technology Parks to highlight innovative techniques and high potential technologies that provide opportunity research and intensify farming system in sustainable manner. The CE SAIN headquartered is located at The Royal University of Agriculture to advance the expertise of agriculture, researchers and practitioners to demonstrate their cutting-edge agricultural technology to the general public, decision-makers and funding organizations. Moreover, Cambodian Agricultural Research and Development Institute (CARDI) is the government's leading institution for agricultural research and development. It conducts research on various aspects of agriculture, including crops, livestock, fisheries, and natural resource management. CARDI also disseminates information to farmers through extension services, training programs, and publications. In addition, the Centre for Policy Research in Agriculture and Rural Development (CPRI) also play a significant role in conducting research on agricultural development in order to inform the policy decision to enhancing the standard of farmers living and rural communities.

On the other hand, through the promotion of family gardens, scaling up home gardens for Food & Nutrition security in Cambodia project that funded by the Australian Centre for International Agricultural Research (ACIAR) was implement to increase food and nutrition security in Cambodia, also known as "Family Farms for the Future (FF4F)". Farmers who wish to raise nutrient-rich fruits and vegetables in their home gardens can receive instruction from the project.

All these projects are play a significant role in contributing the National Strategic Development Plan (NSDP) by enhancing communities' livelihoods, poverty reduction, improving food security, development of modern technologies, increase farming practices and skills, access to information and diversification of crop, boosting livestock resilient in the agricultural sector.

4. Enhancing Climate Resilient on Water Management and Agricultural Practice in Cambodia

This project was aim to support the farmers to deal with climate change and water scarcity, funded by the United Nation Development Programme (UNDP). This project is focusing two main areas: a) scaling up climate resilient water management: including development of solar irrigation system, rainwater harvesting system and improving water management practices; b) promoting climate resilient agricultural practices: including promoting diversity cropping systems, enhancing soil management techniques and introducing drought-tolerant crop cultivars. The initiative strives to ensure the long-term sustainability and productivity of Cambodia's agricultural sector by giving farmers access to solar-powered irrigation equipment and other climate-resilient measures.

5. Public-Social-Private Partnerships for Ecologically-Sound Agriculture and Resilient Livelihood in Northern Tonle Sap Basin (PEARL) – FP199

The Northern Tonle Sap Basin in central-west Cambodia is home to one of the region's most important agricultural systems, where farmers produce mainly cashew, mango, rice, and vegetables. The area is also severely threatened by climate change disruption as temperatures have increased steadily by 0.8C° since 1950. At the same time, rainfall is becoming less frequent and the rainy seasons, more turbulent resulting region is facing a dual threat of flooding and drought putting a total of 1.45 million people at risk either directly or indirectly. The PEARL project is supported by Green Climate Fund (GCF), together with funding USD 42 820 231 of which USD 36 231 981 grant is provided by the GCF. The PEAL aims to enhance the climate change resilience of smallholder farmers and local communities by increasing their access to growing premium market segments while using their improved market access to incentivize their transition to climate-resilient practices, mainly through effective public-social-private partnerships. Overall, the PEARL project seeks to help smallholder farmers and other local value-chain actors access and leverage market opportunities and instruments that will reduce their vulnerability to the impacts of climate change while improving agricultural production and livelihoods. Special focus is dedicated to the proactive involvement and ownership of vulnerable groups across the project interventions. In particular PEARL will improve the adaptive capacity of women, youth and Indigenous Peoples thorough capacity development and dissemination of climate-resilient practices and technologies. PEARL targets 450 000 individuals located in the four provinces of Oddar Meanchey, Kampong Thom, Preah Vihear, and Siem Reap, 124 farmer organizations. Rice, vegetables, mango and cashews are the targeted value chains. The project is being implemented under the leadership of the Royal Government of Cambodia, co-executed by the Ministry of Agriculture, Forestry and Fisheries and the Ministry of Environment. It will also have participation of the Ministry of Water Resources and Meteorology, Ministry of Commerce, Ministry of Women's Affairs and the Agricultural and Rural Development Bank.

6. TCP/RAS/3903-Strengthening capacity of policy makers to mobilize investment for resilient and low emission agrifood systems in Asia under Article 6 of the UNFCCC Paris Agreement

The project is implemented under the Paris Agreement with funding support USD 500 000, started in October 2023–September 2025. The overall objective of the project is to enhance capacity to mobilize resources for resilient and low emission agrifood systems using the Paris Agreement Article 6 instruments. This is a regional project being implemented in four countries, Cambodia, the Philippines, Thailand and Viet Nam. In meeting its objective, the aim is to address:

1. The lack of awareness amongst target countries regarding the opportunities under the UNFCCC Paris Agreement Article 6 instruments and related processes including the UNFCCC long-term strategy process to support investment in Nationally Determined Contribution priorities for agrifood systems
2. The lack of capacity to use credible assessment tools and approaches to design initiatives to scale-up investment in near and long-term priorities for resilient and low emission agrifood systems that can be supported by the Article 6 instruments and related processes.

7. GCP/CMB/045/LDF-Promoting Climate-Resilient Livelihoods in Rice-Based Communities in the Tonle Sap Region

This project is funded by Global Environmental Facility with the funding USD 8 932 420 between 2022–2027. The overall objective of this project is to reduce their climate vulnerability and increase community resilience to climate change through an ecosystem-based, market-driven approach. The project works in five target provinces around the Tonle Sap Lake i.e. Pursat, Battambang, Banteay Meanchey, Siem Reap, and Kampong Thom. This is a major rice-growing region with abundant rainfall but limited access to irrigation and most vulnerable communities having little adaptability to climate change. It is expected to impact 37 000 rice-based households (170 200 people) directly with increased resilience/adaptive capacity. It is being implemented by partners: Ministry of Agriculture, Forestry, and Fisheries-General Directorate of Agriculture; Ministry of Environment-General Directorate of Local Community; FAO, With technical and operational support from the German Agency for International Cooperation (GiZ), the International Rice Research Institute (IRRI), and the Wildlife Conservation Society.

8. JIRCAS Project on Greenhouse Gas Emission Reduction Through Paddy Water Management in Cambodia Provisionally Selected for SATREPS Program

The Project for development and social implementation of greenhouse gas emission reduction technologies in paddy fields of West Tonle Sap Lake by establishing a large paddy area water management system. The project period is 5 years implementation from 1 April 2024 to 31 March 2029. This research aims to establish an efficient water management system for the Damnak Ampil irrigation district in Pursat Province, Cambodia, where irrigation and drainage facilities have been developed through Japanese ODA. In addition, a large-scale "methane emission reduction water management system" will be developed to reduce methane emissions while maintaining the quality and yield of paddy rice by introducing the alternate wetting and drying (AWD) technology. A methodology is established to effectively measure, report, and verify (MRV) greenhouse gas emissions from rice paddies in the target area through the use of ICT such as tower monitoring and drones. Furthermore, the methodology will be used to develop a method for generating "high quality" carbon credits to be used as an incentive for farmers. The developed "methane emission reduction water management system", the MRV methodology, and the methodologies for generating and utilizing "high quality" carbon credits will be packaged together to create a model that simultaneously achieves climate change mitigation and improves farmers' livelihoods. The Long-Term Strategy for Carbon Neutrality (2021) reported the development of alternate wetting and drying practices for irrigation. GHG reduction targets are determined by a country based on Article 4 of the Paris Agreement. It includes proposed and planned mitigation efforts required to achieve the set targets.

5. Barriers to adoption of the high impact climate technologies

The challenges hindering the widespread adoption of high-impact climate technologies in Cambodia. Despite the urgent need for sustainable solutions to mitigate climate change effects, various barriers impede the effective implementation of such technologies. In the Cambodian context, through a comprehensive analysis, this study identifies and discusses key barriers, including technological, financial, institutional, and socio-cultural factors. Understanding these barriers is crucial for policymakers, stakeholders, and practitioners to develop targeted strategies that facilitate the successful adoption and scaling of climate technologies in Cambodia.

1. Technological Barriers
- Lack of Access to Advanced Technologies
- Compatibility Issues with Local Context
- Financial Barriers
- High Initial Costs (agricultural inputs)
- Limited Access to Financing

2. Institutional Barriers
- Weak Policy Frameworks and Regulations (refers ton the enforcement)
- Limited Institutional Capacity

3. Socio-Cultural Barriers
- Limited Awareness and Education
- Cultural Resistance to Change

4. Case Studies: Examples of Successful Adoption
- Solar Energy Projects
- Community-Based Adaptation Initiatives
- Climate-Smart Agriculture Programs

- Agroforestry system
- Integrated farming system

Strategies for Overcoming Barriers

- Strengthening Policy Frameworks
- Enhancing Financial Mechanisms
- Building Institutional Capacity
- Promoting Awareness and Education
- Market linkage with industrial sectors

By addressing these barriers and leveraging successful case studies, Cambodia can pave the way for the widespread adoption of high-impact climate technologies, contributing to both climate resilience and sustainable development goals. However, the main recipients of bank loans in 2019 were retail trade and wholesale businesses, which accounted for 16%, while loans to the agriculture, forestry and fisheries sector accounted for only around 8% of total loans (Figure 8).

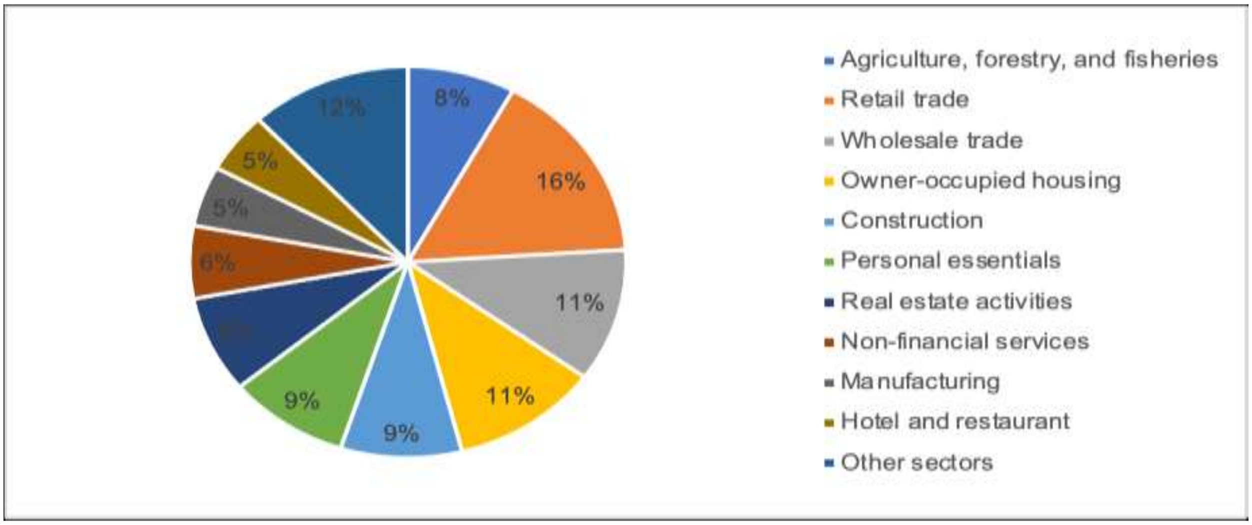


Figure 8. Banks' Loans by Sectors in 2019.
Source: NBC's Annual Report, 2020a.

Furthermore, MFI loans were mostly provided to households (34%), while loans to agriculture sector accounted for (20%) of total loans (Figure 9).

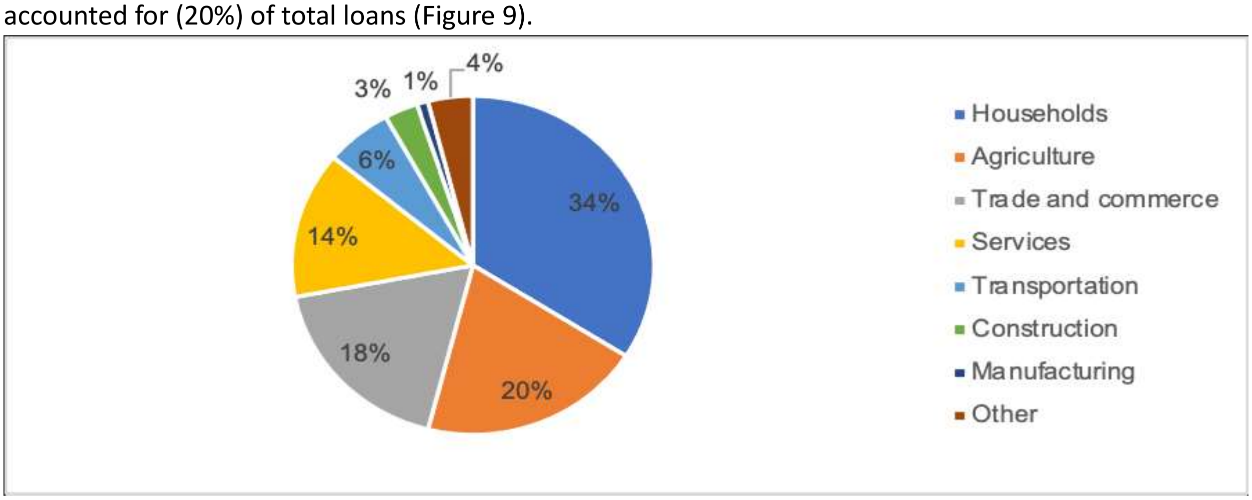


Figure 9. MFIs' Loans by Sector in 2019. Source: NBC's Annual Report, 2020a.

6. Climate technologies with high impact potential for rural development that require technical assistance and financing solutions

Based on the previous part that identified technologies that require TA and financial solutions (those with least market penetration or ongoing initiatives) make impact assessment of these technologies from adaptation, mitigation, cost analysis perspective to be included in the potential climate project pipeline. Climate funds investment criteria to be considered for assessment: impact potential, paradigm shift, sustainable development, needs of recipients, country ownership, and efficiency and effectiveness.

Table 7. Climate technology areas that require technical assistance and climate funding for rural development in Cambodia

Climate technology areas supporting NDCs' goals	% of participants endorsing TA for the NDCs technology
1) Development of Rice crops for increase production, improved quality-safety	65%
2) Development of Horticulture and industrial crops, drought and pest-resistant crop varieties and crop management	82%
3) Harvesting and post-harvesting techniques, agro-food processing incl. solar cooling, food product saving and packaging	94%
4) Bio-digester and biochar production, manure management, and compost-making	53%
5) Water management for improved crop production, improved quality-safety (incl. solar water pumping, hydroponics, and rainwater harvesting system)	76%
6) Agricultural land management techniques	65%

7. Cost benefit analysis of the climate technologies for rural development

An important factor in the economic growth of Cambodia is the agriculture sector. However, because of their heavy reliance on costly and erratic grid electricity, farmers in Cambodia find it difficult to compete with those in neighboring countries like Vietnam and Thailand. In Cambodia, 6.9 million people, or 43.1% of the total population, lack access to consistent power (Long, 2019). By installing and utilizing renewable energy (RE) technology, there are more and more chances for Cambodians living in isolated and rural locations to obtain access to power. Farmers in Cambodia have already begun to use renewable energy technologies like solar panels and methane digesters. Although RE technologies have the potential to be widely used in Cambodia, adoption rates are still low. Lack of knowledge and experience, mistrust of the technology, and expensive upfront expenses are major obstacles to widespread adoption; nevertheless, the most significant deterrent is a lack of access to appropriate financing options.

Case study 1: Pepper Farm and Solar Water Pump

In both domestic and foreign markets, pepper is a strategically important high-value crop. Water irrigation, however, is a crucial component that influences pepper production and culture. There are two distinct seasons in Cambodia: the rainy season, which runs from May to October, and the dry season, which runs from November to May. Farmers need enough water irrigation during the dry season or in times of erratic rainfall patterns to make up for the little rainfall. During the dry season, a pepper vine requires roughly 15 liters of water every three days, according to Kampot Pepper Promotion Association. Farmers require initial funding to dig wells and ponds, install drip irrigation systems, and buy diesel pumps in order to set up supplemental irrigation systems. The pepper industry can use solar water pumps as a practical substitute for diesel pumps. The farm can reduce diesel costs by 50% through investment in a solar water pump. Pepper has grown to be a "Top Ten Product" in five provinces in Cambodia, despite being a relatively tiny industry in comparison to other agricultural commodities grown in the country, including Kampot, Kep, Tbong Khmum, Kratie and Sihanoukville[31]. The Ministry of Agriculture, Forestry and Fisheries (MAFF) Department of Industrial Crops reports that the output of pepper in Cambodia has increased six-fold since 2012, from approximately 5,000 tons in 2012 to 30,000 tons by the end of 2018. Between 2012 and 2018, the cultivated area grew from approximately 1,500 hectares to nearly 8,000 hectares. Currently, 22 provinces across the nation grow pepper. The majority of the plantation area, which is located in Tbong Khmum province, is from Memot district. About 75% of the nation's total production comes from Tbong Khmum, which is situated near the Vietnamese border along the country's eastern border[32].

Mr. Be Youmeng is the owner of a pepper farm on about 12 hectares of land. His farm is located in Busra commune, Pichreada district of Mondulkiri province. A little over 2.5 hectares of land are utilized for pepper production. Typically, peppers grow along vertical poles. Approximately 2,000 pepper poles, which are currently seven years old, were planted on a hectare of land during the initial planting session. In October 2016, about 1.5 hectares of land were planted with approximately 3,000 pepper poles as part of the second round of planting.

Table 8. Pepper production and prices

Items	2015	2016	2017	2018
Pepper production	3,500 kgs	7,000 kgs	10,000 kgs	15,000 kgs
Prices	$8/kg	$7.50/kg	$3.75/kg	$2.50/kg
Revenue	$28,000	$52,500	$37,500	$37,500

Investing in Solar Water Pump

The farmer has made an investment in solar water pumps to lower the costs associated with buying diesel. The sole purpose of the solar water pump is to move water from the well into the pond. About 30 cubic meters of water may be pushed every day thanks to the 2.48 kW capacity of the solar water pump system.

31 Youssey, 2018.
32 https://www.khmertimeskh.com/news/39526/ pepper-production-in-cambodia-to-increase/

Table 9. Solar water pump

Technology	Solar water pump
Capacity of system	2.48kW
Cost of system	$11,268
Payback period	3.5 years
Amount of diesel fuel avoided	4,562 liters per year
Energy saving	$ 3,193 per year
Emission reduction potential per annum	12.27 tonnes of CO_2e reduced per year
kWh of clean energy produced	Approx. 3,530 kWh per year

Source: (Long, 2019)

Mr. Youmeng bought this clean energy technology with funds from Nexus's Clean Energy Revolving Fund (CERF). For now, he uses the money he saves from using less diesel to pay back his debt. An additional benefit of this energy shift is that it will help reduce emissions, which Nexus estimates will save 12.27 tonnes of CO2e annually. Mr. Youmeng is able to cut his operating expenses by 12% and his diesel expenditures by more than 50% by purchasing a solar water pump.

Table 10. Annual operational cost of pepper farm

Items	Cost ($)-Pre-investment	Cost ($)-Post-investment
Fertilizers	6,000	6,000
Workers	8,400	8,400
Diesel (2 engine pumps)	5,880	2,940
Maintenance cost, engine oil, etc.	240	240
Total operational cost per year	$26,582	$23,642

Source: (Long, 2019)

Case study 2: Hybrid solar system

Mr. Oeurn Chanrath is the owner of a pig farm in Dambok Rong commune, Phnom Srouch district of Kampong Speu province, about 85 km to the west of Phnom Penh. The enclosed swine stable system, which is used to power an evaporative cooling system, illuminate the pigs and stables during the day, and pump water to keep them clean, all demand a substantial amount of energy to function. This case study highlights the advantages or benefits for a pig farmer who upgraded his farm with a hybrid solar system. He has saved a substantial amount of money on diesel fuel usage thanks to technology. The predicted rise in meat consumption in Cambodia between 2014 and 2024 is expected to be from 274,479 to 328,085 tons annually, based on an estimated 1.8% annual growth rate in the human population (Long, 2019). Energy consumption of pig farming operations involve appropriate lighting for pigs (both piglets and sows) and an evaporation cooling system.

Table 11. Energy consumption at the pig farm

3 diesel engines	Each has capacity of 75 KVA
Diesel (liter)	120 liters per day
Diesel price	3,000 riels ($0.75) per liter
Diesel cost	$32,400 per year

Source: (Long, 2019)

Investing in Hybrid Solar System

Mr. Chanrath made a smart choice by investing in a hybrid solar system because the pig farm's electricity needs are primarily met by heavy use throughout the day. Because the system is similar to an on-grid solar system in that it is not constructed with battery storage, it is less expensive than an off-grid solar system that uses batteries. The pig farm also helps to reduce greenhouse gas emissions by 14.72 tons of CO_2 annually by utilizing a renewable energy source. This energy source is a clean, dependable, non-polluting option that can also provide the farm with energy independence and security.

Table 12. Hybrid solar system

Technology	Hybrid solar system
Capacity of system	12 kW
Cost of system	$18,738.60
Payback period	3.5 years
Amount of diesel fuel avoided	7,200 liters per year
Energy saving	$5,400 per year
Emission reduction potential per annum	14.72 tonnes of CO_2e reduced per year
kWh of clean energy produced	Approx. 17,919.35 kWh per year

It can be seen that from Table 13 operational costs per year before and after solar installation are different. The farm reduced operational costs by 7.43% through investment in a hybrid solar system. Before investing in solar energy, the diesel expense was about $32,400 per year, but he now spends less money on diesel, about $27,000 annually, representing savings of 16%.

Table 13. Operational cost per year before and after solar installation

Items	Cost ($)-Pre-investment	Cost ($)-Post-investment
Diesel expense	32,400	27,000
Maintenance and oil	1,800	1,800
Workers	30,000	30,000
Food for workers	6,600	6,600
Others (replacing some spare parts/feeding facilities in the stables)	1,800	1,800
Total operational cost per year	$72,600	$67,200

Source: (Long, 2019)

Case Study 3: Biogas Digester Technology

A case study of converting waste-to-energy-biogas digester system for pig farm. Nowadays, a few pig farmers are using biogas digester technology to turn their pig dung into clean energy. Larger-scale pig farms can afford to utilize this technology due of its high initial cost of acquisition and assembly. Owner of a pig farm in the province of Kampong Speu, Mr. Chang Touch, has expressed his happiness with the built biogas system because it has allowed him to cut his operating costs by over 60%. In addition to assisting him in streamlining waste management procedures, the biogas technology investment lowers the amount of methane gas emitted from the farm.

Table 14. Summary of biogas project with pig farm

Farmer owner	Mr. Chang Touch
Farm type	Pig farm
Technology	Biogas digester system
Size of the lagoon	Approx. 5,625m3
Gas storage	Approx. 3,800m3
Simple payback period	About 3.2 years
Payback period (with financing)	About 4.2 years
Cost saving per year	$17,600 per year
Energy saving	106,600 kWh per year

Market – Livestock (Pig)

The predicted rise in meat consumption in Cambodia between 2014 and 2024 is expected to be from 274,479 to 328,085 tons annually, based on an estimated 1.8% annual growth rate in the human population[33]. Pigs have historically been imported into Cambodia from nearby nations like Vietnam and Thailand. The Cambodia Livestock Raisers Association reports that, in order to meet local demand, between 2,000 and 3,000 pigs are imported from Vietnam and Thailand each day[34].

Energy consumption at the farm

The energy is utilized for running the evaporative cooling system, lights (which is required day and night), and pumping water to clean the pigs and stables. The farm receives power from the grid, but Mr. Touch pays roughly 60 million Riels, or about $15,000, for each pig cycle (two cycles per year; it takes about five to six months to produce pig meat).

Investment in biogas digester system

Mr. Touch was introduced to the biogas technology through the National Biodigester Program (NBP). The total investment cost for the biogas system is $56,500. The biogas digester technology was installed by a local supplier, VW.GAS CO., LTD. Table 14 provides cost details for the system.

[33] General Directorate of Animal Health and Production: Overview of the livestock industry in Cambodia, http://gdahp-maff.org/blog/overview-of-the-livestock-industry/

[34] Interviewed with Mr. Srun Peou, Director of Cambodian Livestock Raisers Association.

Table 15. The cost of biogas digester system

Items	Amount ($)
Lagoon-the plastic to cover the gas	11,800
Piping	2,000
Biogas genset 1	24,500
Biogas genset 2	15,000
Water trap system-biogas purification system	2,000
Gas containers	1,200
	$56,500

Tables 16 and 17 provide a comparison of the expenditure on electricity per cycle before installing biogas digester system from August 2017 to January 2018 and after the installation of the biogas system from August 2018 to January 2019.

Table 16. Electricity cost before investment in bio-gas system

Date	Electricity used (kWh)	Rate per kWh	Total cost (Riels)	Total cost ($)
28-Aug-17	7,671	750	5,753,250	1,438
28-Sep-17	14,042	750	10,531,500	2,633
30-Oct-17	15,395	750	11,546,250	2,887
28-Nov-17	16,626	750	12,469,500	3,117
28-Dec-17	16,587	750	12,440,250	3,110
16-Jan-18	10,505	750	7,878,750	1,970
Total	80,826	750	60,619,500	$15,155

Table 17. Electricity cost after investment in bio-gas system

Date	Electricity used (kWh)	Rate per kWh	Total cost (Riels)	Total cost ($)
28-Aug-18	5,425	750	4,068,750	1,017
28-Sep-18	5,811	750	4,358,250	1,090
29-Oct-18	3,178	750	2,383,500	596
28-Nov-18	2,196	750	1,647,000	412
28-Dec-18	3,393	750	2,544,750	636
9-Jan-19	878	750	658,500	165
Total	21,816	750	16,362,000	$3,916

Case study 4: Solar Cooling System

In 2018, Mr. Chhouden Chhim installed a solar egg incubator as part of his initial venture into chicken farming. As a result, Kampong Thom's Green Farmer Community (GFC), a social enterprise, was established. GFC wants to produce high-quality hens and chicks, connect with local farmers through market connections, give them access to healthy and reasonably priced chicks, and provide them with training and vaccinations. For the chick and hen houses at GFC, SOGE installed a Solar Smart Cooling System (SSCS) in 2022. The demonstration site is made up of the following: i) ten sprinklers on the roofs of the hen and chick houses; ii) a tower next to the houses that houses two 1,500-liter water tanks that supply water to the rooftop sprinklers; and iii) a 120-watt submersible pump that is powered by a 250-watt solar panel and has two 12V-65Ah (1,560 Wh) batteries as backup. Benefit of Solar Cooling System:

- increase revenue: solar smart cooling systems increase chicken production (chicks and hatched egg) by reducing mortality rates and creating better living condition for adult egg laying hens.
- Reducing of carbon emissions: can reduce CO_2 emission by 4.36 tCO_2/year
- Increase in operational efficiency: automated system saves on farm labor, allowing staff to focus on other priority tasks.
- Reduction in operational expenses: solar powered system offset costs related to other sources of energy such as grid and/or diesel.

Case Study 5: Solar Water Pump

Ms. Nob Kolab, the demonstration site's owner, has been cultivating her two hectares of land profitably by using smart crop rotation and choosing vegetables according to market need. Ms. Kolab bought a solar water pump in May 2022. This pump is equipped with a powerful 2,730W solar power source, providing her with an efficient and environmentally friendly solution. With a motor voltage of 110V, the pump can support a maximum head of 17m and a maximum flow of 50m3/h, ensuring sufficient water supply for her crops. All things considered, the solar-powered Surface Irrigation System works well and is a dependable option for smallholder farmers such as Ms. Kolab. It supports sustainable farming methods in addition to ensuring a steady supply of water. Benefits of the solutions include:

- Lower operating costs: By optimizing and cutting back on the amount of diesel they use for pumping, farmers can partially offset the cost of utilizing solar water pumps.
- Increasing productivity and money: Farmers can successfully increase productivity and subsequently create higher money by providing more water to plants.
- Decrease in carbon emissions: 1.74 tCO_2 emissions annually are avoided by not using the diesel-powered pump as much.

Case Study 6: Hydroponic Greenhouse

In order to cultivate leafy vegetables, Mr. Sam Sary, the owner of the demo site, built the first hydroponic greenhouse in 2020 behind their home. They made more investments to increase production in the middle of 2021 by building two greenhouses—one for hydroponics and the other for nursery. His specialty is leafy vegetables, including Chinese kale, pok choy, curly cabbage, and lettuce. Cycles take around 28 days to complete from seeding to harvest. Benefits of the solutions include:

- Operational Expense Reduction: Solar Smart Cooling System will offset grid-electricity costs related to the use of hydroponic pumps, temperature & humidity sensors, and exhaust fans
- Reduction of carbon emissions: reduce CO_2 emissions by 5.89 tCO_2/year by offsetting grid energy used to power pumps & fans.
- Increase in Vegetable Quality: producing under a fully controlled environment (temperature and humidity) will contribute to the improvement of the products' quality and consumer safety.
- Increase revenue: increase production and allow the farmer to produce during the dry season, normally a low vegetable production period.

Case Study 8. Promoting gender equality in rural access to safe water in Cambodia

The case study conducted by CCCA3 (2023[35]) aims to identify the perspectives of women beneficiaries, highlighting their experiences and their roles and responsibilities in contributing to climate action. The biggest danger to water systems is seen to be climate change. It takes the form of shocks (such as more frequent and increased storms and droughts) and stressors (such as declining groundwater levels and increasing sea levels), and it forces water systems to become more resilient in order to fend off potentially disastrous consequences. According to the 2020 Social Economic Survey, the quantity and quality of water made available year-round are vital in a nation where 35% of rural residents still lack access to basic water supplies.

The Ministry of Rural Development (MRD) through its Department of Rural Water Supply (DRWS) is responsible for providing water supply services in rural communities. In order to give rural communities long-term access to clean drinking water and to increase the ability of public employees working in the safe drinking water sector, the MRD and Teuk Saat 1001 with support from CCCA3 have collaborated to conduct a joint project. The initiative has created a mutualized, innovative solution and approach (Figure 10) to provide drought-affected rural communes in Trapeang Thum commune (Siem Reap province) and Tuek Chour commune (Banteay Meanchey province) with access to safe water. Each commune has a newly installed water kiosk with 4 employees, and that they are able to produce around 2,350-2,950L per day, sold at an average price of 1590 riel/20L bottle. The project has reached 1,510 female-headed households and provided free drinking water to some primary schools.

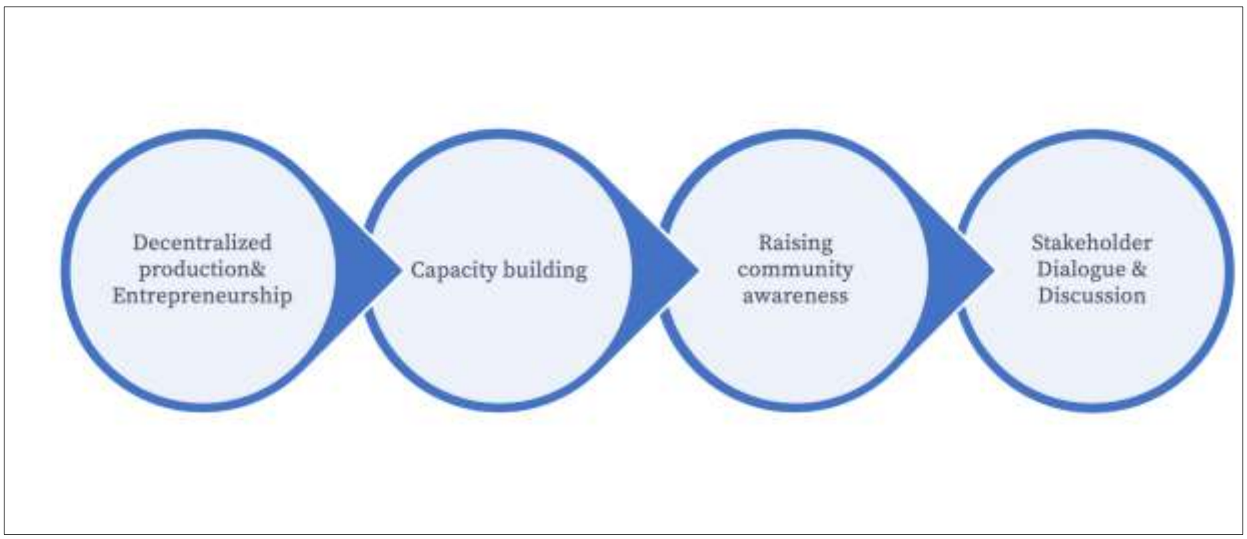


Figure 10. Innovative approaches solutions and methodologies to achieve access to safe water.

Source: CCCA3, 2023

[35] A case study by CCCA3 (2023): Promoting gender equality in rural access to safe water in Cambodia

Mrs. Soy Sareth, a water consumer, a 32-year-old woman entrepreneur, has joined the project and she is currently running the operation of water kiosk in Trapang Thum commune, Prasat Bakong district, Siem Reap province. She noted that the project has empowered her to run a business by being equipped with concrete knowledge of water kiosk management, environmental safeguard-related water control, and other business operation approaches. The job provides her with plenty of opportunities to work with different people from government and private entities and also earns extra income to support her livelihood.

8. Gender Action and SDGs

The Ministry of Women's Affairs (MoWA) is the leading national machinery for the promotion of gender equality and women's empowerment in Cambodia. In 2013, MoWA established a Gender and Climate Change Committee (GCCC) to supervise the overall work on gender equality in climate change, green growth and disaster risk management. At the sub-national level, the Consultative Committee for Women and Children (CCWC) has been established at the capital, provincial, municipality, district and commune levels. The Sustainable Development Goal 5 (SDG 5) is initiated to "achieve gender equality and empower all women and girls". A study by Goh (2012) indicated that climate change in developing countries affected men and women differently in terms of assets and well-being[36]. Women are more vulnerable to threats to their livelihoods and heavier responsibilities when it comes to caring for their families because of the effects of climate-related droughts, flooding, and variability. According to the Climate Asia Study by BBC Media Action (2019), 43% of Cambodians said they had to adjust their occupations or way of life to make ends meet when the weather changed, and 60% of the country was unprepared for extreme weather. The men and women significantly took different actions for extreme weather. The majority of men (82%) knew how to build shelters, swim, or perform first aid in case of extreme weather, while only 42% of women said the same, leaving them more susceptible to dangers like flooding (BBC Media Action, 2019). BBC Media Action (2019) identified men were more likely to report making structural alterations to the home (41% of men, 36% of women), whereas women were more likely to take household actions measures like storing food (53% compared to 44% of men). KAP3 Study by NCSD/MoE (2020), the government stakeholders assumed that women were more vulnerable to the effects of climate change and more likely to experience their effects because they believed that women were physically weaker than men and so less robust. They believed, for instance, that men can withstand hot temperatures better than women, who tend to get sick more easily. At the community level, respondents agreed that women were occasionally more susceptible since they frequently take care of the old and young people. Because of their perceived physical frailty, lack of resources, and difficulty accessing transportation, elderly

[36] Goh, A.H.X. 2012."A Literature Review of the Gender-Differentiated Impacts of Climate Change on Women's and Men's Assets Adn Well-Being in Development Countries."5.

persons, women with disabilities, women head of households, and children were also viewed as being more exposed to the effects of climate change.

By coordinating national policy frameworks on gender and climate change with international commitments, the current agriculture policies and plans incorporate provisions for mainstreaming gender concerns into the climate change adaptation initiatives in agriculture. When it comes to agricultural policy that addresses climate change adaptation, gender parity is crucial. In light of the updated NDC goals' submission of priority actions for agriculture, MAFF has established targets for women's participation by 2030, ranging from 20 to 75 percent at the national and subnational levels. Additionally, it is predicted that youth involvement in climate action will help achieve objectives in a few priority subsectors, including crop production, livestock, and fisheries[37]. The disparity between males and females in the adoption of new agricultural technologies is one of the overall gendered effects of climate change on local farmers. Female-headed households also face lower rice yields as a result of flooding, droughts, and insect outbreaks, as well as losses from investments in agriculture. It is thought that women have less access to economic opportunities, financial resources, and information to mitigate these losses.

According to UN women (2021), there are several indicators that would increase the gaps of women and men by provide priority to the women through: 1. striving to close the gap between the law and practice and bolstering women's land rights are necessary to address these issues. 2. Reducing the barriers to financing for female agribusiness owners, 3. Improving community resilience to climate change and lowering the agriculture sector's carbon footprint, the organization aims to prepare women for the workforce and link them to markets. UN women 2021. "Empowering women through climate resilient agriculture in west and central Africa"). It will also keep advancing creative solutions and best practices, such as collaborating with men and traditional leaders to alter social norms and systems that underlie economic discrimination against women and advocating for policy changes in key areas that are essential to women's economic participation. With these approaches will boost influence in crucial areas for women's empowerment by lowering vulnerability and improving autonomy and agency.

According to the Gender Impact of Technological Upgrading in Agriculture (2020) The study's conclusions show that gender plays a significant role in the diffusion, adoption, and use of agricultural technology, starting with its conception in research and development. Technology plays a critical role in promoting ecologically sustainable agricultural practices that are necessary to mitigate the effects of climate change and enhance the livelihoods of rural women, who are among those most vulnerable to them, as well as women's participation in higher-value activities in global agri-food chains. However, there are numerous gender-based hurdles that prevent women from using technologies, and the ones that are available frequently don't suit their specific needs. To solve the gender gaps in agricultural technology, innovation and access, this project will extension services as well as credit provision and measures supporting women's ownership and technology management. The 2030 Sustainable Development Goals, which include gender equality, sustainable agriculture, food security, and the empowerment of all women and girls, would be greatly advanced by implementing these.

The influence of gender roles in taking actions in Cambodia, women are typically expected to take care of the home, the children, and the food and clean water supply. This is frequently on top of their work in agriculture or other jobs that bring in money. Wives frequently migrate abroad with their husband in

[37] GSSD-MoE. 2020."Cambodia's Updated Nationally Determined Contribution."

search of employment, adding to this additional load and leaving them as the only breadwinners for extended periods of time. This leaves women especially susceptible during severe weather. According to survey result from KAP3 nationwide conducted by NCSD/MoE (2020), 89% of a woman's responsibility is to take care of her home and family. The likelihood of men and women agreeing with this was the same, although 63% of respondents from rural areas and 55% from urban areas strongly agreed with it.

9. Analysis of Business Models, Governance, and Policy Frameworks

Agriculture sector played an important role in supporting Cambodia' economic growth and development over the past years. As of 2021, 77% of rural households rely on agriculture, forestry, and fisheries for their food, while the sector employs over 35% of the labor force. Agriculture is a pillar of the Cambodian economy, contributing 22.2% of the country's GDP. As reported by the Ministry of Agriculture, Forestry and Fisheries (MAFF) in 2023, agricultural crops account for 57.1% of the overall production, followed by fisheries, livestock, and forestry. Approximately 2.04 million households (57%) in Cambodia are involved in agricultural and allied practices, with smallholder farmers comprising the majority (70%) who own less than 2 ha of land (NIS, 2022)[38].

Additionally, the climate technology in agriculture in Cambodia may include the provision of climate-smart agricultural inputs, such as drought-resistant seeds, efficient irrigation systems, and weather monitoring tools. Additionally, agribusinesses may offer advisory services and training on climate-resilient farming practices. The challenge faced by the SMEs and smallholder farmers to accessing climate smart technology are: a) limited financial resources, b) inadequate infrastructures, and c) knowledge gaps. With these regards there should be addressed by utilizing creative financial approaches that suitable for Cambodia agri-business and for the farmers, more leveraging public-private partnerships and seek international cooperation to promote technology adoption.

Poor levels of end-user awareness and trust in Renewable Technology (RE), along with the lack of flexible financial instrument for RE technology investment, resulted in poor adoption rates across the nation for decades. Substantial efforts have been made in recent years to develop and foster use of climate-financial instrument for climate adaptation and mitigation for policy and decision making. Cambodia is one of the countries working more efforts to address climate change issues. Business models, financial and other incentives need to be understood and leveraged to boost adoption levels and deliver scale out strategies that have the capacity to reach millions of farmers in the country. The opportunities for novel financial instruments to promote agricultural technology adoption, including from climate finance are still limited access.

By installing and utilizing renewable energy (RE) technology, there are more and more chances for Cambodians living in rural and remote areas to obtain access to electricity. Energy from solar panels is a practical and sustainable source of power that could lead to energy independence because of Cambodia's high appropriateness for solar power[39]. Due to this energy transition, solar panel prices have started to drop significantly, making solar technology a financially viable choice for agricultural purposes. Another renewable energy option that has potential in Cambodia is biogas technology, which is starting to gain traction in the agricultural sector, especially in commercial pig farming. Because biogas systems lower methane emissions and unpleasant odors while also saving farm owners money on electricity, they are

38 Draft MAFF Climate Change Priority Action Plan (CCAP 2030)
39 ADB, 2015

advantageous for the environment and the economy[40]. Thus, RE technologies such as solar systems and biogas digesters have already gained some traction and have been adopted by Cambodian farmers. Although RE technologies have the potential to be widely used in Cambodia, adoption rates are still low.

The Clean Energy Revolving Fund (CERF) was introduced by Nexus for Development (Nexus) as a project to mitigate climate change. It began in 2016 and was scheduled to conclude in three years. With assistance from the Austrian government and the Blue Moon Fund (BMF), the Renewable Energy and Energy Efficiency Partnership (REEEP) made the first investment in the novel funding model. The CERF encouraged Small and Medium Agri-businesses (SMAs) and farmers in Cambodia to adopt clean energy technologies by offering affordable financing. This, in turn, decreased CO_2 emissions, promoted an early transition away from fossil fuel-based energy, and increased productivity in food processing. The fund's strategic objective was to enhance the adoption of renewable energy technologies in Southeast Asia, with a primary focus on Cambodia, by offering loans at reasonable rates to the agri-food sector through the use of a blended finance model. Other agri-food subsectors, renewable energy technologies, and nearby regional markets in the region were looked into for possible growth and scaling-up throughout the fund's implementation. The initiative was regionally unique, bringing to the clean energy market an innovative concept based on a blended finance approach. It was intended to become a model for a more adaptable and market-driven funding source for small and medium-sized agribusinesses (SMAs) in the GMB that wanted to implement clean energy solutions. This financing would come in the form of low-interest soft loans. Consequently, the fund sought to reduce the risk associated with renewable energy business models and provide room for larger donors, local banks, commercial lenders, and other individual investors. Nexus concentrated its efforts on a range of agri-food industry segments, including livestock, fruit, vegetable, and spice farms, processors, and water treatment plants using technologies including off-grid solar systems and solar water pumps, following additional market research. Though solar energy was found to be the most appropriate technology for the agri-food sector in Cambodia in the current market, CERF was open to supporting other technologies, such as biogas systems.

Together with technical assistance and capacity building, CERF offered SMAs and farmers special and flexible financial terms (loan tenors and repayment schedule that were tailored to agricultural cycles). Low financing costs were imposed in exchange for the RE technology being utilized as collateral. By reinvesting the energy cost savings as capital to expand their enterprises, CERF allowed SMAs and farmers to benefit from lower energy costs. For SMAs and farmers, the payback period for RE investments was usually realized in three to five years, so businesses could expect to see in medium- and long-term growth.

Over the three-year project life, 15 loans were approved by the CERF. Solar water pumps and on-grid solar systems for SMAs cultivating fruits, vegetables, and peppers, as well as livestock farms like pig farms, constituted the majority of the clean energy investments made. Additionally, one community-based water treatment plant was part of the loan portfolio. The majority of the investments fell between 10,000 and 15,000 USD, while the loan quantities ranged from 7,000 to over 50,000 USD. Up to 90% of the cost of the technology was covered by CERF loans; the investees contributed the remaining funds. A total of 331,204 USD was invested in clean energy, of which 261,014 USD came from CERF capital (Long, & Louie, 2019). Through the installation of 85.76 kW of solar energy and the production of 115,264 kWh of clean energy, CERF investments have reduced annual CO2 emissions by 168 tonnes. It is believed that the pepper, pig,

40 National Biodigester Programme (NBP) through collaboration with some international donors, and United Nations Industrial Organization (UNIDO) are supporting large and medium pig farmers to adopt the biogas digester system

and longan sub-sectors alone comprise about 7,000 SMAs and larger farmers. Approximately 10 tonnes of reduced CO2 emissions were generated annually by each CERF project. 70,000 tonnes of CO2 emissions were reduced annually if Nexus funded 7,000 SMAs to implement RE technologies (Long, & Louie, 2019).

Blended finance approach

To continue providing loans in Cambodia, Nexus/CERF would need to apply for a banking license under the country's current regulatory framework. In order to further show the bankability of renewable energy technology and create suitable financial solutions for the market, The Nexus forms agreements with Cambodian financial institutions. Since 2018, Nexus has been investigating the ways in which it might collaborate with financial institutions (FIs) in Cambodia, including commercial banks, MFIs, and rural credit operators, and shared our goal of assisting SMAs and farmers in becoming more competitive and sustainable.

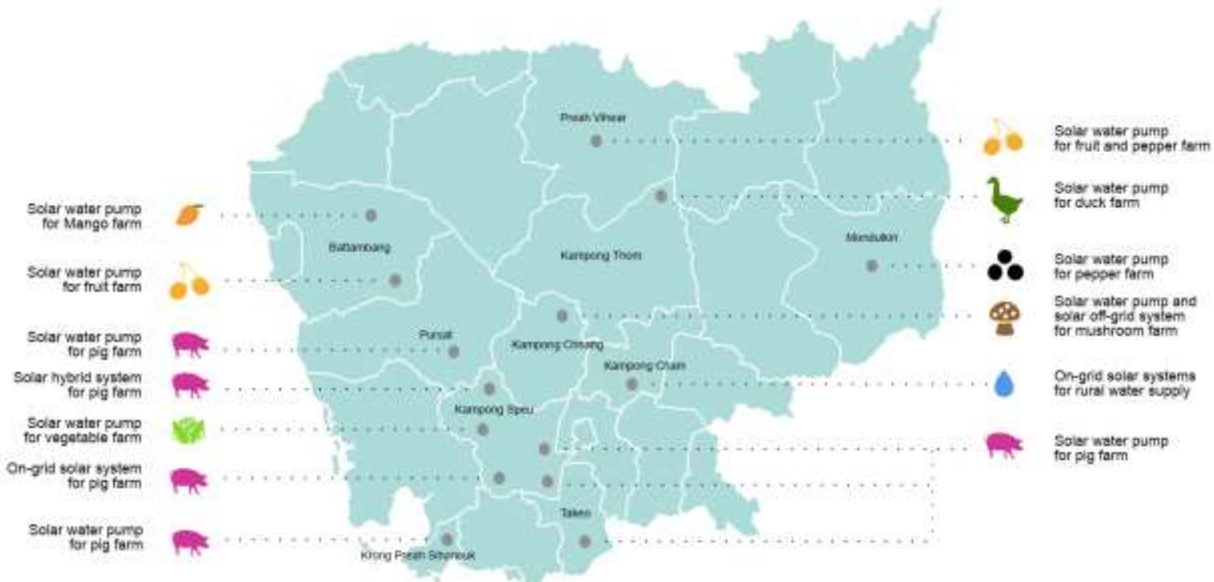


Figure 11. CERF Investments - Snapshot 2018.

Source: (Long, & Louie, 2019)

CERF model

Who is eligible for the Fund?

According to Long and Louie (2019), in order to apply for CERF model, eligible investments have the following characteristics:

- Small and Medium Agri-food Businesses (SMAs): SMAs in Cambodia including farms, farmer cooperatives, food processors, distributors, transporters and exporters.
- Renewable energy: Any type of renewable energy technology with proven quality and reliability in its application, including solar energy, biogas, and gasification.
- SMAs in Cambodia who wish to adopt renewable energy technologies and are interested to access financing from CERF need to demonstrate cash generation to service the loan payments and an ability to make a 10-15% upfront payment for the purchase of the technology.

General terms of CERF loans

- Loan sizes vary depending on the size of the renewable technology unit required and ranged from 10,000 to 100,000 USD.
- SMAs and farmers pay back the principal amount plus 8% per annum in interest.
- Loan tenors of 3 to 5 years adjusted to the needs of the SMAs.

How are the funds disbursed?

- Nexus signs a contract with the SMAs and farmers. The contract includes a conditional clause that the Technology Provider (TP) provides a warranty and minimum maintenance on the equipment. Separately, the farmers or SMAs need to sign a purchase agreement with the TPs directly before signing the financial agreement with Nexus.
- Upon approval by the Investment Committee (IC) and receipt of the upfront payment from the business owner, Nexus will disburse the loan funds directly to the technology providers for purchase and installation of renewable energy technologies.

What is the repayment structure?

- Various repayment structures are utilized, however, none of the portfolio loans included grace periods for principal or interest. Payments commenced after the equipment is installed and commissioned, and according to a fixed repayment schedule (paid either monthly or quarterly).
- Where possible, repayments will be linked to fuel or electricity savings as the fund's objective was reduce the operational costs of SMAs.

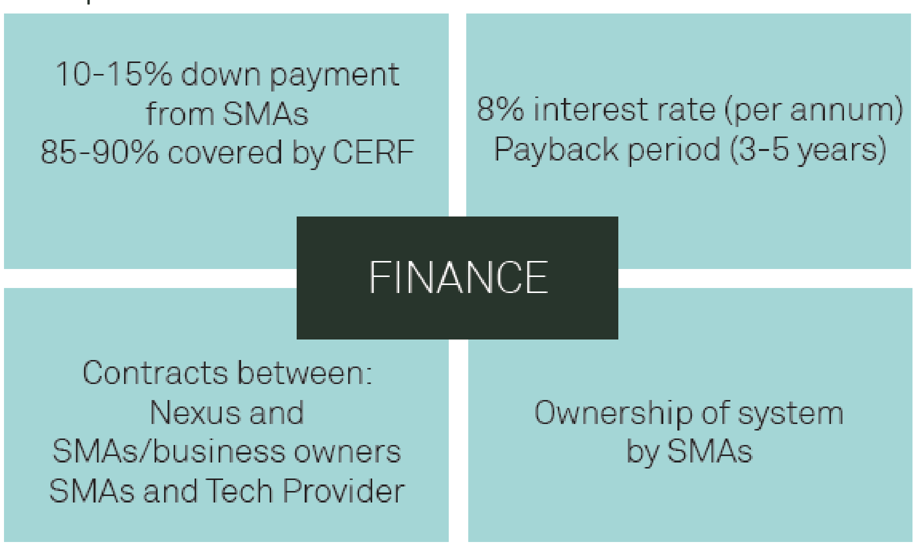


Figure 12. Financial model.

Source: (Long, & Louie, 2019)

Funds management team

On behalf of the donors, Nexus's funds management team oversees CERF, with the assistance of an impartial investment committee. The members of the fund management team come from a variety of disciplines, including technological know-how, stakeholder engagement, finance, and fund management. When making decisions about technology provider partners, investment strategy, and credit risk, Nexus consults the IC's experience. The team at Nexus also writes and distributes minutes, oversees the IC meetings, and acts as a communication link for the investees.

Risk Management

For CERF, actions were taken by the funds management team to reduce the likelihood of a risk event occurring. The method of addressing and mitigating risks, including i) loan default by a loan recipient, ii) Technology-related risk, iii) Fund disbursement, and iv) Delinquency.

CERF Process

Nexus established partnerships with three local technology providers (TPs) in Cambodia including, International Multi-Business Group (IMB), Ecosun Energy Cambodia (Ecosun) and Solar Green Energy Cambodia (SOGE). There are over 20 local solar TPs in Cambodia working in different segments of the market (i.e. household scale distributed energy system, rooftop solar systems for residential buildings, SMEs, etc.). The primary responsibility of TPs is to identify possible projects by providing qualified applicants with the chance to submit a loan application. These TPs are skilled in engaging with farmers and SMAs and have direct sales experience with them. Nexus played a special role in the CERF model; for pipeline and approved investments, Nexus acted as a technical advisor to the farmers and SMAs, helping them to better grasp the technology and develop their capacity. Nexus' funds management team was tasked with managing the fund and its portfolio of loans on behalf of the donors and the IC. Three steps comprised the four to six-week process from due diligence (DD) to loan approval: i) Energy assessment; ii) Full due diligence; and iii) Validation by the IC. In conclusion, it is expected that the loan contract, loan monitoring and payments, and loan payback schedule.

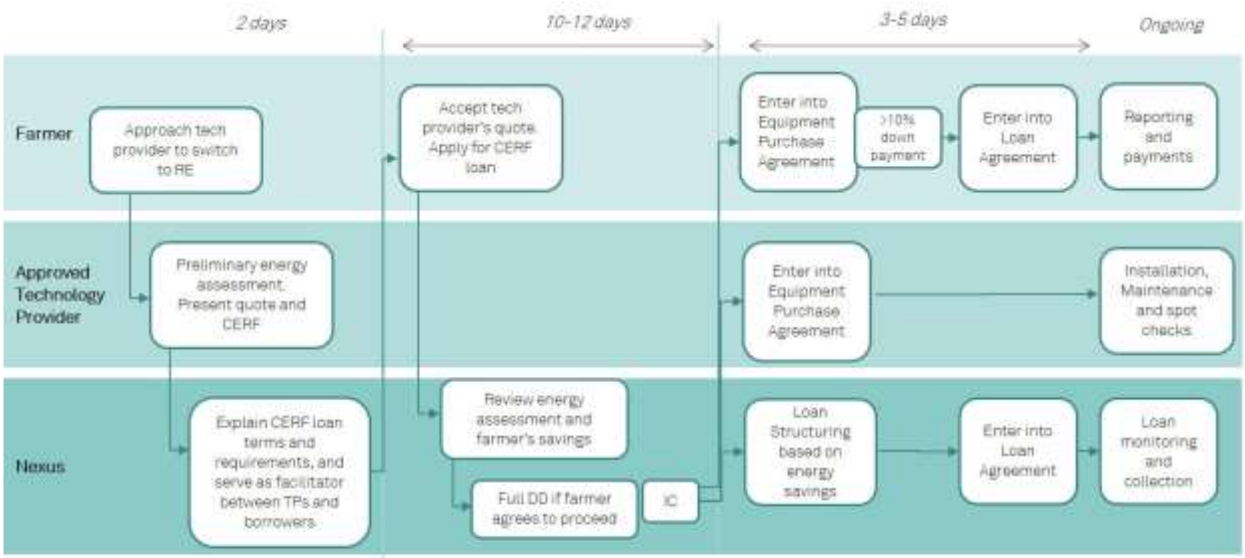


Figure 13. Loan approval and monitoring.

Source: (Long, & Louie, 2019)

Overall, although the CERF model has the potential to develop, Nexus was not interested in registering as a financial institution under NBC in order to continue investing in its expansion. Local financial institutions (FIs) in Cambodia are in the best position to capitalize on the market potential given the regulatory framework limits for Nexus. By adjusting the financial model or creating a new structure to see what works best for them, local financial institutions could provide RE financial loans in the agri-food industry. FIs may be able to expand their reach to SMAs and farmers and achieve economies of scale since they have more stable lending procedures, operations, and broad networks with a solid presence across numerous provinces.

When it comes to financing, two FIs such as, the Agricultural and Rural Development Bank (ARDB), have expressed interest in growing their bank portfolio to include RE loan instruments, indicating that there is already a shift in the nation's thinking toward green lending. The ARDB gave local businesses loans totaling $159.11 million in 2018, and Cambodia is examining the possibility of selecting the Agricultural and Rural Development Bank of Cambodia (ARDB) as a green-financing mechanism, in a bid to attract green investment to the country. The three-day 47th Association of Development Financing Institutions (DFIs) in Asia and the Pacific's (ADFIAP) annual meetings that kicked off organized by ARDB in Phnom Penh in May 2024, outlining the role of technology and innovation in enhancing agricultural productivity, improving food security. Focusing on technology's role in sustainable agriculture, it aims to highlight the intersection of agriculture, technology, climate smart practices and sustainable development. It also aims to inspire dialogue, collaboration and action amongst stakeholders to unlock the potential of agriculture, technology, and sustainable practices in building a climate smart future in Achieving the Sustainable Development Goals. The approval of climate financing for Cambodia in March, which provided $109 million in concessional funding consisting of a $50 million loan from the Green Climate Fund, $5 million in technical assistance, and the remaining $54 million to be provided by the other co-financing partner, including the Ministry of Economy and Finance of Cambodia during the annual meeting of the 47 ADFIAP[41]. In addition to supporting the government's top priority of promoting resilience, sustainable, and inclusive development, the initiatives aim to increase green financing, reduce emissions, and improve climate resilience. The emphasis on environmental sustainability is on developing a green economy. The funding proposal of Cambodian Climate Financing Facility (CCFF) has been designed to support Cambodia's low-emission and climate resilient development pathways through climate responsive transformation of the national financial system with leveraging public and private sector capital at scale. The CCFF programme aims to transform the country's state-owned bank – i.e., Agricultural and Rural Development Bank (ARDB) – into the very first green development bank. The overall goal of the program is to accelerate Cambodia's green leap and accelerate the implementation of its Nationally Determined Contribution (NDC) and post-pandemic recovery with a climate focus. It consists of two facilities: (i) a US$100 million lending facility; and (ii) a US$5 million Technical Assistance (TA) grant facility. The CCFF initiative, in particular, will improve the access of a variety of local beneficiaries to long-term, blended climate finance while addressing non-financial barriers (which have a negative impact on the mobilization of climate finance) like inadequate data sets, institutional and local level capacity, and technological gaps. Furthermore, the SME Bank of Cambodia (SME Bank) opened with an initial capital of $100 million with the goal of promoting agro-processing and other SMEs (The Phnom Penh Post, 2020). However, donors should provide guarantee instruments to reduce the risk of RE investments, cover losses, and promote a reduction in collateral requirements in order to encourage local financial institutions (FIs) to develop financing products for technical innovation in the agri-food industry. Cambodia has the potential to do more with its agricultural output than it currently does, but in order to fully realize this potential, the government must be willing to implement the necessary policies.

[41] https://www.khmertimeskh.com/501489148/meet-focuses-on-technologys-role-in-sustainable-agriculture/

Policy Frameworks to support green financing

Over the past ten years, Cambodia has made significant strides toward creating procedures for carrying out climate change actions. The National Strategic Development Plan (2014–2018), the nation's overarching development plan, emphasizes the significance of carrying out Cambodia's Climate Change Strategic Plan (2014–2023) and contains indicators to track the implementation of climate change actions. In addition, Cambodia's Intended Nationally Determined Contribution (INDC) calls for a 27% reduction in greenhouse gas emissions by 2030. The INDC lists promoting the use of renewable energy sources and implementing energy efficiency as two of the mitigating methods. Approximately 168 tons of CO_2 equivalent are avoided year from the 14 CERF investments. This is regarded as micro-scale, but it could still be applied to Cambodia's INDC through mitigation efforts in the manufacturing and other sectors. More significantly, the goal of this pilot project was to show how this unique finance model could help achieve INDCs if it were expanded and backed by regional financial institutions. The Royal Government of Cambodia (RGC) is committed to fighting against climate change and accelerating the transition to a climate-resilient, low-carbon, sustainable mode of development (NCSD, 2020). Green financing offers investors several profitable methods to contribute to environmental protection, as climate change is increasingly seen as one of the primary sources of uncertainty for economic growth and could negatively affect social and environmental situations. Two memorandums of understanding (MoUs) on "Cooperation of Sustainable Finance" were signed by the Association of Banks in Cambodia, the MoE, the National Bank of Cambodia (NBC), and the United States Agency for International Development (USAID) at the beginning of August 2019. The purpose of the MoUs was to improve and develop sustainable financial cooperation in the banking sector and support environmental protection, natural resource management and climate change. For the RGC supported the green financing through the relevant national legal frameworks as follows:

- Cambodia Climate Change Strategic Plan 2014-2023
- RGC, MoE, Climate Change Action Plan 2016 – 2018
- The Convention on Biological Diversity, ratified by Cambodia in 1995
- Biodiversity Country Profile Cambodia
- Cambodia National Biodiversity Strategy and Action Plan (February 2016)
- Cambodia National REDD+ Strategy 2017-2026 (Reducing Emissions from Deforestation and Forest Degradation in developing countries)
- National regulations requiring Environmental Impact Assessment for specific projects (e.g. Draft law on Environmental Impact Assessment, Environment and Natural Resources Code of Cambodia in 2023)
- Country Environment Profile, Royal Kingdom of Cambodia (produced with support from the European Union Delegation to Cambodia, April 2012)
- CITES - the Convention on International Trade in Endangered Species of Wild Fauna and Flora

For the environmental sector, there are vital legislations such as:

- 1996 Law on Natural Resources Management and Environmental Protection
- 1999 Sub-Decree no. 72 on Environmental Impact Assessment Process
- 2009 Prakas no. 376 on General Guideline for Preparing the Initial Environmental Impact Assessment
- 2020 Prakas no. 021 on Classification of Development Projects for Environmental Impact Assessment

10. Policy Analysis for Agriculture Sector

The Royal Government of Cambodia (RGC) is committed to combating climate change and accelerating the transition to a climate-resilient, low-carbon, sustainable mode of development (Updated NDC, 2020). The RGC has been signatory of the UNFCCC since 1996. The country developed a legislative point of view, as it already has two laws, 26 policies and 13 climate targets in place.

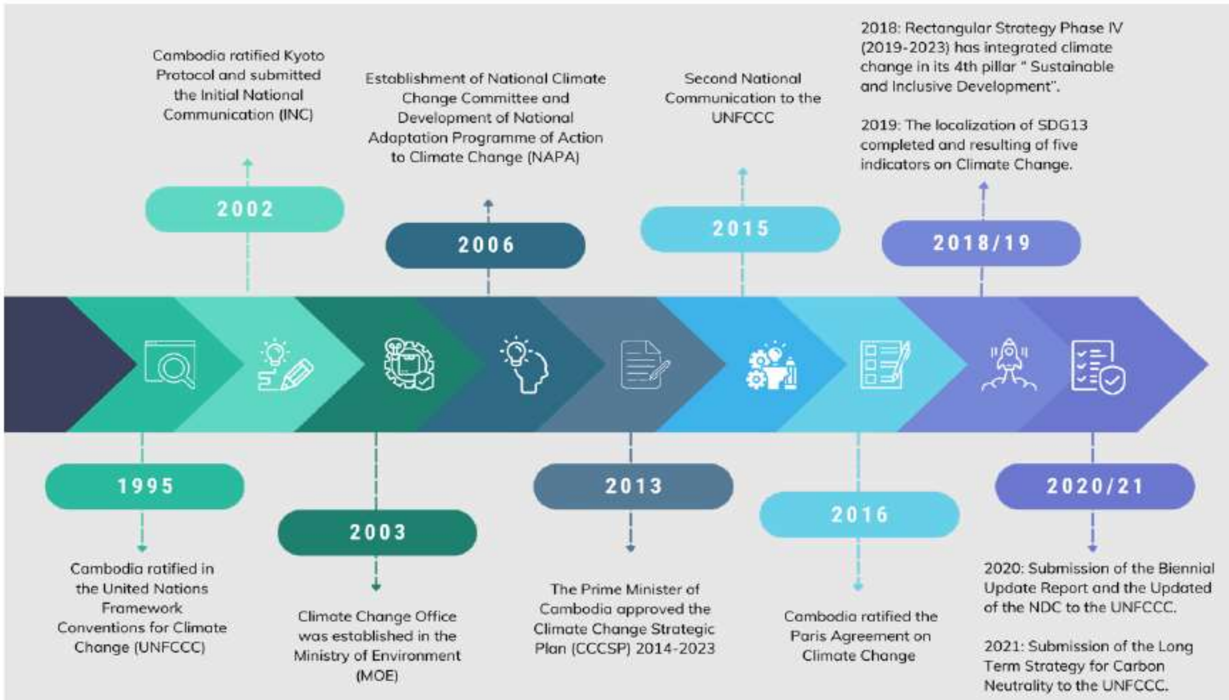


Figure 14. Historical overview of Cambodia's climate engagement and legislation.

Source: Draft CCPAP-2030

Nationally Determined Contribution (NDC): Under agriculture, the NDC has 17 prioritized adaptation actions with an emphasis on horticulture, livestock, aquaculture, agribusiness, and the growth of rice and other cash crops. The NDC adaptation component listed the requirements for additional research, capacity building, improved institutional structures, new technology development, and agriculture support services. With the goal of reducing 50% of global emissions by 2030 under the REDD+ program, Cambodia prioritized mitigation efforts in the Forestry and Other Land Use (FOLU) sector, with 23% going toward the agriculture sector (NDC, 2020). A biodigester program will be implemented by the MAFF and other pertinent ministries as one of the mitigating measures mentioned in the amended NDC.

Long-Term Strategy for Carbon Neutrality 2050: Cambodia also published their "Long-Term Strategy for Carbon Neutrality 2050 (LTS4CN)," in December 2020. With the submission of this policy, the country is the second least developed nation. Its main sectors for decarbonization were 1) FOLU, 2) energy, and 3) agriculture of the existing NDC goals. The specifics of the NDC and LTS4CN are presented in Table 17. This plan is strategically aligned with nationally evolving climate priorities and commitments. Additionally, Cambodia's NDC set adaptation commitments across nine major sectors and various national ministries, considering its high dependency on climate-sensitive sectors like agriculture, water resources, forestry, fisheries, and tourism. The government's Second National Communication to the UNFCCC (NC2) from

2016 and its Third National Communication to the UNFCCC (NC3) in 2022 provide more details on these initiatives.

Table 18. Overview of NDC and LTS4CN priorities and targets

Cambodia NDC Update	LTS4CN	
The updated NDC has proposed a 42% reduction in GHG emissions below BAU by 2030. The estimated 2030 emission reductions of the NDC scenario are listed below; most targets identified are conditional on international financial and technical support.	The LTS4CN aims for national carbon neutrality by 2050 across sectors, with the FOLU sector as the main driver of carbon neutrality in terms of both carbon sinking and reduction of GHG emissions.	
• FOLU: 50% reduction below BAU by 2030 • Energy: 40% reduction • Agriculture: 23% reduction • Industry (IPPU): 42% reduction • Waste: 18% reduction	Agriculture	• Less methane-intensive rice cultivars • Direct seeding practices • Alternate wetting and drying practices • Promotion of organic fertiliser and deep fertiliser technology • Feed additives for cattle • Improved fodder management • Introduction of composting technology
	Forestry and Croplands	• Reducing deforestation rate by 50% by 2030 and stopping deforestation entirely by 2045 • Afforestation, improved forest management and forest restoration • Agroforestry and commercial tree plantation • Full implementation of REDD+ Investment Plan by 2050

Source: Draft CCPAP-2030

Pentagonal Strategy Phase 1: Under this Pentagonal strategy, the government pays particular attention to the promotion of the agricultural sector and rural development, including its linkage with the National Action Plan for Zero Hunger Challenge 2016–2025. The current state of agriculture is a key sector, but it suffers from low productivity. To modernize agriculture, the strategy considers the following recommendations for modern techniques and technology: Promote the use of modern irrigation, high-yield seeds, and pest management. To implement, key activities must be in place: i) provide subsidies for the adoption of modern agricultural technologies; ii) establish extension services to educate farmers on modern practices; and iii) facilitate access to credit for smallholder farmers to invest in technology.

The Agriculture Development Policy 2022-2030: MAFF's strategy, outlined in the 2022-2030 National Agricultural Development Policy (ADP), is aligned with the 2050 vision and the aim for Cambodia to be an upper-middle-income country by 2030. In line with this, the ADP's ambition is 'to modernise the agriculture sector so it can become competitive, inclusive and resilient to climate change in a context of environmental sustainability', with the overall development goal being 'to increase agricultural growth with high competitiveness and inclusivity by providing high-quality products which result in food safety and nutrition, while taking into account sustainable management of land, water, forestry and fishery resources.'

11. Solutions and action plan- potential project pipeline development

Climate events are occurring more frequently and with greater severity, which is having an impact on farming activities. As a result, smallholder farmers and monoculture farmers face crop failure or yield loss. Adaptation to climate change in the agricultural sector requires to combine of technological smart farming, research, market, and regulatory solutions to solve the main challenges. This will involve the development of research to determine the most effective adaptation options, the strengthening of extension services that offer farmers technical support on how to improve their resilience to climate change by creation of incentives, credits and other financing mechanisms to support adaptation efforts, and the support of private sector actors into this agricultural development is critically important to expand technologies and innovations to other areas and communities and help to facilitate the adoption of new technologies, goods, and services.

Currently, many of agricultural practice's adaptations and mitigation strategies could be used as part of this project to increase the ability of Cambodia's agroecosystems to respond to climate change. For instance, these alternations are connected to the adoption of selecting seed variety, utilizing irrigation techniques, green housing, net housing, applying cover crops, conducting crop rotations, encouraging diversity or altering the planting schedule. The adoption of climate resilient practices is a gradual process that necessitates adjustments at several levels. Therefore, Cambodia can unlock the potential of climate technologies to improve agricultural productivity, enhance food security and promote sustainable rural development. To contribute to sustainable development goals, this project needs to consider on: 1. **Equity** by ensuring the benefit will widespread to smallholder farmers, women and marginalized groups disproportionately impacted by climate change, 2. **Inclusiveness** by promoting participatory approaches by involving farmer from the planning to implementation stages, 3. **Sustainability** by prioritize technologies that not only climate smart but promote long-term environmental sustainability. At the same time, the further actions should facilitate to scale up in several features:

- **Engaging to agricultural technology**: through agricultural technique and strengthening access of climate information and agriculture such as adoption of early warning system information, digital app or platform for agricultural training and information, etc.
- **Facilitating financial access:** through piloting an index-based insurance plan or testing digital lending mechanism in partnership with a digital service provider and micro finance institution.
- **Market linkage:** Identifying specific market opportunities for farmers production and encouraging the creation of connections between current consumers and producers through aggregators such as Agriculture Communities in order to better respond to market opportunities and secure more additional equitable price.
- **Enhancing extension services:** through business development initiatives that help Agriculture Communities expand their markets through establish contract farming, food processing, packaging and branding, etc. Alternatively, trainings in digital, financial, and business literacies could be developed and implemented for Agricultural Communities, service providers or individual farmers.
- **Policy development support:** through developing case studies or lesson learned from successful smart agricultural farming, support establishing and implementation of roadmaps, guideline of adoption on climate smart agriculture technologies.

1. **Promoting changes of the agriculture practices**

Many of the current strategies for adaptation and mitigation of climate change might be encouraged throughout the implementation of the project in order to improve the ability of Cambodian agroecosystems to adjust to it, as will be further explained below.

- Introducing **mechanical direct seeding**, this transplantation method produces high quality production rather than traditional rice seeds which require a lot of labor. There are currently four distinct mechanical rice seed drills on the market that can be used with two or four-wheel tractors and are appropriate for both wet and dry sowing. The benefits include the rice's ability to endure brief droughts, the development of a stronger root system, and the fact that it is planted in rows, which improves air circulation inside the crop and reduces the prevalence of pests and diseases.
- Promote the **zero-tillage, use of Laser land leveling, contour plow, mulching, and cover crops** which replenish the soil with organic nutrient and less inorganic fertilizers. Additional advantages of growing cover crops include lowering soil erosion and preserving soil moisture.
- Increase the number of **crop plantation with tolerant cultivars** that adopt flood and drought such as Phka Mealdei. This seed is a fragrant rice cultivar that can command a premium in the market.
- Capacity building on innovative technologies and technique in agricultural production such as introducing **alternate wet and dry (AWD)** that reduce water used and methane emission.
- Encourage the farmers **shift planting calendar, mixed crops, and crop rotation** depend on difference eco-zone to increase soil fertilizers, yield nutrient, decrease weed stress, soil pollution and erosion as well as reduce pest and diseases.
- Introduce and promoting use of **net house** to allow for year-round vegetable growth, insect control without the use of pesticides and rain protection of veggies.
- Training and Capacity building to strengthen quality of agricultural production techniques such as **food processing ideas, agricultural storage, and quality check**.
- Training and capacity building on agricultural business ideas including **packaging, hygiene, safety, storage, branding, and market linkage** for small business enterprises.
- Encourage the additional water system for agricultural practices such as **water harvesting, water storage, solar irrigation and pumping system, sprinklers, dripping and hydroponic technique** that give enough water for crop and vegetable needs, reduce water evaporation, water loss.
- Supporting **new business models, innovation, research development and techniques** that could contribute to the farmers and livestock producer in order to adopt and build resilience to climate change.
- Encourage the implementation of the **integrated pest management (IPM)** strategy, which combines a number of tactics including habitat alteration, biological control, adaptation of cultural practices, and the use of resistant cultivars.
- Encourage the implementation of provide convenience to the farmers on the information from **Early Warning System (EWS)**
- Conducting **soil analysis and identify zoning plantation variety** with providing cropping methods to assist the farmers to growth the plants.
- Encourage **livestock variety selection and breeding**.
- Training about **pollution and emission mitigation** plan.
- Introducing **smart aquaculture farming system** (ex. solar fish pond irrigation, resilient aquiculture variety selection, disease control, environmentally friendly aquaculture farm management)

2. **Facilitate access to finance**

- Capacity building on **Financial Literacy Training** by equip farmers with financial management skills, including budgeting, loan applications, and accessing government programs. Feasibility study on digital loan mechanisms by collaborating with MFI and a digital service provider by digital app that can connect the farmers to stakeholders involve in value chain with in low interest.
- Assessment on Potential support **group-based financing schemes** with Agricultural Communities and implementation (Group-based lending, self-help group, cooperative loan such as risk-sharing agreements, leasing, pay-go systems, etc.)
- Provide government **grants or subsidies** to reduce upfront costs of technology adoption of farmers and climate risks, particularly smallholders and vulnerable group.
- Expand access to **affordable load designed** for agricultural technology purchases, with flexible repayment schedules tailored to the agricultural cycle.
- Develop **insurance of agricultural productions** to protect the farmers from crop failures due to climate extreme events. Encourage collaboration between insurance company and farmers for broader reach.
- Explore the issuance of **green bonds or blending finance mechanisms** to mobilize funds for climate adaption projects in agriculture.

3. Market linkage

- Conduct market research to **identify potential** agricultural customers, products need and preference, existing competition and current market trends.
- Develop a **competitive pricing strategy** in production costs, transportation and desired profit margin.
- Build a **strong connection** between farmer communities, farmer's market and Community Support Agriculture (CSA) with local retailers, restaurants, hotels, and distributors to establish reliable sales channels.
- Explore ways to **add value to agricultural products**, such as processing, packaging, branding, and diversification into new products (e.g., jams, juices, dried fruits).
- Implement **quality control measures** to ensure product consistency, freshness, and compliance with food safety standards.
- Consider pursuing relevant **certifications** (e.g., organic, fair trade) to attract premium buyers and differentiate the product in the market.

4. Enhancing extension services

- Promoting local **agricultural business** by subsidize to run and encourage agricultural communities to link with market directly.
- Develop a compelling **brand story** that highlights the local origin, sustainability practices, and unique qualities of local products. **Utilize digital platforms** (social media, online marketplaces) to showcase the products and connect with potential customers.
- Participate in **local events and festivals** to raise awareness and promote agricultural products directly to the community. Develop efficient and cost-effective transportation systems, proper storage to extend shelf life and minimize post-harvest losses to deliver products to markets while maintaining freshness and quality.
- Assist the CASIC platform by arranging events to raise awareness and arranging **regional tours** for national and local stakeholders to get insight from other agroecological endeavors.

- Improve reactive learning and participatory management, work with local authorities to establish **participatory farm-level interaction** (such as Farmer Field Schools and meetings with several stakeholders).
- Establish and carry out **digital literacy trainings** for Agricultural communities, Service provider and individual farmers to get benefits and safe use.
- Disseminate **technical knowledge about climate smart practice** that are currently in place for the agricultural sector (such as CHAIN, CSmart, CHAIN).
- Establish **community's livestock and aquiculture service center and vaccination campaign**

5. Policy development support

- Develop **policy briefs** to promote uptake of climate resilient agriculture practices.
- **Develop scenario of rice monitoring, forecasting, and mapping** of rice areas that most affected by droughts, floods, and other negative impacts of climate change.
- Encourage **policy discussions** that will facilitate the implementation of climate resilient practices by collaborating with public and private sectors such as financial inclusion and digitalization, risk sharing arrangements, etc.
- Develop **feasibility study and case studies** on sustainable farming to inspiration to the government, farmers, private sector.
- Supporting new initiative **roadmap or guideline** for smart agriculture technology to enhancing capacity of rural development.

Table 19. Summary of climate smart agricultural technologies and techniques existing in Cambodia

No	Challenges	Climate Smart Agricultural Technology	Existing project	Institution
		Before harvest		
1	Lack of appropriate equipment and techniques	Hand-held tools and small-scale machinery, laser landing leveling system, hydroponic, net house, green house, solar-powered irrigation systems: Optimize yield, save water, save energy, and minimize crop damage.	USAID -Harvest III AIMS Project	Larano
2	Lack of pest control techniques and disease	Drone pest control management	-XAG Agricultural drone conducts aerial spraying on cassava production. -University of Queensland and CARDI training drone service providers in Prey Veng. Agricultural and Rural Development Bank (ARDB) doing a pilot project on puddy rice and modern technology to cultivate 5ha at Prey Veng province.	ARDB, CARDI, XAG Agricultural drone

3	Lack of water resources	Rehabilitate canals, water reservoirs, and irrigation systems	French Development Agency (AFD) provide support on dam and canals of Prasat Pram irrigation system.	AFD, ADB, CAPRED, CAVAC)
4	Lack of technical support to facilitate the water using respond to climate resilience	Energy-efficient processing technologies and low-cost, (solar irrigation, dripping irrigation, hydroponic system, rain water harvesting and storage,): Facilitate value addition and income generation.	-The Food and Agriculture Organization (FAO) promotes water-efficient irrigation practices. -The World Bank's "Water and Agriculture Strategy" supports investments in water management infrastructure. - IR-CSA Project: Demonstrations of crop rotation, drip irrigation, and agro-clinics. -Promoting Solar Technologies Project: Challenge fund for innovative solar water pumping solutions -World Vision: Rainwater harvesting and conservation agriculture practices.	FAO, World bank, CCCA, CTCN, ISA, Worldvision,
5	Lack of resilient crop seeds	Select resilient seeds (Phka Mealdei), Crop Insurance providing,	World Bank's "Scaling Up Renewable Energy in Low-Income Countries (SREP)" program supports solar-powered technologies for agriculture.	AVSF, Syngenta, World Bank
6	Soil degradation and loss of nutrient	- Small-scale bio-digesters: Generate biogas for cooking and lighting, and bio-fertilizer for improved soil fertility. - Biochar production: Convert organic waste into a valuable soil amendment that enhances water retention and nutrient cycling. - Composting techniques: Create nutrient-rich organic fertilizer while reducing waste and improving soil health.	-The International Biochar Initiative (IBI) provides resources and technical assistance for biochar production. -The World Agroforestry Centre (ICRAF) promotes composting and biochar use in rural communities. -The Cambodian Ministry of Agriculture and Forestry supports bio-digester pilot projects. -ATECBIO website: online business with farmer by Ethic biogas plant can convert cattle and pig manure into	IBI, ICRAF, ATECBIO, MAF

		- Provide subsidies or microloans for initial investment in bio-digesters and biochar production units. - Develop carbon credit schemes to incentivize adoption and emissions reduction.	gas for safe cooking and natural fertilizer for your crops.	
7	Lack of access to climate information	Strengthening reliable Early Warning system, establishing app support to farmers	Developing a comprehensive digital solution for climate change adaptation by early warning phone service **EWS1294** real-time online data extended to 24,628 new subscribers under the project "strengthening Climate Information and Early Warning Systems in Cambodia to Support Climate Resilient Development and Adaptation to Climate Change".	UNDP and MOWRAM
Post-Harvest				
8	Limited knowledge and skills for food preservation and processing.	Solar-powered drying and storage solutions: Reduce reliance on traditional drying methods, improve shelf life and quality of product	FAO's "Save Food Initiative" provides training and resources for reducing food loss and waste.	FAO, CAPRED
9	Lack of innovation research, techniques that respond to the market	- improved harvesting practices, food preservation techniques, and basic processing methods - Support the development of farmer cooperatives and women-led businesses in agro-processing.	The SNV Netherlands Development Organization promotes sustainable food processing technologies in Cambodia.	SNV, CFAP, CSA,
10	Limited collected points, packaging, branding to the market	- Establishing Agricultural Communities - Engage access to finance for agricultural business - Promoting digital support and mainstreaming session	Global agriculture & food security program (GAFSP) with Aceleda bank promoting access to finance solution to smallholder farmers, agriculture firms, small and medium enterprise of agriculture.	AMK, ARDB, Wing, World bank, ADB, RFD, USAID, EFAD, DFAD
Technical and Digital Technology Tool Support				

11	Lack of Research, information and Technique	Developing agricultural technology parks for research and study model.	CE SAIN Transforming Agri-food systems (the Royal University of Agriculture) that develop Agricultural Technology Parks (ATPs) in difference agro-hydro ecological-zones in Cambodia that demonstrate the new technologies and strategies to attract the private sector participation with in research and farmer networks and to organize innovation fairs, field days and workshops.	CE SAIN
12	Lack of awareness of digital agriculture technologies	Develop a platform developed for digital agriculture technologies that can be used jointly by the government, farmers, private sector actors and development partners.	**Khmer Smart Farming App, Chamka App** initiated by the ASPIRE offers information on climatic, technical, and agricultural inputs, **AngkorSalad** supported by ICCO Cooperation, which gives vegetable producers market information, expertise, and technical guidance. **East West Seed,** which is the Knowledge Transfer Platform from offers technical knowledge to vegetable farmers through a Youtube channel**, CropWiki App,** which is a detailed catalogue app, and the **Tonlesap App,** developed by AMK to disseminate technical and market information to its clients, are just a few examples of the services	UNDP, Khmer Smart Farming App, Chamka App, AngkorSalad, East West Seed, CropWiki App, the Tonlesap App, Metkasekor platform.

12. Case study of potential program: Financial solution for hard-to-reach small farmers for climate change adoption for rural development in Cambodia

According to the survey results, rural farmers were affected by events like pests (27%), floods and vector-borne diseases (25%), and droughts (23%), respectively (Figure 15). In particular, pests were difficult to control. However, they are aware of ways to deal with its impacts on the farms by using three adaptation measures: protection (applying natural pesticides that follow the set standard), biological control, and chemical control.

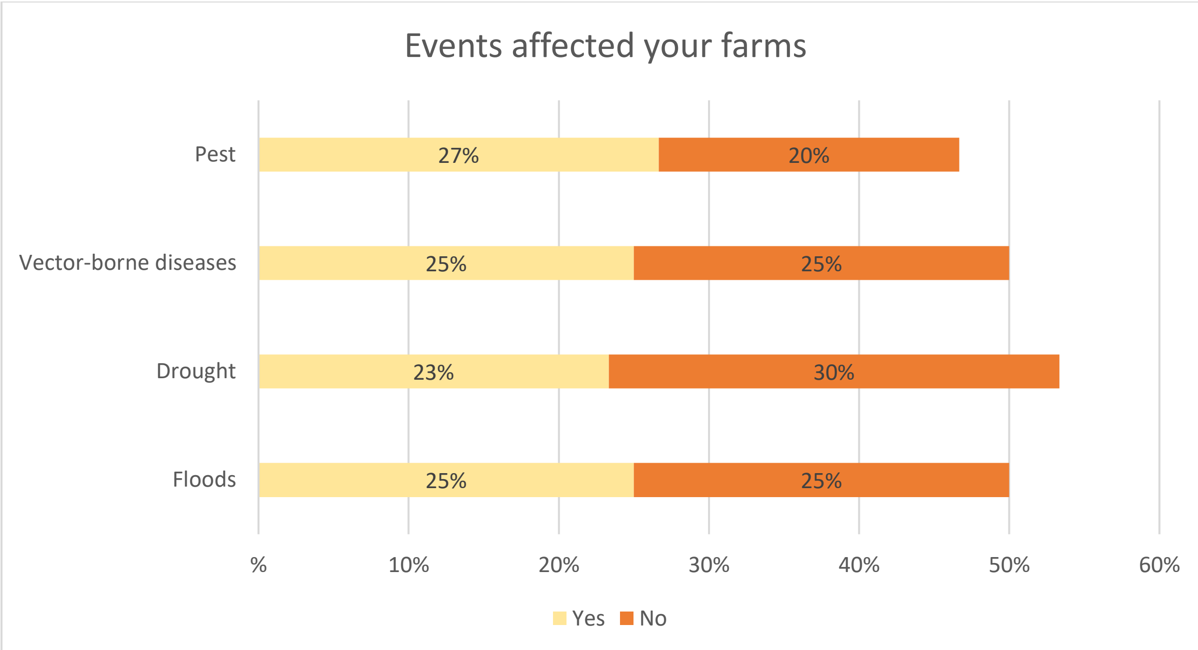


Figure 15. Event affected your farms.
Source: household survey, 2024

Figure 16 indicates that 53% of the respondents know ways to deal with climate's impacts, while nearly half of them (47%) have access to knowledge on climate risk. They normally accessed the knowledge by attending the training workshop on climate change, sensor systems, timers (used for irrigation vegetables, IoT, and roof covers). Furthermore, they also attended community events, a virtual training, or website sharing (on Facebook or Youtube), but only some farmers are able to use smart phones.

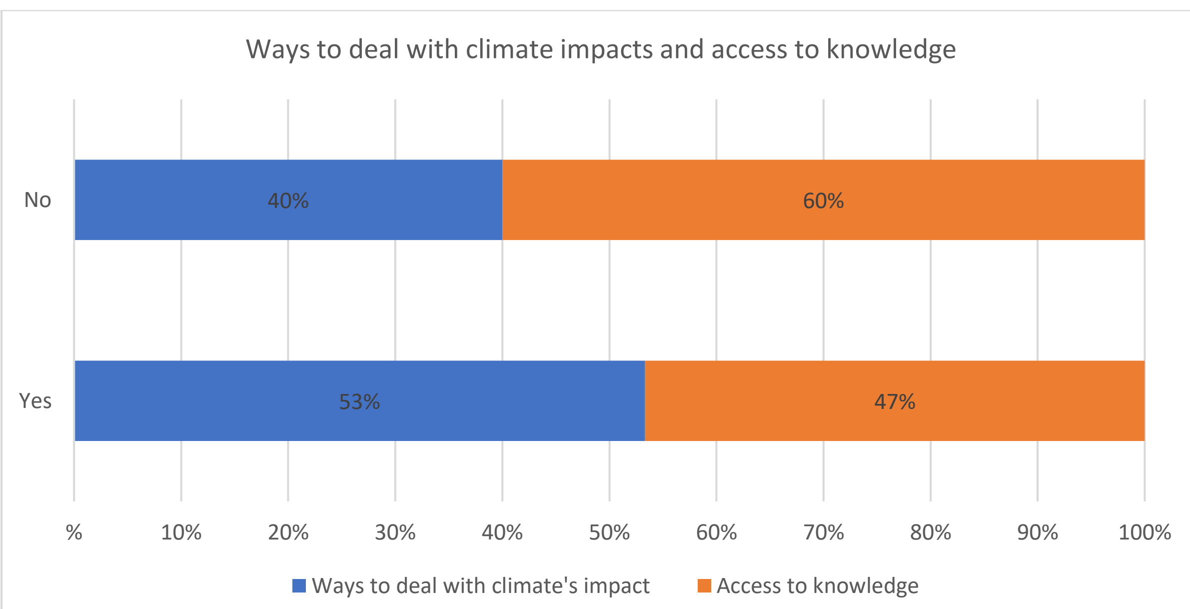


Figure 16. Ways to deal with climate impacts and access to knowledge.
Source: household survey, 2024

In contrast, when asked about the main challenges facing accessing knowledge in their own area, they reported living in remote areas (27%) the highest, followed by a lack of ICT knowledge (23%), and hindering knowledge sharing (22%), respectively (Figure 17). The survey results found that 27% of the respondents are not involved with local authorities. Although they faced challenges and constraints in starting to use new technologies on their specific farm, they had an impact on climate change in the community. For instant, a mini-dry season prolongs in the area, the pond is restored, or wells are restored but lack financial support. Farmers require initial funding to dig wells and ponds, install drip irrigation systems, and buy diesel pumps in order to set up supplemental irrigation systems. Farmers can switch to solar water pumps as a practical substitute for diesel pumps. However, a timer sensor system, a net house loaned by PDAFF/ASPIRE, and Lormeat Meanchey Agricultural Cooperative was needed as necessary for their farms. Lastly, most of the respondents lack a business plan to apply for loans at financial institutions.

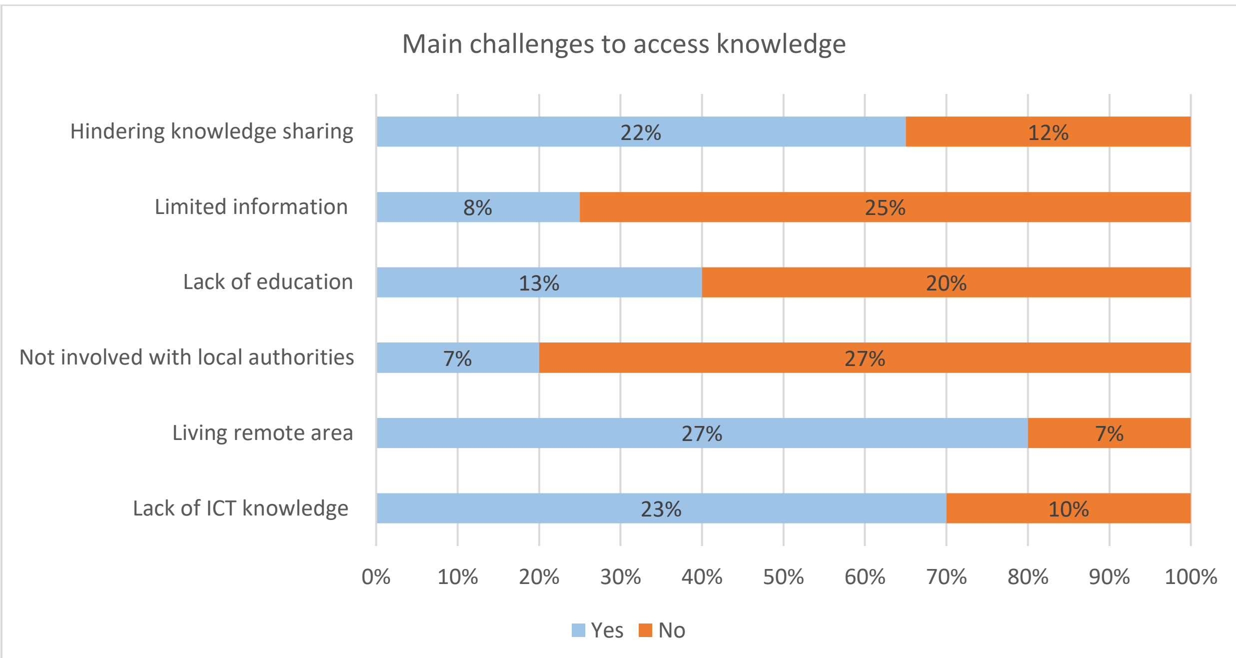


Figure 17. Main challenges to access knowledge.
Source: household survey, 2024

In the face of climate change, a variety of technologies are starting to be embraced in Cambodia's agricultural sector, but farmers lack the knowledge to fully utilize them. The results from the survey show the key potential climate technologies applied to their farm. Figure 18 illustrates that 21% of the respondents answered that the timer sensor system is applied in their farms, followed by drip irrigation (20%) and rainwater harvesting (17%), respectively. Also, mulching is an important technology in their own areas. However, some of the other technologies, including hydroponics, pond restoration, and net-houses, are not interested by their farmers due to the high cost of installation and changed rainfall over the last few years. Together with solar system technology, 17% of the respondents were concerned about the challenges and impact of solar technology adoption in the agriculture market. Though technology has developed into modern versions, farmers have not understood the revolution. They have not adapted to new technologies because they still live with old habits. As mentioned, there are types of solar that people often use for farming, including vegetable farms, fruit processing, livestock farms, and the fisheries sector.

Therefore, some potential sectors where middle-sized farmers use solar systems but small farms do not use solar energy yet.

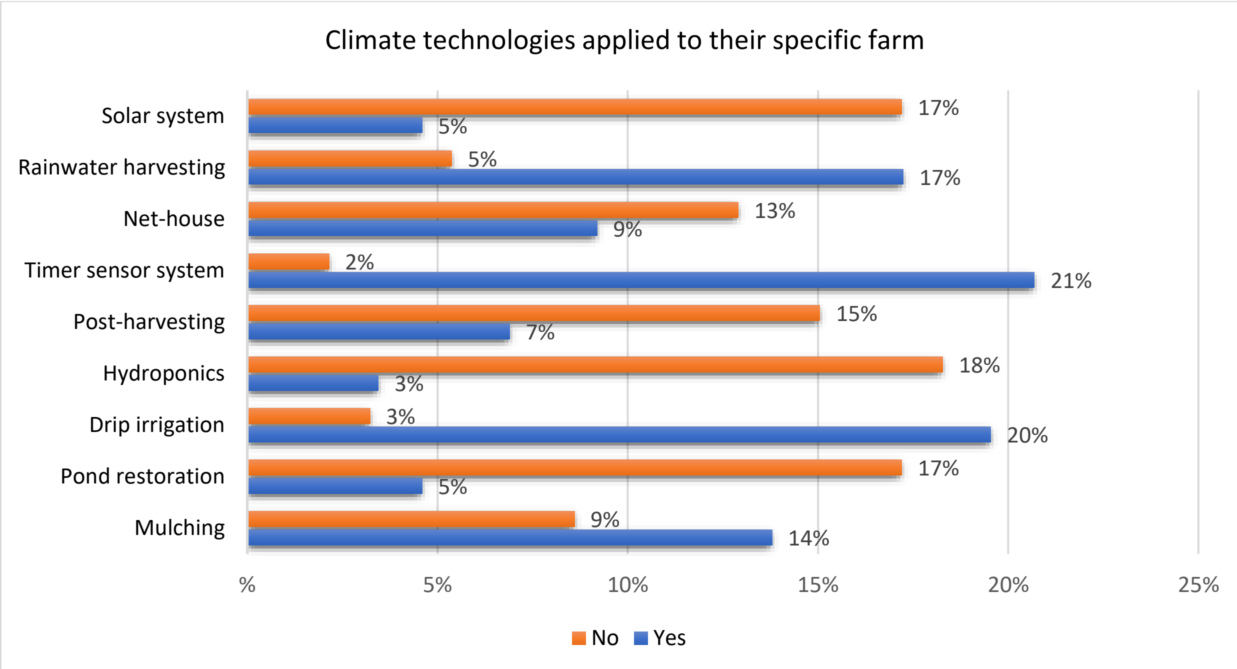


Figure 18. climate technologies applied to their specific farm.
Source: household survey, 2024

Figure 19 shows the market orientation of the farm products from the farmers. Most of the products from the households are subsistence (self—supply) in majority 57%, and 42.86% of the farm is mixed (subsistence/commercial). The price of agricultural products on the market could also affect their farms due to the price of agricultural inputs, while they generate less income from agriculture products. To address this challenge, most of them need to develop an agricultural business plan with available resources.

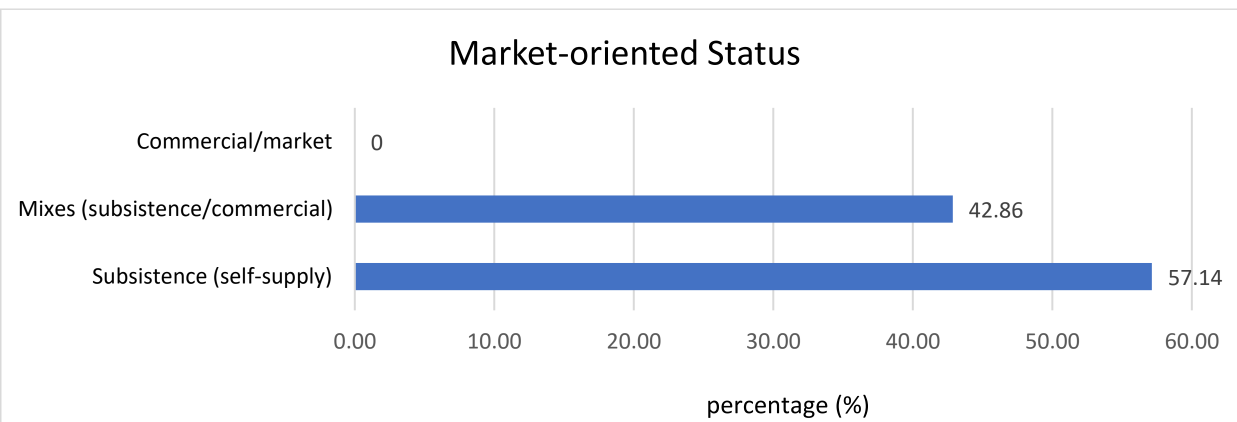


Figure 19. Market-oriented by farm products.
Source: household survey, 2024

There are many best ways to share knowledge with farmers on climate risks management for farming among the relevant stakeholders, particularly the farmers. According to the field survey result showed that most of the communication initiatives are not based on delivering top-down information which is intended to inform people's decision-making. Many of these focus on sharing information that farmers are producing rather than responding to the specific needs of local people. Initiatives more closely focused on knowledge sharing on climate risk are fewer, but some good examples are emerging that incorporate more learning-focused methodologies and have a stronger focus, particularly at local levels. Figure 20 indicates that the most effective way respondents received information was directly from the company experts (17%), on-the-job training (16%), followed by video clips and community training on climate change (15%). The reason behind this is that those make them see and understand exactly the climate-friendly technologies, together with their own concept to start up their microbusiness or scale up their practices with financial instrument support.

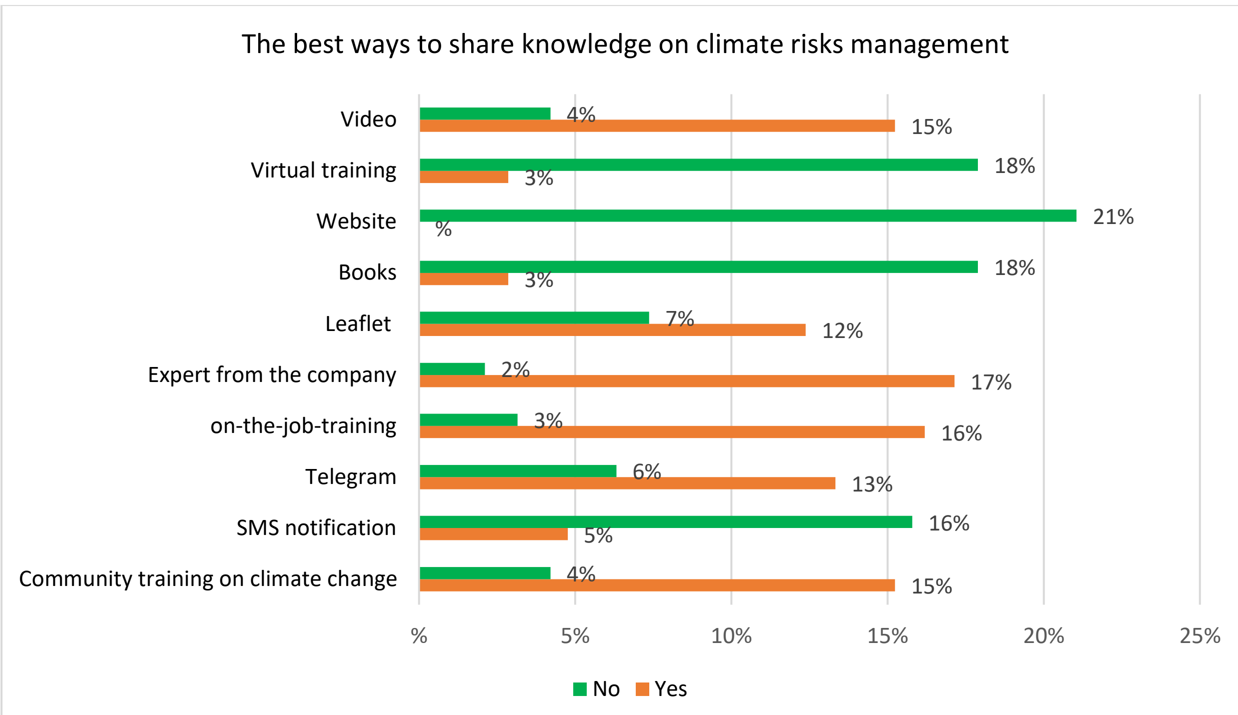


Figure 20. Best ways to share knowledge on climate risk management.
Source: household survey, 2024

According to the results of the survey (Figure 21), the main difficulties faced in getting financial support to improve farms are a high collateral requirement (17%) at first, a high interest rate and complexity of the loan application procedure (16%), and a lack of financial statements about sources of finance for both debt and equity financing (15%), respectively. Also, there is a lack of knowledge of financial management (13%), while the informality of business is 7%. Lastly, only 5% of the respondents are lack information about sources of finance. Overall, the high-interest rate and high collateral requirements are the main challenges for smallholder farmers in the target areas as they are inaccessible to finance are caused by the informality of businesses. Collateral is a major obstacle to obtaining financing in Cambodia. Moveable assets, including warehouse receipts and invoices, are now only accepted as collateral by a few numbers of banks, and even then, primarily for big trading transactions and the rice sector. Financing restrictions can be lessened by the availability of leasing services; however, most leasing is concentrated on consumer products, and only a small number of enterprises lease agricultural machinery, primarily tractors.

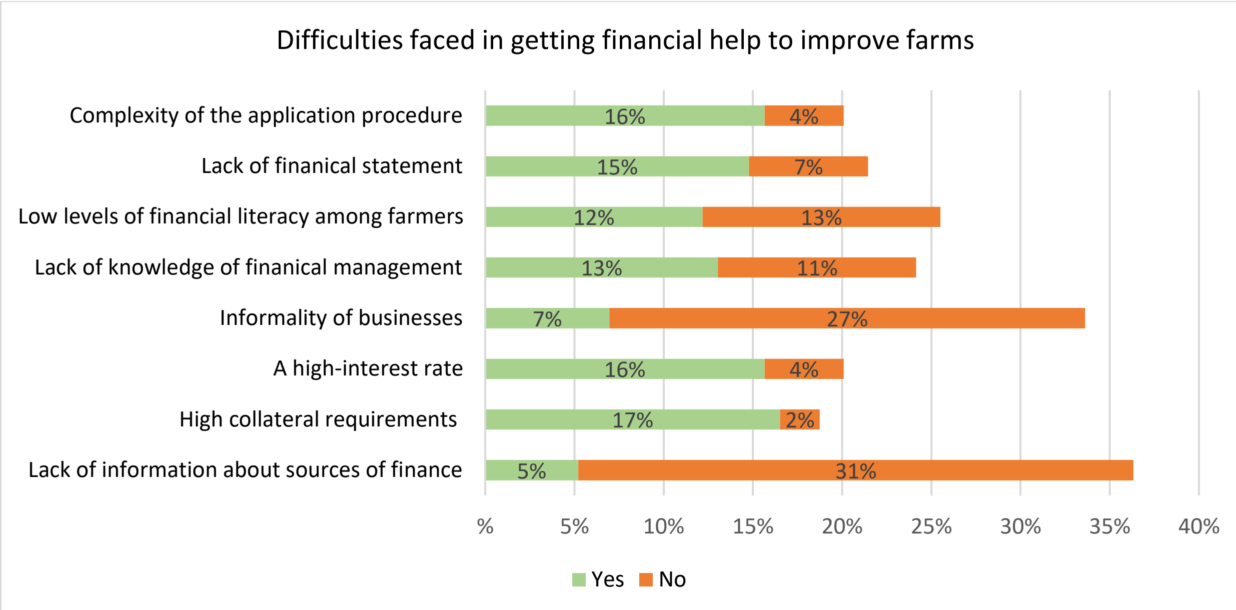


Figure 21. Difficulties faced in getting financial help to improve farms.
Source: household survey, 2024

The survey data showed that farmers and farm owners are looking for different options to get financial help to use climate-friendly technologies to decrease their cost. All surveyed respondents are interested to invest in climate technologies, even though it was self-acknowledged that they have limited information or are less familiar with new technologies. A range of farm owners who are interested in investing in climate-friendly technology, like solar and biogas systems, may be eligible for financing from FIs. Cost of technologies may be quite affordable for SMAs compared to the loan amounts offered by commercial banks. Furthermore, it has been noted that some MFIs would be open to offering larger loan sizes. Figure 22 indicated that about 15% of respondents claimed that they took loans from FIs to either set up their farms or to support the operation of their farms by considering a low-interest loan and clear government policy engagement as key requirements. Following the two options, they report 14% of incentives for farmers and blended finance and on-farm demo (13%), respectively. In contrast, 26% of the respondents reported that a business pilot is not required. Last but not least, based on the interview, farmers lack access to finance, lack of resource and capacity to adopt new technology and innovation (e.g., indigenous people in Mondolkiri and Ratanakkiri provinces), absence of private sector service in rural areas, lack of interest of investors and financial assistance in agriculture and rural development, poor internet connection, limited rural infrastructure, and policy support. Finally, some condition for considering the financial help to use climate-friendly technology should be applied in climate financial instrument.

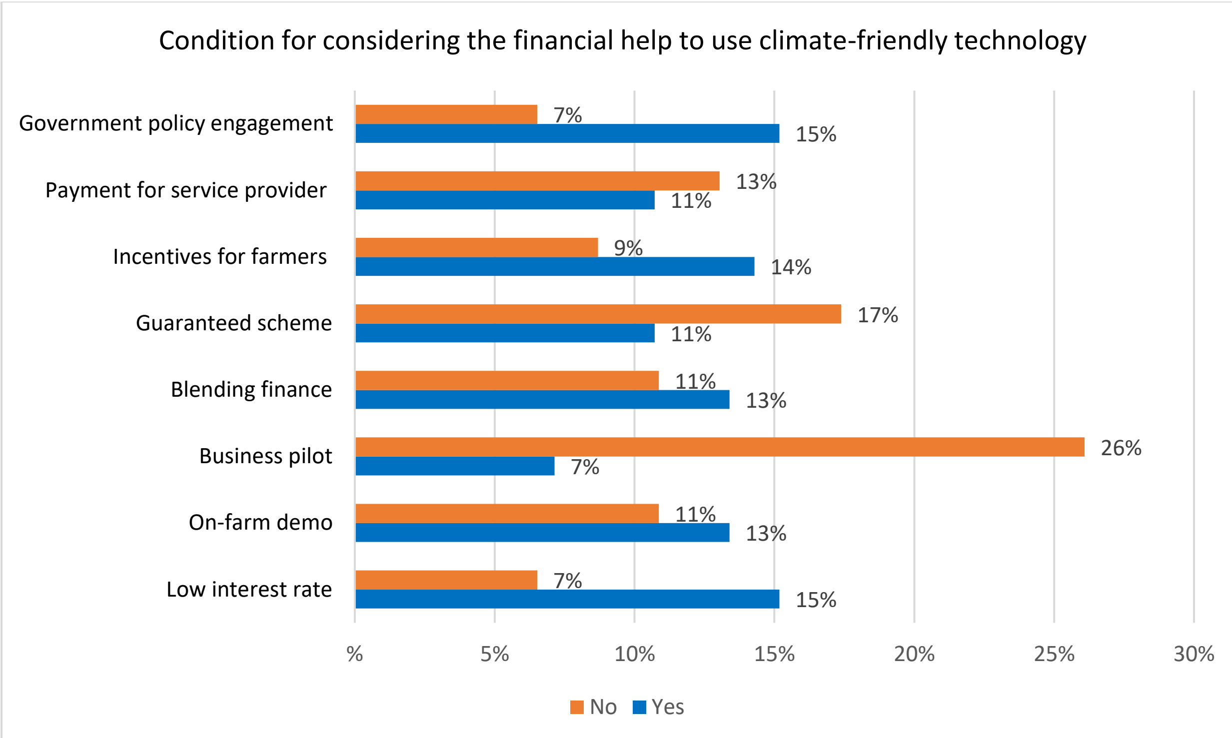


Figure 22. Condition for considering the financial help to use climate-friendly technology.
Source: household survey, 2024

13. Conclusion

Cambodia, one of the least-developing nations in South East Asia. The country is already heavily affected by the climate change. Increased variability in rainfall patterns is causing more frequent droughts and more frequent and intense floods. In 2015–2016, 18 out of 25 provinces had a severe drought that affected nearly 2.5 million people. The expected cost of the droughts linked to the 2019 El Nino-related losses in rice output was $100 million. The most intense rains in three years struck 14 provinces in September 2022, resulting in severe flooding that affected almost 85,000 households and landslides that forced 5,000 more to from their homes. Cambodia has succeeded in moving from a least-developed country to a lower-middle-income country, with a stable annual economic growth by 7%. The country has set a far-reaching objective to further transform its economy and reach upper middle-income status by 2030 and a high-income country by 2050.

Agriculture is a pillar of the Cambodian economy, contributing 22.2% of the country's GDP. As reported by the Ministry of Agriculture, Forestry and Fisheries (MAFF) in 2023, agricultural crops account for 57.1% of the overall production, followed by fisheries, livestock, and forestry. Approximately 2.04 million households (57%) in Cambodia are involved in agricultural and allied practices, with smallholder farmers comprising the majority (70%) who own less than 2 ha of land. Notably, 61% of Cambodians live in rural areas and rely mostly on agriculture, fishery, and forestry for their livelihoods.

The nation and its citizens are at serious risk from the effects of climate change, which also has the potential to make development issues worse. Increased losses to homes, businesses, highways, and educational institutions are predicted, along with the disruption of vital supply chains and services.

Reduced yields from fisheries and staple crops due to climate change are expected to cause problems for food security and nutrition. Increased illness prevalence is linked to warmer temperatures and more intense rainfall, both of which have a negative influence on health. Nonetheless, actions taken by the public and commercial sectors can lessen the worst effects of climate change, and the report lays out the top objectives and suggestions for quick action. Government-led adaptation might, for instance, increase the resilience standards for infrastructure related to health and education and make current road networks more resilient to climate change. Investments in flood-resistant structures and energy-efficient cooling systems are examples of private initiatives. Globally, the cost of sustainable energy technology, like as solar energy, is declining quickly, which offers Cambodia additional opportunities. The cost of solar energy is expected to continue to drop in Cambodia, making it a desirable choice for the nation's energy requirements.

In addition to fighting climate change, the Royal Government of Cambodia (RGC) is dedicated to hastening the shift to a low-carbon, climate-resilient mode of development. According to the RGC's long-term carbon neutrality plan, Cambodia will have net-zero emissions by 2050. Since 1996, the RGC has participated in international efforts to combat climate change as a Party to the United Nations Framework Convention on Climate Change (UNFCCC). With an ambitious Intended Nationally Determined Contribution (NDC), demonstrating advancements in climate policy, and proposing mitigation objectives and adaptation measures in line with national priorities, Cambodia embraced and ratified the Paris Agreement. Key goals related to mitigation and adaptation under Cambodia's NDC include:

- 27 percent reduction in emissions below BAU by 2030.
- LULUCF contribution of 4.7 tCO_2e/ha/year.
- 60 percent increase in forest cover of national land area by 2030.
- Development of horticulture and other food crops for increased production, improved quality-safety, harvesting and post harvesting technique, and agro-business enhancement.
- Climate proofing existing and future solar/hydropower infrastructure

To achieve these, the finance and banking sectors have been considered to play an essential role in promoting sustainable economic growth. Sustainable finance involves making investment decisions that consider financial returns. Otherwise, a variety of different business model from different financial institutions were initiated. The Clean Energy Revolving Fund (CERF) was introduced by Nexus for Development (Nexus) as a project to mitigate climate change. It began in 2016 and was scheduled to conclude in three years to create a pilot revolving loan fund to provide access to finance for the adoption of renewable energy solutions in the Cambodian agri-food sector. The strategic objective of the fund was to provide affordable loans to the agri-food sector leveraging a blended finance model to increase the adoption of renewable energy technology in Southeast Asia. With technology like off-grid solar systems and solar water pumps, Nexus concentrated its efforts on a range of agri-food industry areas, including processors, water treatment plants, and farms that raise cattle, produce, vegetables, and spices. Though solar energy was found to be the most appropriate technology for the agri-food sector in Cambodia in the current market, CERF was open to supporting other technologies, such as biogas systems. CERF helped reduce CO_2 emissions from the agri-food sector by funding renewable energy investments, and in so doing encouraged an early shift away from fossil fuel based energy sources as the sector grows. Together with this fund, some case studies were addressed to see the business model and lesson learnt.

In 2019, the Association of Banks in Cambodia signed two memorandums of understanding (MoUs) on "Cooperation of Sustainable Finance" with the MoE, the NBC and the United States Agency for International Development (USAID) to strengthen and develop sustainable financial cooperation in the banking sector. The goal of the MoUs was to improve and develop sustainable financial cooperation in the banking sector and support environmental protection, natural resource management and climate change in Cambodia.

Lesson learned:

- Barriers of technology adoption are lack of awareness and experience, lack of trust in the technology, and high upfront costs.
- It is acknowledged that initially FIs may face some challenges due to a lack of expertise in technical aspects of RE products.
- The major knowledge gaps include: (1) a lack of expertise in helping farmers to assess product quotes and the quality of the respective RE products, (2) limited to no existing expertise in offering technical support to clients for product maintenance, and (3) a lack of knowledge to ensure that RE technologies are installed properly and will lead to the realization of any estimated cost savings.
- However, to design RE loan products the FIs can develop partnerships with technology providers, which would support the transfer of knowledge and necessary expertise. It is recommended that FIs also engage with other stakeholders such as NGOs and governmental agencies who are already working in the RE sector to support the successful design and delivery of their RE loan products.
- Climate finance should be established and encouraged by local financial institutions (FIs) to enable the switch to climate-friendly technologies. Although Cambodia has one of the most vibrant microfinancing sectors in the world, RE loan products are not considered a potential market by these banks. The FIs are hesitant to engage in RE investments as they believe market opportunities are limited, and investments are deemed too risky and unprofitable. In addition, in some instances the FIs might not have a good understanding of climate technologies offered in the market, the requirements or in-house knowledge for an energy assessment, or an understanding of the possible return prospects on such investments. Another noticeable reason RE financial products have not been a priority of the FIs is because they are concerned about the quality of RE products, and after sale servicing by technology providers.

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