Provision of Feasibility and Viability Study of Using Blockchain Technology for a Real-Time Climate Risk Insurance System in Thailand's Agricultural Sector

PREPARATORY ANALYSIS FOR THE BLOCKCHAIN-BASED PARAMETRIC CROP INSURANCE IN THAILAND

Research Division I
Emerging Technology Division

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GLOSSARY

°C	The symbol representing the unit of temperature degree Celsius
Adaptation	Adjustment to climate vulnerability and change involves ecological, social, and economic systems adjusting to climatic stimuli to mitigate adverse impacts or seize new opportunities. The goal of adaptation is to reduce the risks posed by climate impacts, minimize damage, and take advantage of potential opportunities.
Agro-ecological	It refers to an approach to agriculture that emphasizes the ecological processes underlying agricultural systems. It integrates ecological science with sustainable farming practices to enhance biodiversity, improve resource efficiency, and promote resilience to environmental challenges.
Animal husbandry	Animal husbandry is the branch of agriculture concerned with animals that are raised for meat, fiber, milk, or other products.
Artificial Intelligence (AI)	A technical and scientific field devoted to the engineered system that generates outputs such as content, forecasts, recommendations or decisions for a given set of human-defined objectives. (International Standardisation Organisation, 2022)
Blockchain	Distributed ledger with confirmed blocks organized in an append-only, sequential chain using cryptographic links. Note to entry: blockchains are designed to be tamper-resistant and to create final, definitive and immutable ledger records.
Blockchain-based parametric insurance (BBPI)	It is a type of insurance that combines blockchain technology with parametric insurance principles. It provides predefined payouts based on the occurrence of specific measurable events or parameters, such as a certain amount of rainfall, wind speed, or temperature, rather than compensating for actual losses incurred. This approach is designed to be more efficient, transparent, and automated compared to traditional insurance.
Distributed Ledger Technology (e.g. Blockchain)	A system whereby replicated, shared, and synchronized digital data is geographically spread (distributed) across many sites, countries, or institutions.
Escrow	It is an arrangement for a third party to hold the assets of a transaction temporarily. The assets are kept in a third-party account and are only released when all terms of the agreement have been met. The use of an escrow account in a transaction adds a degree of safety for both parties. The main purpose of an escrow is to ensure that everybody sticks to their end of the bargain. It can be seen as a mediator of the transaction. It asserts that the transfer of assets only happens when all the obligations of the transaction have been met.
Et al.	An abbreviation of the Latin phrase et alia, meaning "*and others*"
Extreme weather events	They are severe weather conditions that deviate significantly in frequency or intensity from the normal patterns in a particular region
Geographic Information System (GIS)	A GIS consists of integrated computer hardware and software that store, manage, analyze, edit, output, and visualize geographic data. ("Fundamentals of geographic information systems," 1997) (Lagrosa et al., 2012).
Green revolution	It refers to a set of agricultural innovations and initiatives that began in the 1940s and expanded in the 1960s, aimed at increasing food production to alleviate hunger, particularly in developing countries

Internet 4.0	It is also called the Symbiotic web as it involves a symbiotic association between humans and machines. It incorporates the latest technologies such as artificial intelligence, machine learning, big data analytics, cloud computing and the Internet of Things (IoT) to create a more connected, intelligent and data-driven digital experience, enabling systems to respond to end user behavior, making interactions, enhancing decision making and delivering more personalized content efficiently.
Internet of Things (IoT)	An infrastructure of interconnected objects, people, systems and information resources together with intelligent services to allow them to process information of the physical and the virtual world and react. (ISO/IEC JTC 1, 2015)
Parametric insurance	It is an insurance product that uses data to make a loss assessment, instead of a human checking the level of damage from an event and paying based on a subjective loss estimate. Parametric insurance uses datasets as its index and a trigger to make a payment.
Resilience	The ability of a system to anticipate, prepare for, respond to, and recover from the impacts of climate change. Resilience involves not just adapting but also building the capacity to survive and thrive despite climate stressors, allowing systems to maintain their function or bounce back quickly from disruptions
Smallholder farmer	It is a farmer who cultivates small plots of land, often less than 2 hectares, and relies on family labor.
Smart contract	It is a computer program stored in a DLT system, wherein the outcome of any execution of the program is recorded on the distributed ledger. Note to entry: A smart contract can represent terms in a contract in law and create a legally enforceable obligation under the legislation of an applicable jurisdiction.
Yield	It is the amount of crop produced per unit area of land, typically measured in metric tons per hectare

LIST OF ACRONYMS

ADB	Asian Development Bank
ADP	Agricultural Development Plan
AEZ	Agro-Ecological Zoning
AI	Artificial Intelligence
APCCA	Action Plan for Climate Change in Agriculture
ASEAN	Association of Southeast Asian Nations
BAAC	Bank for Agriculture and Agriculture Cooperatives (BAAC)
BBPI	Blockchain-Based Parametric Insurance
BCG	Bio-Circular-Green
BCI	Blockchain & Climate Institute
CCAM	Conformal Cubic Atmospheric Model
CCMP	Climate Change Master Plan
CRI	Climate Risk Index
CTCN	Climate Technology Centre and Network
EbA	Ecosystem-based Adaptation
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organization
FDA	Food and Drug Administration
FFTC	Food and Fertilizer Technology Centre
FMD	Foot-and-mouth disease
GCF	Green Climate Fund
GDP	Gross Domestic Product
GEF	Global Environment Facility
GIS	Geographic Information System
IBTrACS	International Best Track Archive for Climate Stewardship
IIASA	International Institute for Applied Systems Analysis
IoT	Internet of Things
OIC	Office of Insurance Commission
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
LAO	Local Administrative Organization
LDC	Least Developed Country
LMIC	Low- and Middle-Income Country
MNRE	Ministry of Natural Resources and Environment
MOAC	Ministry of Agriculture and Cooperatives
MRC	Mekong River Commission
NAP	National Adaptation Plan
NAP-Ag	Integrating Agriculture into National Adaptation Plan

NCC	National Climate Change Committee
NDC	Nationally Determined Contribution
NGO	Non-Governmental Organization
NXPO	The Office of National Higher Education Science Research and Innovation Policy Council
OAE	Office of Agricultural Economics
ONEP	Office of Natural Resources and Environmental Policy and Planning
PPP	Public-Private Partnership
RCP	Representative Concentration Pathway
SARCCIS	Southeast Asia Regional Climate Change Information System
SCALA	Scaling up Climate Ambition on Land Use and Agriculture
SDG	Sustainable Development Goal
SSP	Shared Socioeconomic Pathway
TCFD	Taskforce for Climate-related Financial Disclosures
THB	Thai baht (official currency of Thailand)
UCSUSA	Union of Concerned Scientists of the United States of America
UNDP	United Nations Development Programme
UNDRR	United Nations Office for Disaster Risk Reduction
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
USAID	United States Agency for International Development
USD	United States Dollar (the official currency of the United States of America)
USDA FAS	United States Department of Agriculture’s Foreign Agricultural Service

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EXECUTIVE SUMMARY

Thailand's agricultural sector, contributing 8.6 % to the gross domestic product and employing 31 % of the workforce (2024), faces escalating climate risks — droughts, floods, and erratic rainfall — that cause annual losses estimated at THB 20-50 billion. Smallholder farmers, who produce 70% of the country's rice, rubber, and cassava, are particularly vulnerable due to high basis risk, slow indemnity payouts, low insurance penetration (under 10 % for crop insurance), and distrust in traditional schemes.

This preparatory analysis demonstrates the strong technical, economic, and operational feasibility of introducing a blockchain-based parametric crop insurance (BBPCI) system. By leveraging smart contracts, satellite/IoT remote sensing, and Chainlink oracles, the platform automates transparent, near-instant payouts triggered by objective climate indices, reducing basis risk by 20-25 %, eliminating fraud, and cutting administrative costs by up to 40 % compared to conventional indemnity insurance.

Key findings:

- Market readiness: Existing schemes (e.g., NAIC, BAAC-supported) cover only 15-20 % of eligible farmers due to complexity and delays. Parametric models tested globally (Etherisc, Arbol, AgriSure) show 85-95 % farmer satisfaction when payouts occur within days.
- Technical viability: Integration of high-resolution data sources (Thai Meteorological Department, GISTDA satellites, ground IoT stations) with Ethereum/Avalanche-compatible blockchains is fully achievable. Open-source frameworks (Etherisc DIP) and ISO-compliant AI governance (ISO/IEC 42001) ensure scalability and trust.
- Economic attractiveness: Premiums can be priced 15-30 % lower than indemnity products while maintaining insurer profitability through reduced overhead and reinsurance efficiency. Farmer willingness-to-pay surveys indicate strong demand at THB 500–1,500 per rai for rice/rubber coverage.
- Regulatory pathway: The Office of Insurance Commission (OIC) sandbox (active since 2020) provides a clear route for pilot testing; full integration into the National Crop Insurance Scheme is feasible post-PoC.

The proposed 24-month implementation roadmap (Phase 1 PoC: USD 325,000; Phase 2 national scale-up: co-financed) positions Thailand as a regional leader in digital agricultural resilience. With strong stakeholder buy-in (BAAC, TMD, private insurers) and alignment with the 2nd NDC and Digital Economy Master Plan, BBPCI offers a transformative opportunity to protect millions of smallholders, enhance food security, and unlock new climate finance flows.

1 - INTRODUCTION

Thailand's agricultural sector, a cornerstone of rural livelihoods and national food security, is increasingly vulnerable to the impacts of climate change. Smallholder farmers face mounting risks from extreme weather events such as droughts, floods, and unseasonal rainfall, which threaten crop yields and income stability. Existing crop insurance schemes, while present, remain limited in coverage, often slow in processing claims, and inaccessible to a large number of farmers due to high transaction costs, lack of transparency, and complex procedures. These issues are compounded by insufficient climate risk data, low awareness, and limited trust between farmers and insurers. As a result, there is a pressing need for innovative financial tools that are both efficient and inclusive. The blockchain-based parametric crop insurance project aims to address these challenges by automating claims, reducing costs, and enhancing trust through transparent and real-time data processing—ultimately strengthening the climate resilience of Thailand's agricultural sector.

The Climate Technology Centre and Network (CTCN), the operational arm of the United Nations Framework Convention on Climate Change (UNFCCC) Technology Mechanism and hosted by the United Nations Environment, contracted Blockchain and Climate Institute (BCI) to provide technical assistance for the provision of a feasibility and viability study of using blockchain technology for a real-time climate risk insurance system in Thailand's agricultural sector. The objective of this technical assistance is to develop a technical and economic feasibility study for using blockchain technology for an improved parametric crop insurance product. Using blockchain technology has the potential to reduce transaction costs and automatize transparent indemnity payments, thus making crop insurance more attractive and accessible to farmers whilst remaining economically viable for insurance providers. Beyond the feasibility study, an implementation roadmap will support the national stakeholders in the subsequent steps of developing, testing, and implementing such a blockchain-based product beyond this technical assistance. The aim is to increase the resilience of Thai farmers to climate-induced extreme weather events.

This report aims to analyze the agricultural sector and the existing environment for crop insurance in Thailand to understand the market status, trends, underlying problems, and drivers.

In the first part of this report, a general overview of the agricultural sector in Thailand will be provided, highlighting key figures, land use, crop production distribution, and farmland distribution by the number of farmers. Additionally, an assessment of vulnerability and climate risk impact will be conducted, identifying key climate risks and vulnerable geographies.

The second part of this report will examine and analyze existing insurance products in Thailand, focusing on their coverage of crop types, geographic reach, target audience, costs, terms and conditions, disbursement mechanisms, data usage (crop, weather, etc.), and level of automation/digitalization. If available, data on the number of insured farmers, insurance payments, and market size will be collected.

The third part of this report will describe a farmer survey conducted to understand their exposure to climate-related impacts, their experience with crop insurance products, and their readiness for blockchain-based parametric crop insurance. Depending on the type of crop they plant, exposure to different climate hazards will be mapped. Farmers will be surveyed regarding their experience with crop insurance, the perceived and actual benefits and limitations of having crop insurance, and the reasons for not having crop insurance. Lastly, factors influencing their readiness to benefit from blockchain-based parametric crop insurance will be identified, including holding a bank account, access to a mobile phone, access to mobile money, and financial management in case of risk. Farmers will be classified into different segments, including female farmers, large-field farmers, smart farmers, agricultural entrepreneurs, and cooperatives. Particular attention will be given to the specific experiences, interests, and requirements of female farmers. A representative share of female farmers will be targeted with the survey.

1.1 - Methodology

This section outlines the steps for conducting an in-depth analysis of the agricultural sector, the crop insurance market, and farmer experiences with climate-related risks and insurance in Thailand. The methodology is structured to achieve the activity objectives, focusing on key elements such as sector analysis, climate risk impact assessment, crop insurance product mapping, and farmer survey implementation.

1.1.1 - Literature review

The methodology for this analysis begins with a comprehensive review of existing literature, reports, and data on Thailand's agricultural sector, crop insurance market, and farmer experiences with climate impacts and insurance mechanisms. The literature review serves as the foundational element guiding the entire analysis, drawing from a wide range of sources including academic studies, government reports, market analyses, and case studies from both Thailand and other countries with similar agricultural systems and climate risks.

The objective of this review is to gather and synthesize existing research related to key areas such as the structure of Thailand's agricultural sector, trends in crop production, and the experiences of farmers with crop insurance products. Specifically, the review aims to identify key figures in land use, crop production distribution, and farmland distribution by the number of farmers. Additionally, it highlights key trends, challenges, and gaps in the current knowledge to inform the subsequent stages of the analysis.

In parallel with the literature review, data collection will involve gathering quantitative data from national statistical offices, agricultural departments, and international organizations like the World Bank, etc. Data from Geographic Information Systems (GIS) will also be employed to map crop production and farmland distribution across the country, helping to visualize the geographic distribution of key crops and farming regions. The combined use of literature and data provides a comprehensive overview of the agricultural sector and enables a detailed understanding of the crop insurance market and farmer experiences, forming a strong basis for further analysis.

1.1.2 - Mapping of adaptation strategies

This section of the report focuses on identifying and mapping the various adaptation strategies (existing and potential) to cope with extreme weather events recorded in Thailand, such as floods, droughts, storms, and heatwaves. The aim is to identify the different methods to protect crops and livelihoods from climate risks. By analyzing the effectiveness of each strategy with a Strengths-Weaknesses-Opportunities-Threats (SWOT) matrix, the study will provide valuable insights into the resilience of farmers and inform policy recommendations and support programs tailored to their needs. The strategies will be ranked to determine an attractiveness scale.

1.1.3 - Farmer survey

The farmer survey is a critical component of the methodology for analyzing Thailand's agricultural sector, crop insurance market, and farmers' experiences with climate impacts and insurance products. The objective of the survey is to gather first-hand data on farmers' exposure to climate-related risks, their use of crop insurance products, and their readiness to adopt innovative solutions such as blockchain-based parametric crop insurance.

1.2 - Economic background

Despite its decreasing share in the gross domestic product (GDP) (Figure 1), agriculture remains a cornerstone of Thailand's economy and society, employing a significant portion of the population and contributing substantially, 8-10%, to the country's export value (**Error! Reference source not found.**). However, the agricultural sector is increasingly vulnerable to a variety of risks, both natural and human-induced (DCCE, 2023a)

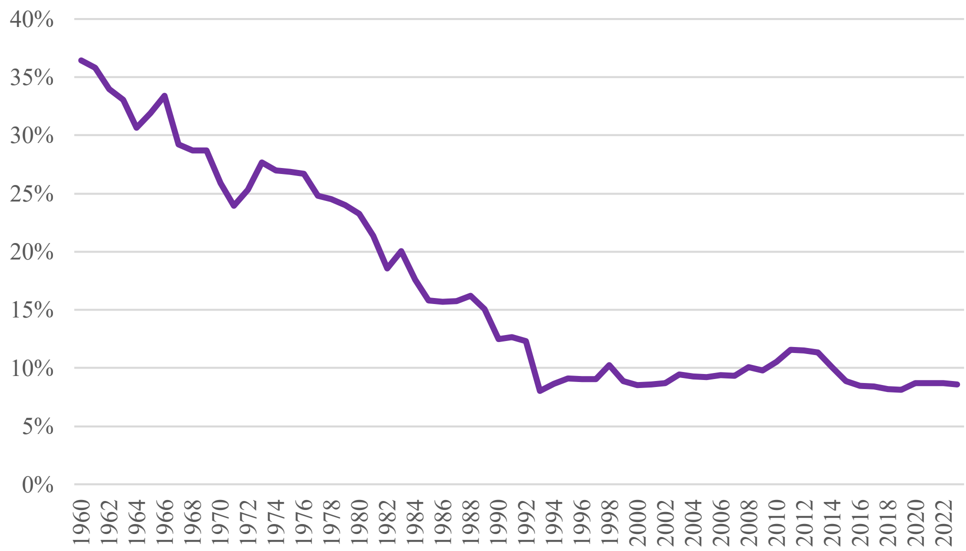

Figure 1: Value added of agriculture, forestry, and fishing, as a percentage of GDP (source: World Bank, 2024)

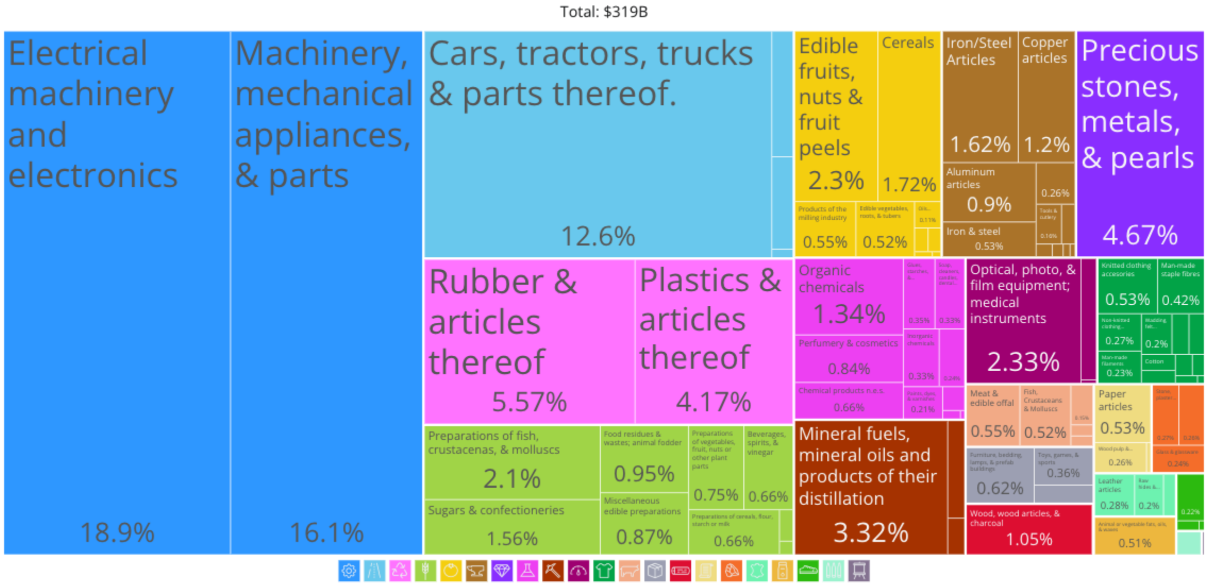

Figure 2: 2023 Thai exports in value (source: the Observatory of Economic Complexity)

In the figure above, the agricultural sector (mostly foodstuff in green and vegetable products in yellow), account for approximatively 16% of the total exports.

Thailand, like many countries in the Global South, faces severe climate change impacts. Its status as a climate vulnerability hotspot is evident, as it ranks 9th in the world for long-term climate risk, according to the 2021 Global Climate Risk Index. Owing to its geography and socio-economic characteristics, different regions in Thailand face varied climate threats, including floods, rising sea levels, and extreme temperatures. This broad exposure places both rural and urban populations at significant risk.

The agricultural sector is particularly vulnerable, as it employs around 30% of Thailand's workforce (Figure 3). Agriculture, forestry, and fisheries are critical not only for economic output but also for ensuring national food security. Climate change is expected to exacerbate existing challenges such as water scarcity, pollution, and soil degradation across Thailand. These compounding pressures threaten to destabilize agricultural productivity and the livelihoods of Thai farmers (Udomkerdmongkol, 2020)

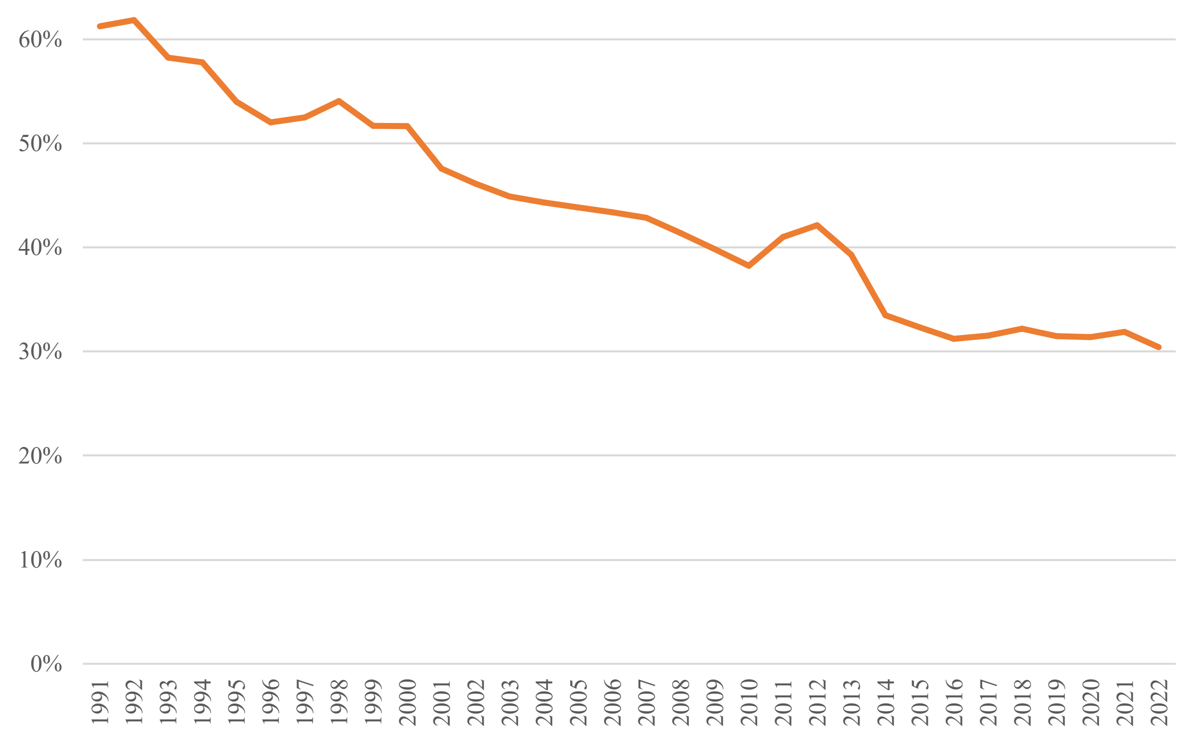

Figure 3: Employment in agriculture as a percentage of total employment (source: World Bank, 2024)

1.3 - Climate change trends and impact on agriculture

While agriculture's share of GDP in Southeast Asia has been diminishing, it remains a vital sector, especially in Thailand. However, it is acutely vulnerable to climate risks, particularly floods and droughts, which are the most severe hazards affecting agricultural productivity. Historical data from 1980 to 2020 reveal that floods have impacted more people than any other natural hazard in Thailand (World Bank, 2012). Figure 4 highlights the prevalence of floods, storms, and droughts during this period, underscoring the rising frequency of these disasters.

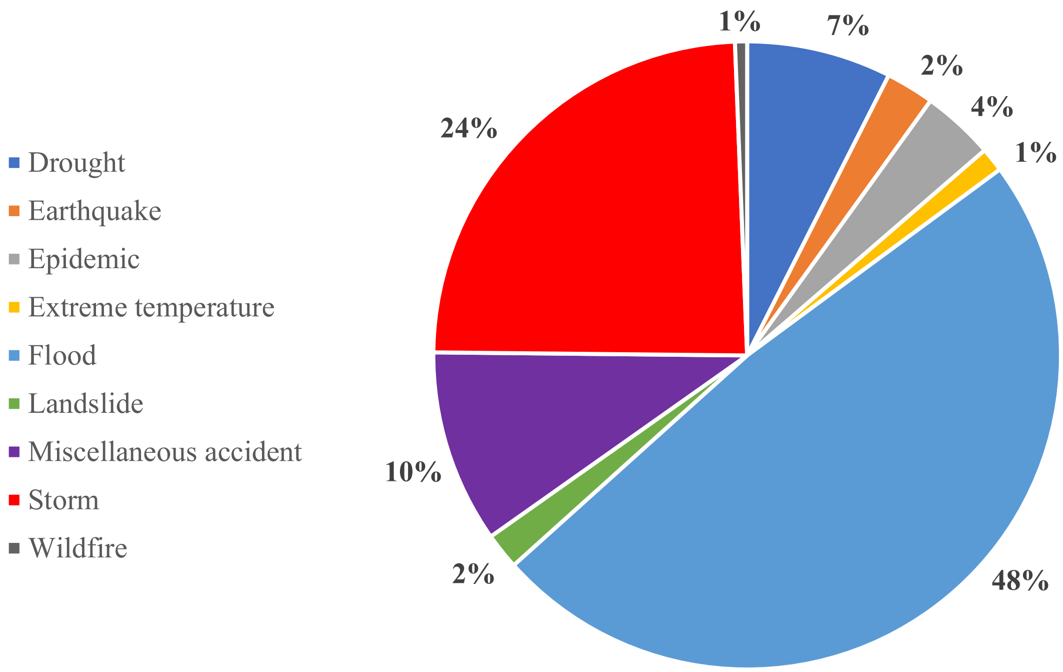

Figure 4: Average annual natural hazard occurrence in Thailand from 1980 to 2020 (source: World Bank, 2021)

Thailand's hydrological features, combined with its geographic location, exacerbate the risk of climate-induced disruptions to agriculture. These disruptions affect essential resources such as water availability, soil fertility, and crop health, and increase the incidence of pests and diseases (DCCE, 2023a). In 2020 alone, 848 km² of agricultural land (1.20%) was lost to drought, while in 2021, 9,120 km² (3.82%) were destroyed by floods, with an additional 2,241.22 km² (1.40%) damaged later that year (Ibid).

The seven key impacts of climate change on Thai agriculture, according to Waqas (Waqas et al., 2024) include extreme weather events, reduced agricultural productivity, disrupted crop development, shifting sustainability practices, resource degradation, and increased pest and disease outbreaks. These challenges are further compounded by the increased intensity of floods and droughts, particularly in the Northeast and Southeastern regions (Udomkerdmongkol, 2020).

The most destructive flood in recent memory occurred in 2011, affecting 66 of Thailand's 77 provinces and damaging over 20,000 km² of agricultural land. The total economic cost was estimated at THB 1.44 trillion (USD 46.5 billion), with nearly 900 lives lost (World Bank, 2012). Projections suggest that climate risks will continue to threaten key crops, such as rice and sugarcane. For instance, a study by the Office of Natural Resources and Environmental Policy and Planning (ONEP) in 2016 estimated that 25,569 km² of rice fields are at risk of future flooding, particularly in the Central Plains (DCCE, 2023b)

The vulnerability of Thailand's agricultural sector to climate change is a significant threat to the economy. Between 2011 and 2019, storms, droughts, and floods caused an estimated USD

160 million in total damages (Department of Climate Change and Environment of Thailand, 2023). The 2011 floods alone caused USD 46.5 billion in damages, necessitating USD 14 billion in loans for recovery (World Bank, 2012). These figures underscore the urgent need for comprehensive climate adaptation strategies, particularly for impoverished farming households that are most exposed to these risks. Without adequate insurance, social security, or institutional support, these communities face severe financial instability and food insecurity (Prommawin et al., 2022).

2 - AGRICULTURAL SECTOR OVERVIEW

Thailand's agricultural sector plays a pivotal role in its economy, employing approximately 30% of the national workforce and contributing significantly to its GDP (FAO, 2021). Key crops include rice, which forms the backbone of Thai agriculture, along with rubber, cassava, sugarcane, and maize. The agricultural sector is highly region-specific, with rice being predominant in the central plains, while the southern region specializes in rubber and oil palm production (FAO, 2021). Despite its importance, the agricultural sector is increasingly facing challenges, including climate change, which threatens crop yields, and fluctuating global commodity prices, which impact farmer incomes and sustainability.

Understanding Thailand's climate vulnerability, particularly in the agricultural sector, begins with recognizing its geographical and climatic context. Thailand is in Southeast Asia, covering 513,115 km^2, with borders shared with Myanmar, Laos, Cambodia, and Malaysia (World Bank, 2021). Geographically, the country is divided into five regions: Northern, Northeastern, Central, Eastern, and Southern (Waqas et al., 2024) .

Thailand's agricultural sector is competitive, diverse, and specialized, with its export performance standing out on the global stage. The country is a world leader in the export of several agricultural commodities, including tapioca products, natural rubber, and canned pineapple. Additionally, it has diversified its agricultural output to meet both domestic and international market demands. The range of crops produced for the market includes cassava, maize (corn), kenaf, longans, mangoes, pineapples, durians, cashews, vegetables, and flowers (International Trade Administration, 2024). Thailand's agricultural exports are bolstered by strong global demand, particularly in the Asian and European markets.

Approximately 45% of Thailand's total land area is dedicated to agriculture (World Bank, 2021) and this area has been gradually increasing since 1961 (Figure 5). This makes Thailand especially vulnerable to climate hazards such as floods, droughts, and extreme temperatures. Cash crops such as rubber, coffee, sugarcane, and various fruits are predominantly grown on large estates owned by agribusinesses, a trend that emerged in the late 20th century. Rubber production has increased by over 80%, as shown in

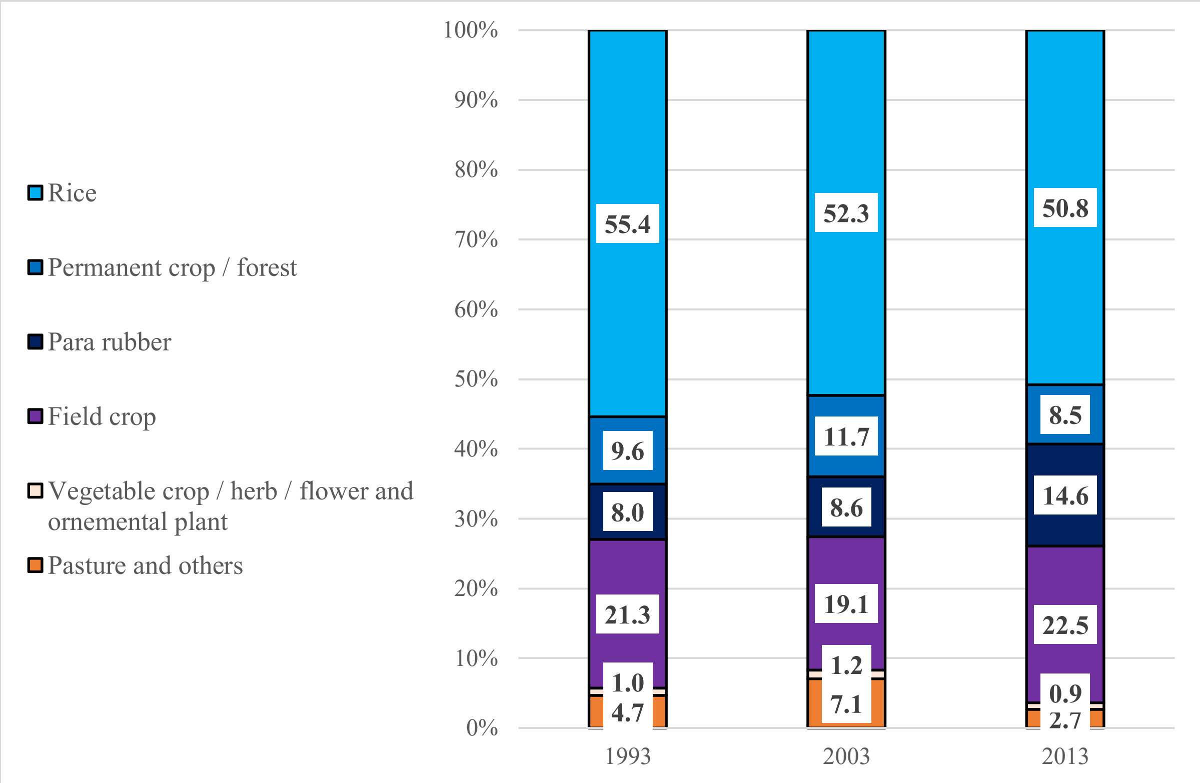

Figure 6: Thailand's crop distribution based on land area (1993-2013) (source: National Statistical Office, 2014)

, reflecting significant growth in this industry. However, some traditional crops, such as tobacco, have experienced a decline in demand (International Trade Administration, 2024), leading to a reduction in cultivation.

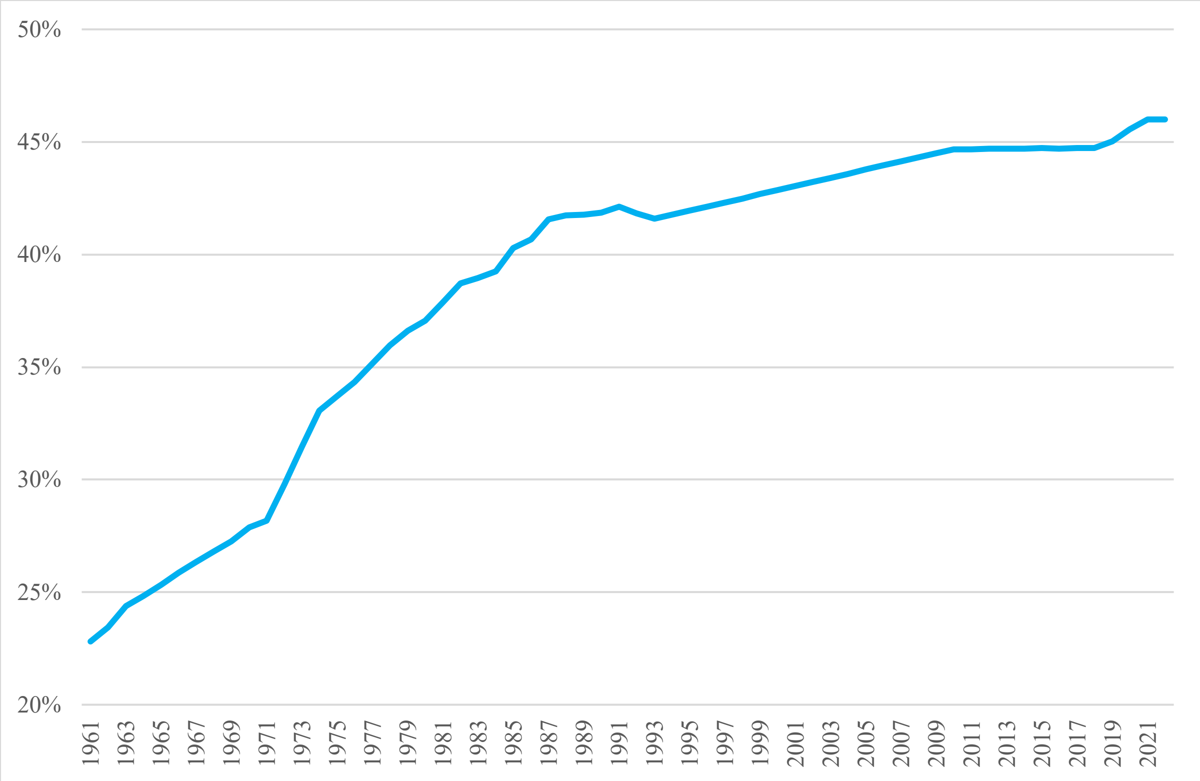

Figure 5: Percentage of agricultural land in Thailand (source: World Bank, 2024)

Among all crops, rice holds a special place in Thai society and agriculture (Evenson et al., 1996). Rice cultivation occupies over half of the arable land (

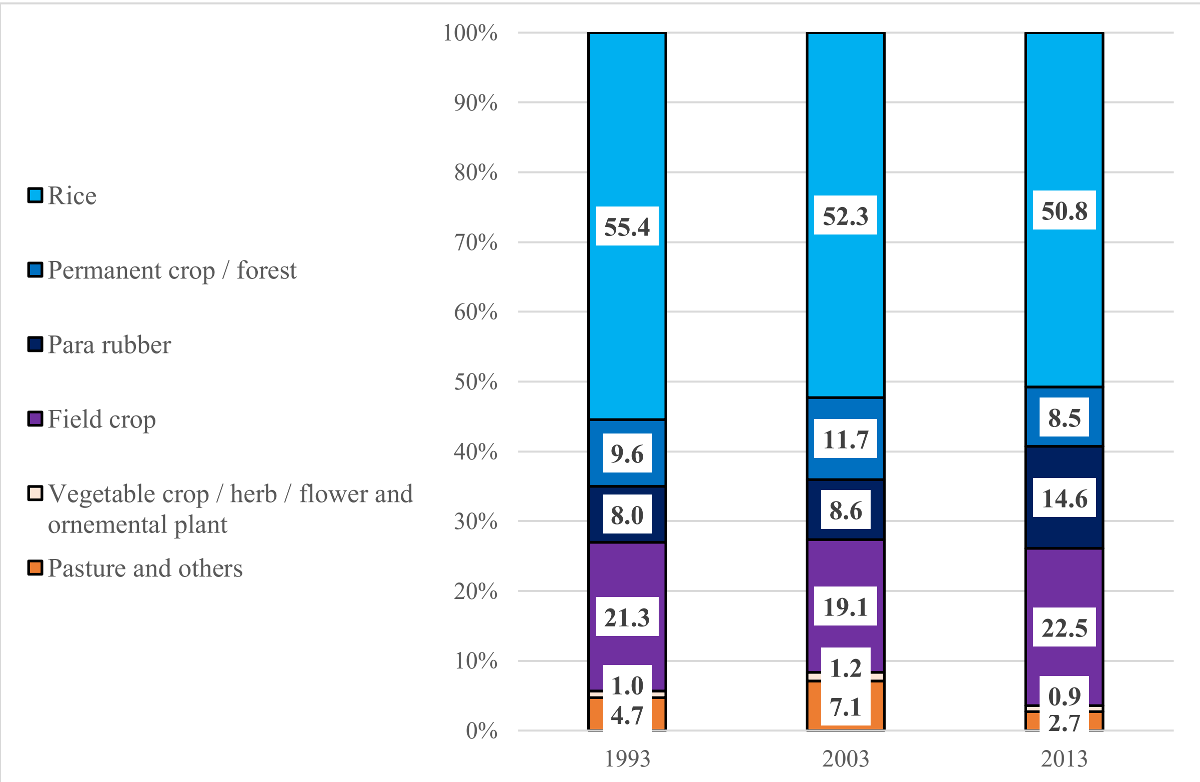

Figure *6*: Thailand's crop distribution based on land area (1993-2013) (source: National Statistical Office, 2014)

) and employs a similar proportion of the agricultural labor force. This crop not only supports domestic consumption but also serves as a major export commodity, reinforcing Thailand's position as one of the world's top rice exporters, accounting for about 15% of total exports (USDA, 2024). More than 60% of Thailand's agricultural land is allocated to rice farming, which is heavily dependent on water. Farmers typically grow rice twice a year during the wet and dry seasons. Production estimates for 2023-24 call for 19.9 million tons of rice, more than 60% of Thailand's agricultural land is allocated for rice farming (Reidy, 2024).

Despite its strengths, Thailand's agriculture sector must navigate critical issues such as environmental degradation, climate risks, and shifting market dynamics. With increasing competition and the growing impacts of climate change, particularly droughts and floods, Thailand faces the dual challenge of ensuring food security and maintaining its competitive edge in global agricultural markets.

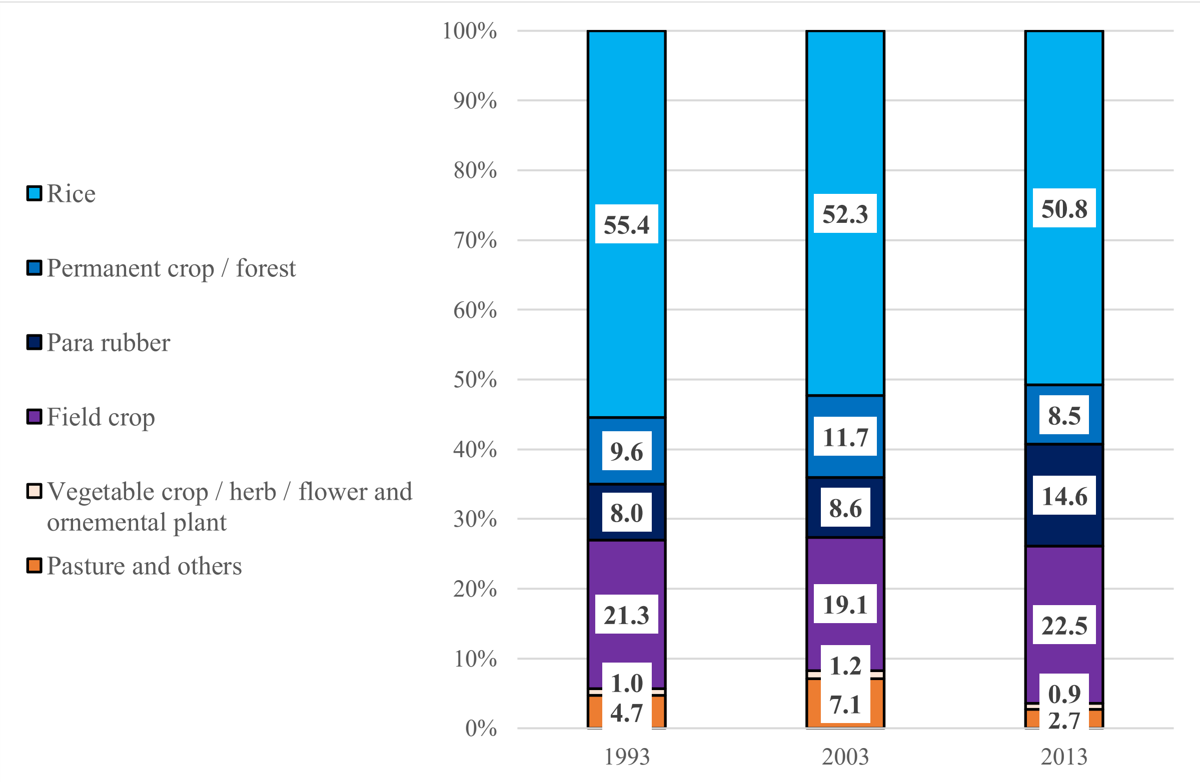

Figure 6: Thailand's crop distribution based on land area (1993-2013) (source: National Statistical Office, 2014)

2.1 - Farming practices and technology

Farming in Thailand has a rich history that dates back over a thousand years, shaped by the country's monsoon climate, river systems, and fertile soils. Historically, agricultural practices were centered on subsistence farming, with rice being the staple crop, given its significance in

Thai culture, economy, and diet. Early farming techniques relied on manual labor, simple tools, and natural irrigation methods, particularly around the Chao Phraya River Basin, where abundant water and fertile soil supported rice production (Punyalue et al., 2020).

Land holdings in Thailand are relatively small, with the average farm size being 4 hectares per household (FAO, 2024), whilst there is little less of a trend of large-scale farming seen in other regions. The fragmented nature of Thailand's agriculture has led to continued reliance on low-scale technology. For instance, farmers in the rice sector typically use low-powered tractors, while sugarcane cultivation demands more high-powered machinery. Other major crops, such as cassava, maize, and rubber, rely on medium-powered tractors for production.

Thailand is increasingly focusing on climate-smart agriculture to combat the effects of climate change. This involves developing climate-resilient plant species, enhancing early warning systems, and improving farmers' adaptive capacity to mitigate production risks. Technologies that support sustainable practices are gaining traction, especially in areas prone to floods and droughts (FAO, 2021).

Historically, rice cultivation in Thailand was supported by traditional methods such as "floating rice," a practice designed for flood-prone areas. This method allowed rice to grow with rising water levels during monsoon seasons. Over time, upland farming and mixed cropping emerged in regions like the north, where hill tribes cultivated a variety of crops including maize, vegetables, and even opium (Kaosa-ard and Rerkasem, 2000).

During the mid-20th century, Thailand began transitioning towards modernized agriculture with the introduction of chemical fertilizers and mechanization as part of the Green Revolution. However, many smallholder farmers have retained traditional practices, particularly in rural areas, while there has been a resurgence in interest toward organic and sustainable farming methods that draw upon local knowledge.

In recent years, precision agriculture has begun to influence Thai farming practices, particularly in rice production. Technologies such as drones for crop monitoring and automated irrigation systems are being integrated to enhance productivity and sustainability. Mobile applications providing real-time weather updates are also gaining popularity among farmers, helping them make informed decisions (FAO, 2021).

Despite such technological advancement, rice production in Thailand remains somewhat inefficient compared to regional competitors. The average yield per hectare was 2.9 tons in 2013, far lower than Vietnam's 5.3 tons per hectare (Pente and Müller, 2024). Thailand has the potential to harvest up to three rice crops annually, with the majority (82%) being cultivated during the wet season. However, due to water shortages, the government is encouraging a shift to less water-intensive crops or reducing the number of rice crops per year (Reuters, 2016). Only 28% of cropland is currently irrigated, with the rest reliant on rainfall (United States Agency for International Development (USAID), 2011).

A promising approach to improving yields and sustainability is inter-cropping, where different crops are grown in proximity to reduce pest pressure and limit the need for insecticides (Nature, 2016). These strategies are vital as Thai farmers face growing challenges from climate change and water scarcity, which threaten agricultural output and long-term sustainability. Section 5 - CLIMATE ADAPTATION STRATEGIES will describe more adaptation approaches.

2.2 - Agricultural regions, distribution of crops and farmer populations

Thailand can be divided into four agricultural regions: the Northern, Northeastern region, Central and Southern regions. Each region is distinguished by its unique climate, soil composition, and elevation, which influence crop production and suitability.

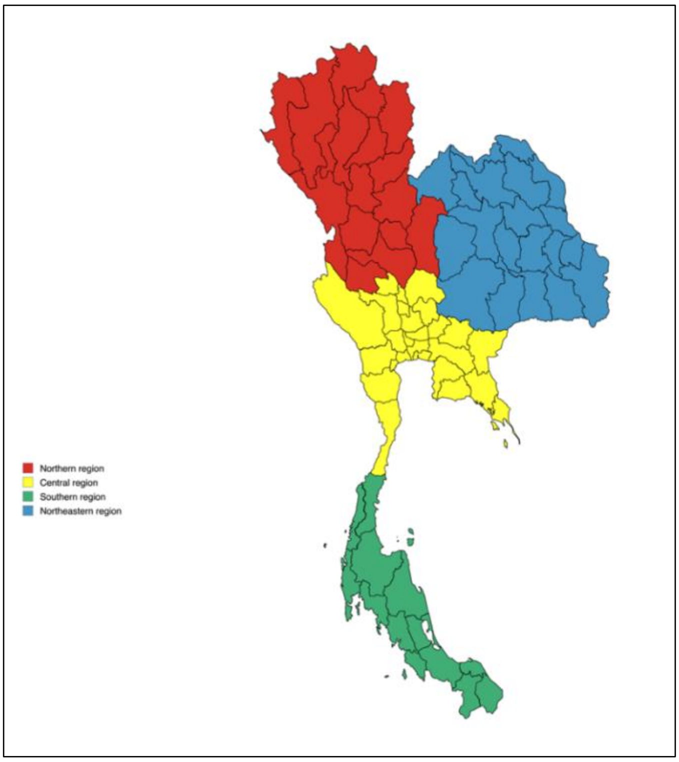

Figure 7: Thailand's 4 regions (source: BCI, 2024)

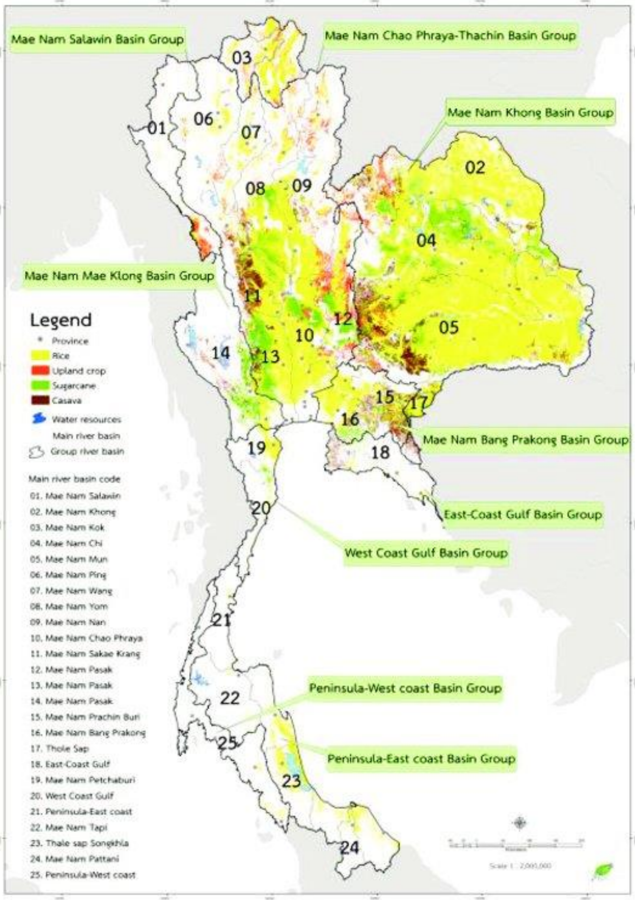

Figure 8: Land use for agricultural areas in Thailand (source: Chaowiwat et al., 2016)

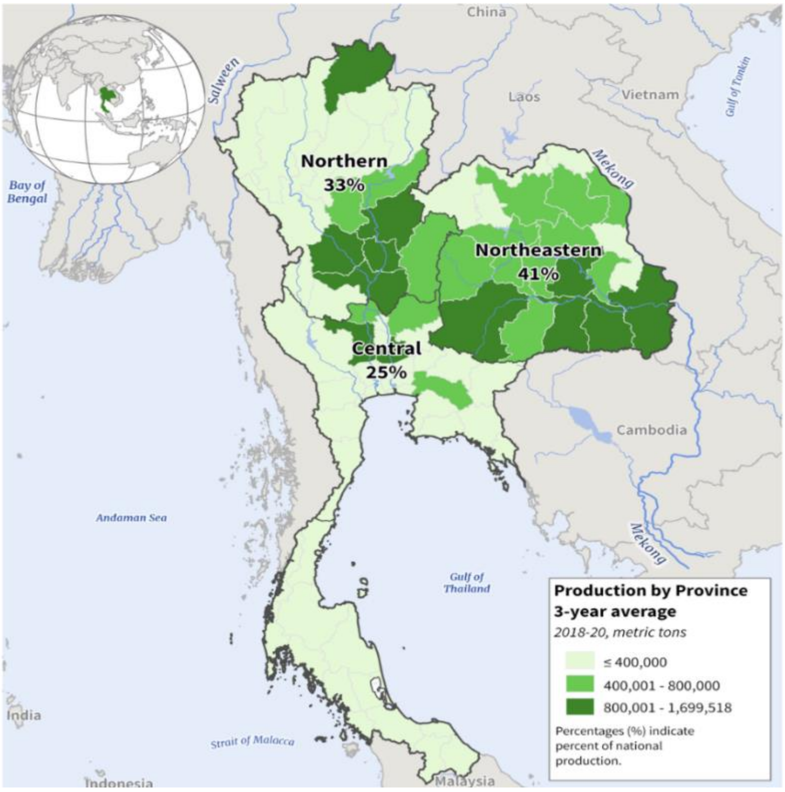

Figure 9: Thailand rice production by region (source: Thailand Statistical Yearbook, 2020)

2.2.1 - Northern region

This region, populated by 1.5 million farmers according to Statista, is characterized by high altitudes (mountainous terrain) and cooler temperatures. The region's higher altitudes and cooler temperatures support diverse crop types not found in other parts of the country including fruits like longan and lychee, as well as vegetables. The region is ideal for producing maize, upland rice, and tea plantations (Punyalue et al., 2020; Office of Agricultural Economics (Office of Agricultural Economics (OAE), 2021).

It is also the primary region for Arabica coffee production due to its higher elevations and cooler temperatures. This region's agriculture benefits from agroforestry and mixed cropping systems, particularly on smallholder farms (Angkasith, 2002).

2.2.2 - Northeastern region

The Northeast region, also known as Isan, is characterized by poorer, sandy soils and a more arid climate. The Isan region focuses on drought-resistant crops. This region cultivates cassava, sugarcane, and rubber, which are well-suited to dry conditions. It is the largest agricultural region in terms of land area, and it has the largest agricultural population, with about 85% of the total population engaged in farming. This translates to around 14.45 million farmers according to the Agroecological and Socioeconomic Environment of Northeast Thailand.

Despite its generally poorer, sandy soils, it is the main producer of rice, particularly glutinous rice, which dominates the landscape. The Khorat Plateau, a significant part of this region, is one of Thailand's main rice-producing areas, supported by extensive rain-fed agriculture.

2.2.3 - Central region

This region is in the Chao Phraya River Basin. The fertile soil, ample water supply from the Chao Phraya River, and favorable climate create ideal conditions for rice cultivation, particularly wet rice farming.

The central plain, with its around 2.5 million farmers according to Statista, is the heartland for irrigated rice farming due to its flat terrain, fertile soils, and access to extensive irrigation systems. This region produces high rice yields and is essential for Thailand's staple food production (OAE, 2021).

The Central region includes the highly fertile Chao Phraya River Basin, which is the country's most productive rice-growing area. It features larger farm holdings (Pente and Müller, 2024) and more advanced irrigation systems, allowing for higher yields and multiple cropping seasons. Sugarcane, pineapple, and vegetables are also important crops in this region, along with increasing livestock farming.

2.2.4 - Southern region

There are approximately 1.2 million farmers in the Southern region. This region, also called the Southern Peninsula, is a tropical climate region with high rainfall. This area is known for rubber and oil palm plantations, both of which thrive in the hot, humid climate. The combination of high humidity and consistent rain supports these cash crops, which are integral to the region's economy (Nagara, 1991). In addition, the southern region is a major producer of tropical fruits like durian and rambutan.

Over half of the cultivated land here is dedicated to rubber, making Thailand the world's largest exporter of this product. Robusta coffee is also grown extensively in the South, along with coconuts and fruit crops, which thrive in humid conditions. Coastal areas are suited to fishing and aquaculture, particularly shrimp farming.

Each of these regions has developed specific agricultural practices based on their distinct environmental conditions. These regional specializations help diversify Thailand's agricultural output, providing resilience against climate and economic fluctuations while catering to both domestic needs and export markets. The Chao Phraya Basin and the Khorat Plateau are the primary commercial rice-producing areas, while coconuts are widely cultivated along the coasts and inland plantations. Coffee production is split between Arabica in the cooler north and Robusta in the wetter southern region (Azavedo, 2021). Pineapple cultivation, on the other hand, spans central to southern Thailand. <u>The characteristics of each of these regions will inform our selection of interviewees for the farmer survey and feasibility studies afterwards.</u> As described in Section 2.4 - Policy landscape, Thailand's agro-ecological zoning (AEZ) supports this diversity (Fischer and Velthuizen, 2016; Nagara, 1991).

	Characteristics
Northern region	• mountainous terrain • cool temperatures • forest cover • cultivation of maize and coffee
Northeastern region	• poor soils • prolonged dry season • rice is the dominant crop
Central region	• flat terrain • fertile soils • consistent rainfall • proximity to Bangkok
Southern region	• hilly and mountainous terrain • year-round rainfall • world's largest producer of natural rubber • fishing and aquaculture

Table 1: Thailand's regional characteristics (source: BCI, 2024)

2.3 - Economic contribution of agriculture

2.3.1 - Contribution to the gross domestic product

While Thailand's economy has diversified significantly since the late 1970s, agriculture continues to contribute to approximately 8-10% of the country's GDP (World Bank, 2020), making it one of the top three sectors in the country. In the 1960s, agriculture, forestry, and fishing contributed around 36% of Thailand's GDP. Agriculture once accounted for 100% of Thailand’s export revenue. This contribution declined significantly, reaching a low of 8.03% in 1993. The sector's decline in proportion to GDP reflects the growth of industries like manufacturing, but it remains a major pillar of the Thai economy (Singhapreecha, 2014). In recent years, agriculture’s contribution grew again. In 2022, the agriculture, hunting, and forestry sector contributed approximately THB 1.53 trillion to Thailand's gross domestic product (GDP) (Walderich, 2024). This is approximately 8.8% of Thailand’s GDP (World Bank, 2023).

Agricultural growth has played a crucial role in improving rural livelihoods and reducing poverty in Thailand. Research indicates that agricultural productivity is a key driver of poverty reduction in rural areas, directly contributing to income enhancement. Over the past few decades, Thailand has made remarkable progress in reducing poverty, with the national poverty rate falling from 58% in 1990 to 6.8% in 2020. However, poverty remains higher in rural areas, where 79% of the poor reside (Warr and Suphannachart, 2021) (World Bank, 2022). However, the sector is vulnerable to climate change, which threatens its productivity and hence, the country’s economic stability as described in section 3 - KEY CLIMATE RISKS TO AGRICULTURE BY REGION.

2.3.2 - Contribution to employment

Agriculture remains a significant source of employment, employing about 30% of Thailand's total workforce (International Labour Organization (ILO), 2022). In 2022, approximately 12.7 million workers were engaged in agricultural activities, many of whom are smallholders (FAO, 2019). Despite a gradual decline in the number of workers over recent decades, agriculture continues to provide a livelihood for a large portion of the rural population.

Rice farming is especially vital, with about 16 million Thai people employed in rice cultivation alone. In 2017, rice represented around 12.9% of all farm production by value, illustrating its critical role in sustaining both the economy and the livelihoods of millions (Economist, 2013) (Blake & Suwannakij, 2016).

2.3.3 - Contribution to exports

Thailand is a major player in global agricultural exports, particularly for rice, rubber, cassava, and seafood. Agriculture contributes roughly one-eighth of export earnings and about one-tenth of the GDP (Brittanica, 2024). By 2021, Thailand was the world's leading exporter of natural rubber, accounting for 34.1% of global exports, with a value increase of 45.7% to USD 16.1 billion (United Nations, 2022).

The Thai government has been actively promoting rice production and is aiming to expand rice cultivation by adding 500,000 hectares to the current 9.2 million hectares of rice-growing areas. Rice accounts for 50% of Thailand's cultivated land, making the country the second-largest exporter of rice globally.

2.3.4 - Development of rural areas

Agriculture is a major force behind rural development in Thailand. Improved agricultural productivity directly enhances food security and the livelihoods of rural farmers, contributing to the reduction of poverty in these regions. Technological advancements and government-led initiatives that focus on sustainable farming practices have been critical in boosting the sector's overall output and ensuring the welfare of rural communities.

For instance, the poverty rate in rural areas has significantly declined from 32.4% in 2003 to 13.2% in 2011 (Siriwardena et al., 2020) (Walderich, 2024) (World Bank, 2023). Section 2.4.3 - Climate change adaptation elaborates on climate adaptation strategies, to help farmers adapt to changing environmental conditions further contributing to development of rural areas.

2.4 - Policy landscape

Thailand's agricultural policy landscape is shaped by national initiatives, international agreements, and efforts to address climate change, sustainability, and productivity challenges. This section highlights key policies, programs, and strategies that impact Thai agriculture, focusing on climate change adaptation, innovation, and sustainable development.

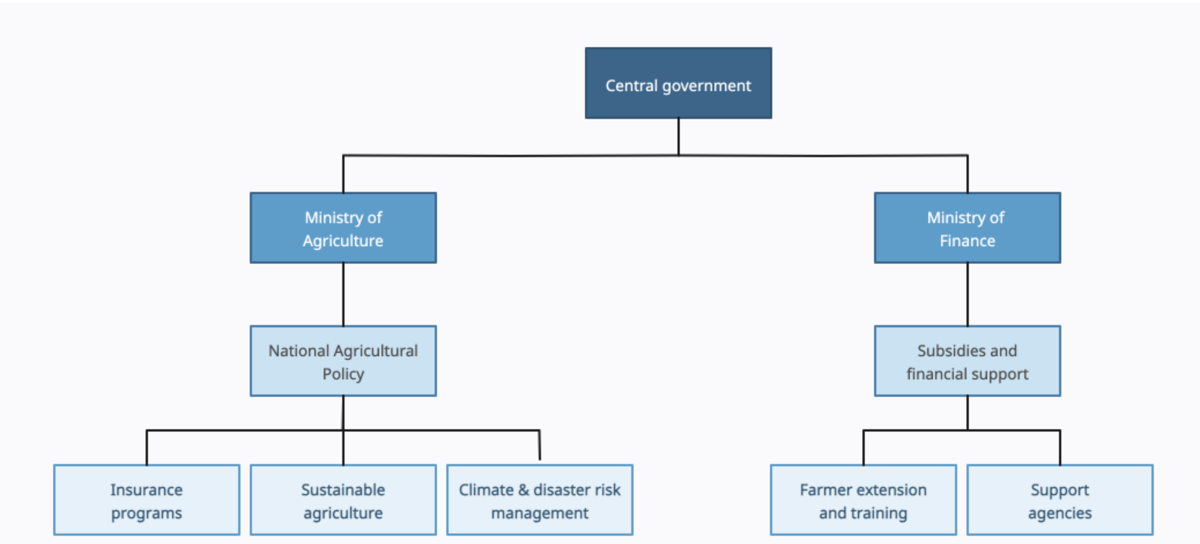

Figure 10: Thailand's agricultural policy landscape (source: BCI, 2024)

2.4.1 - National agricultural policy

The Thai government has implemented several policies to support the agricultural sector. One of the most significant is the Agricultural Development Plan (ADP), which aims to enhance productivity, diversify crops, and improve food security. This plan emphasizes sustainable resource management and increasing farmers' resilience to external shocks like climate change (Ministry of Agriculture and Cooperatives, 2021).

Thailand's agro-ecological zoning (AEZ) supports helps to match specific crops to their most suitable regions based on climate, soil type, and water availability. This zoning model improves agricultural planning, boosts productivity, and enhances sustainability, particularly as climate change increasingly affects farming across the country (Fischer and Velthuizen, 2016; Nagara, 1991).

Figure 10 is a hierarchical diagram illustrating Thailand's agricultural policy landscape. At the top, we have the Central government, which branches into two main ministries: the Ministry of Agriculture and the Ministry of Finance. Under the Ministry of Agriculture, there is a sub-branch labeled National Agricultural Policy. This is further divided into three categories: Insurance programs, Sustainable agriculture, and Climate & disaster risk management.

Under the Ministry of Finance, there is a sub-branch labeled Subsidies and Financial support. This sub-branch is further divided into two categories: Farmer extension and training, and Support agencies. This diagram represents how agricultural policies in Thailand are structured and managed, highlighting the roles of different ministries and their specific focus areas.

Table 2 outlines the climate change adaptation policies for agriculture and water implemented by various organizations in Thailand. It lists key ministries and committees, their policies, and implementation strategies across different years. The Ministry of Interior, Department of Disaster Prevention and Mitigation focuses on 2P2R (prevention, preparation, response, and recovery) measures with collaborations on artificial rainwater distribution, well digging, and canal drainage since 2013.

The Ministry of Agriculture and Cooperatives (MOAC) promotes integrated farming and water resource development to manage crops and livestock in response to climate change, with ongoing efforts. The National Water Resources Management Committee aims to enhance water security and disaster impact reduction through early warning systems and integrated risk mapping, set to be implemented by 2024.

Additionally, the Ministry of Natural Resources and Environment (MNRE) supports water management through ecosystem-based adaptation and nature-based solutions, including water forecasting systems and community-engaged watershed conservation, planned for 2024.

Lastly, the Local Administrative Organizations (LAOs) emphasize participatory policy development for land use and water management, involving local communities in decision-making processes. This comprehensive table captures the various dimensions of Thailand's policy responses to climate change within the agricultural and water sectors.

2.4.2 - Research and innovation

The government prioritizes research and innovation to advance agricultural techniques and sustainability. The National Research Strategy encourages collaboration between universities, research institutions, and industry to improve farming methods, including the adoption of smart farming technologies. This fosters innovation in sustainable agriculture (Wongpiyabovorn, 2020).

The Office of National Higher Education Science Research and Innovation Policy Council (NXPO) is an autonomous public agency responsible for deploying and monitoring national policy addressing research and innovation among others. To effectively deploying policies, NXPO oversees designing strategies and measures, proposing law and regulation amendments, and establishing, maintaining and allowing public access of integrated databases of higher education, science, research and innovation (NXPO, 2024).

2.4.3 - Climate change adaptation

Thailand's National Strategy on Climate Change (2018-2037) outlines the government's response to climate challenges. This strategy integrates climate-resilient agricultural practices and emphasizes water management, drought resistance, and crop diversification to help farmers adapt to changing environmental conditions (National Climate Change Committee, 2018).

The Climate Change Master Plan (CCMP), running from 2015 to 2050, is a core document guiding Thailand's climate policy. It focuses on climate adaptation, low-carbon development, and creating a supportive environment for effective climate management across seven key sectors, including agriculture and food security (FAO, 2022). In terms of technology, the report recommends developing an integrated, accurate and timely early warning system for agricultural purposes which incorporates both the latest technologies. It encourages data on predicted future daily climate from the Conformal Cubic Atmospheric Model (CCAM) climate simulation, consisting of the highest and lowest temperatures, amounts of rainfall, and solar radiation, were also used, along with that on agricultural management patterns and soil property.

In addition to broader national plans, Thailand is developing sector-specific policies like the Action Plan for Climate Change in Agriculture (APCCA) 2023-2027, which focuses on improving adaptation strategies within the agricultural and water sectors (Waqas et al., 2024). These initiatives are critical for mitigating the effects of climate change, which threatens to exacerbate competition, raise production costs, and degrade ecological conditions.

2.4.4 - Sustainable Development Goals

Thailand's agricultural policies align with the United Nations Sustainable Development Goals (SDGs), particularly, SDG #2 (Zero Hunger) and SDG #13 (Climate Action). The government has committed to improving agricultural output while promoting sustainability, supporting smallholder farmers, and enhancing food security (United Nations Thailand, 2020).

2.4.5 - Subsidies and support programs

The Thai government provides extensive support through subsidy programs aimed at stabilizing farmers' incomes and encouraging sustainable practices. These include price guarantees for rice and rubber, alongside incentives for organic farming and environmentally friendly practices (World Bank, 2019). Efforts to modernize farming through infrastructure development—such as investments in irrigation and mechanization—have been crucial to improving productivity. For instance, the Greater Chao Phraya Project has received significant funding from the World Bank to expand irrigation and promote mechanization (World Bank, 2020).

2.4.6 - International collaborations and programs

Thailand participates in international initiatives to boost its climate resilience and agricultural sustainability. For example, the Scaling up Climate Ambition on Land Use and Agriculture (SCALA) program, supported by the FAO and UNDP, helps Thailand meet its Nationally

Determined Contributions (NDCs) under the Paris Agreement by promoting climate-smart agricultural practices (UNDP, 2022).

The 20-year ADP (2017-2036) also emphasizes sustainable agriculture, smart farming, and resilience. It seeks to enhance the competitiveness of Thai agriculture through technological innovation and climate adaptation (Climate Action Tracker, 2022).

2.4.7 - The bio-circular-green model

The Bio-Circular-Green (BCG) Economic Model introduced in 2021 represents a strategic shift towards a more sustainable economy. It aims to integrate green finance into agricultural policies, enabling better access to funding for environmentally sustainable projects. This model supports Thailand's broader goal of reducing its carbon footprint while enhancing agricultural resilience to climate change (Economist Intelligence Unit, 2023).

	Policies	Implementations	Year
Ministry of Interior, Department of Disaster Prevention and Mitigation	Prevention, Preparation, Response, and Recovery (2P2R) measures	Operated under a single command system in collaboration with the Ministry of Agriculture for artificial rainwater distribution, well digging and canal drainage	2013
Ministry of Agriculture and Cooperatives (MOAC)	Crop and livestock management in response to climate change	Integrated farming promotion, and water resource development in irrigated and non-irrigated zones	Ongoing
National Water Resources Management Committee	Enhancing water security and reducing disaster impacts	Development of water security index, early warning systems, and integrated risk mapping	2024
Ministry of Natural Resources and Environment (MNRE)	Supporting mechanisms for water resources management, including ecosystem-based adaptation and nature-based solutions	Water forecasting systems, river basin management, community engagement in watershed conservation	2024
Local Administrative Organizations (LAOs)	Participatory policy development for land use and water management	Involvement of local communities in policy-making and conservation efforts	Ongoing

Table 2: Summary of climate change adaptation policies focused on agriculture and water (source: Waqas et al., 2024)

3 - KEY CLIMATE RISKS TO AGRICULTURE BY REGION

Risk refers to the possibility of adverse consequences involving something valuable, with the uncertain occurrence and impact of outcomes. In the context of climate, risk typically describes the potential for harmful effects resulting from climate-related hazards or from actions taken to adapt to or mitigate these hazards (IPCC, 2018). These effects can impact lives, livelihoods, health, ecosystems, species, economic, social, and cultural assets, services (including those provided by ecosystems), and infrastructure (ibid). Risk arises from the interplay between a system's vulnerability (of the affected system), its exposure over time (to the hazard), the climate hazard itself, and the likelihood of its occurrence (ibid). A further determinant of the magnitude of risk is the capacity for response related to human intervention directly targeting the risk being addressed (Simpson et al, 2021).

The agriculture sector in Thailand is susceptible to three primary physical risks; drought, flooding, and high temperatures with typhoons contributing to the extreme rainfall threat. Owing to the dominance of the monsoon in Thailand's climate, these risks peak at different periods of the year and vary by region. Drought and flooding risks are closely linked to the monsoon season which begins in May and lasts into October (Figure 12) with the typhoon season from September to November (Figure 13) bringing peak flooding risks. The primary food staple crop, rice, is especially predisposed to precipitation-related weather risk. The main crop being planted in May and June and harvested in November and December (Figure 11) is exposed to the risk of delayed onset monsoon drought early in its growing season and flooding risks late during the peak of the monsoon (Figure 12) and typhoon (Figure 13) seasons. As discussed in later sections, the climate pattern has been trending towards a later onset of the monsoon which would pose a threat to crops such as rice, corn, and soybeans.

While the primary threats to agriculture in Thailand are precipitation-related risks, a growing peril, especially for livestock, is the risk of high daily temperatures. Given its tropical climate, Thailand experiences warm temperatures year-round with daily high temperatures peaking near 34 °C in March and April and being at their lowest in December and January when they average 29 °C (Figure 14). As the climate warms, these temperatures will increase stress on livestock.

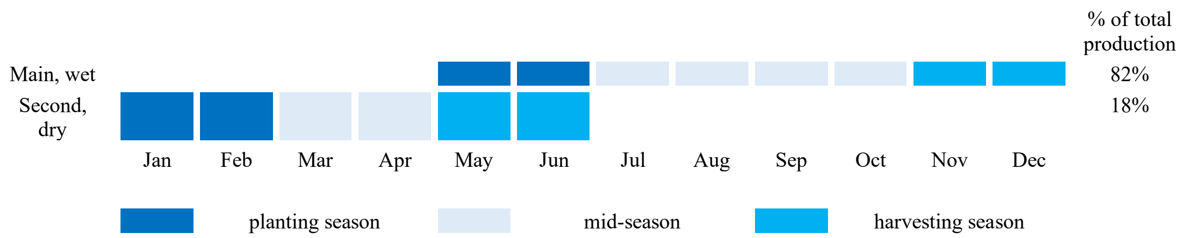

Figure 11: Rice seasons in Thailand (source: Office for Agricultural Statistics, 2024)

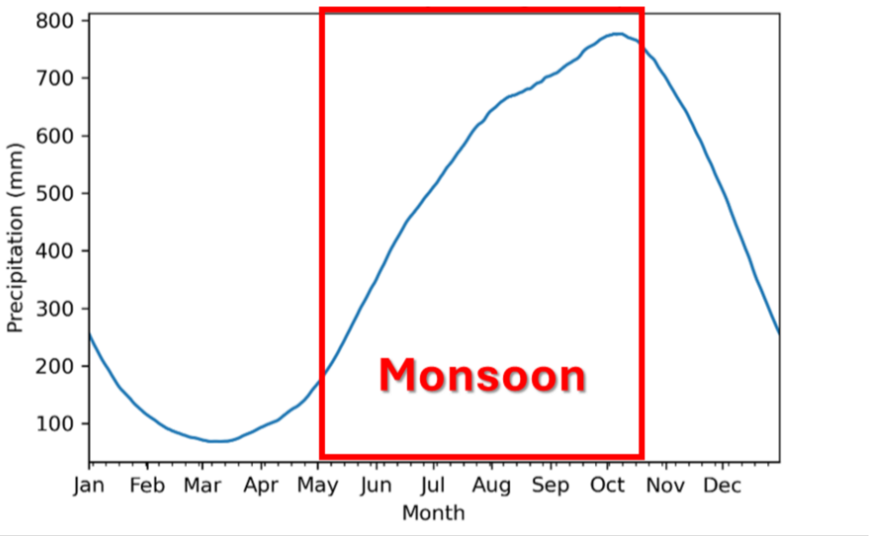

Figure 12: 1970-2023 rolling 90-day average precipitation for Thailand (source: Arbol, 2024)

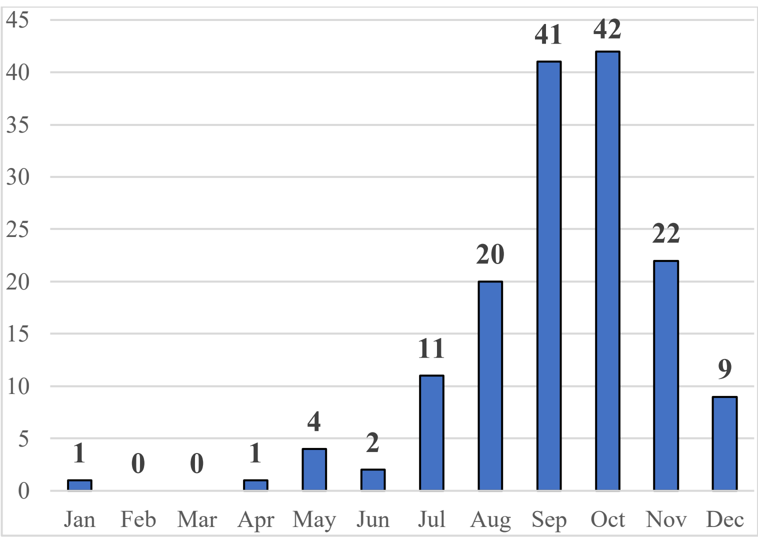

Figure 13: The total number of storms by month Thailand in 1950-2023 (source: Arbol, 2024)

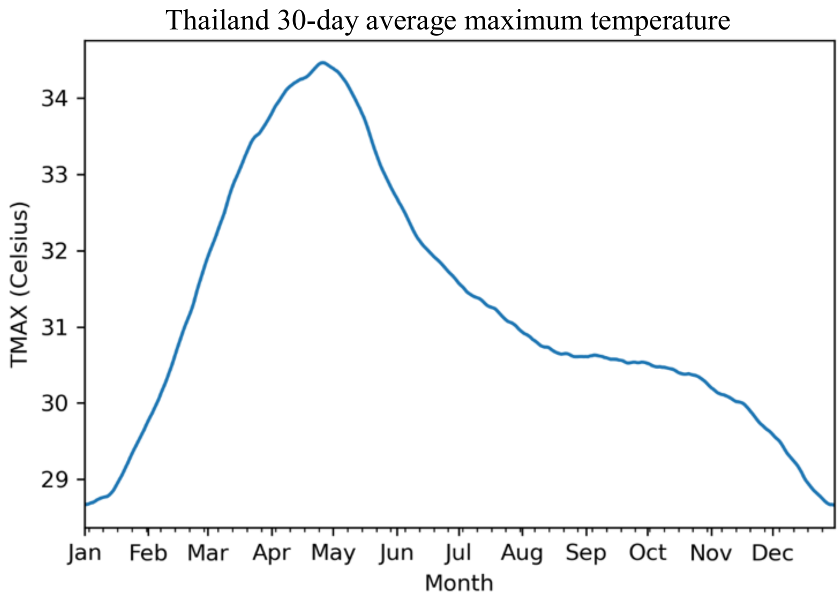

Figure 14: Rolling 30-day average daily maximum temperature in Thailand in 1970-2023 (source: Arbol, 2024)

3.1 - Overview of climate change in Thailand

Thailand's climate is anticipated to undergo significant changes in the coming decades. By the 2090s, average temperatures are expected to rise by 0.95 °C to 3.23 °C compared to the 1986-2005 baseline, with the extent of warming depending on future emissions pathways (UNEP, nd). Figure 15 (World Bank Group, 2021) highlights the projected mean surface air temperature anomaly in Thailand from 1951 to 2100 in each month against the 1995-2014 reference period under the lowest greenhouse gas emissions shared socioeconomic pathway (SSP) SSP1-2.6 whilst Figure 16 (World Bank Group, 2021) presents the projected average mean surface air temperature anomaly under the highest SSP5-8.5. In both SSPs, the greatest anomalies occur in the early and later months of the year. However, the extent of the anomaly is greater under the SSP 5-8.5 scenario with the greatest temperature anomaly of 4.81 °C in March 2091-2100 under this scenario compared with the greatest temperature anomaly under the SSP1-2.6 scenario happening in Jan 2071-2080 with a temperature anomaly of 1.78 °C.

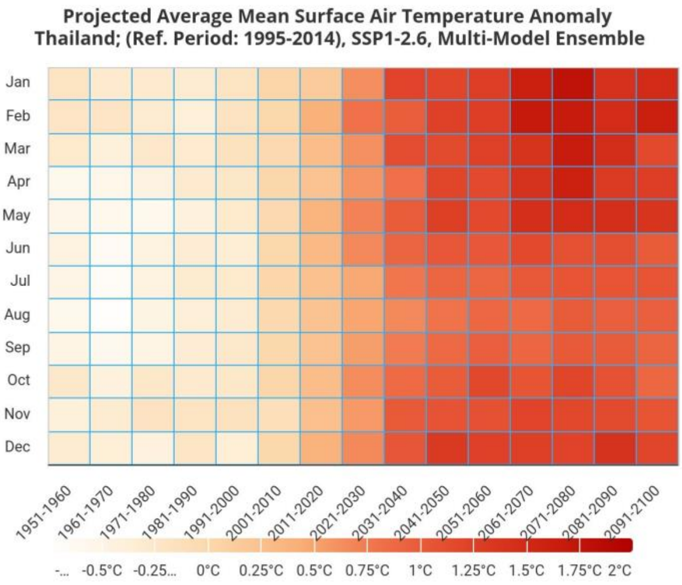

Figure 15: Projected average mean surface air temperature anomaly Thailand; (ref. period: 1995-2014), SSP1-2.6, multi-model ensemble (World Bank Group, 2021)

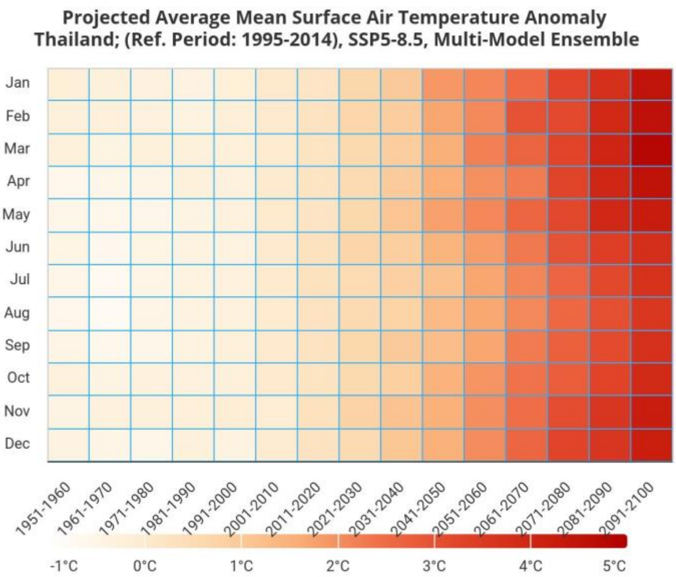

Figure 16: Projected average mean surface air temperature anomaly Thailand; (ref. period: 1995-2014), SSP5-8.5, multi-model ensemble (World Bank Group, 2021)

Figure 15 and Figure 16 (World Bank Group, 2021) highlight how these temperature anomalies correspond to the projected average mean surface air temperature each year under the various SSPs. In the 2014 reference year, the mean surface air temperature is 26.87 °C. In the year 2100, under SSP1-2.6, the median projected average mean surface air temperature is 27.78 °C, under the SSP2-4.5 scenario, the projected median temperature is 28.80 °C, for SSP 3-7.0, the projected median temperature is 30.16 °C and, for SSP 5-8.5, the projected median temp is 31.24 °C.

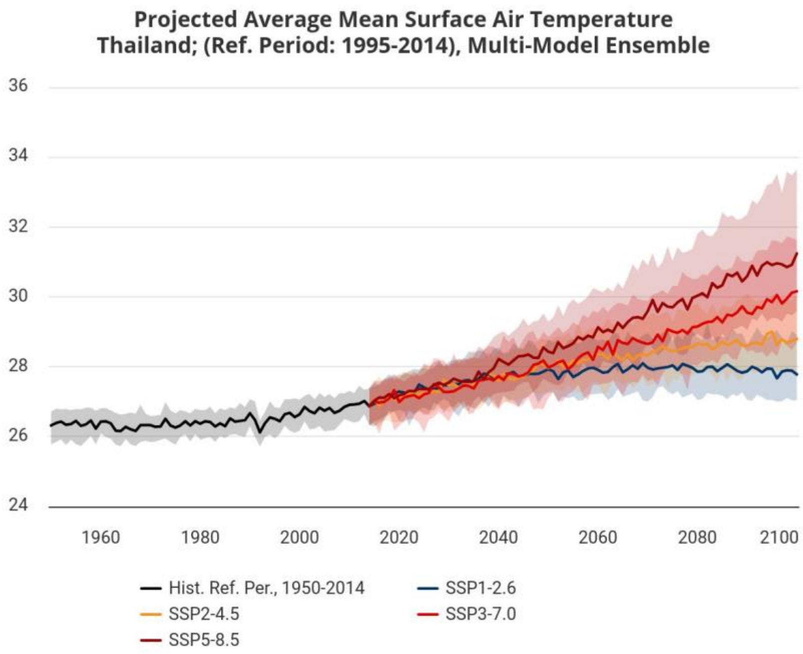

Figure 17: Projected average mean surface air temperature Thailand; (ref. period: 1995-2014), Multi-Model Ensemble (World Bank Group, 2021)

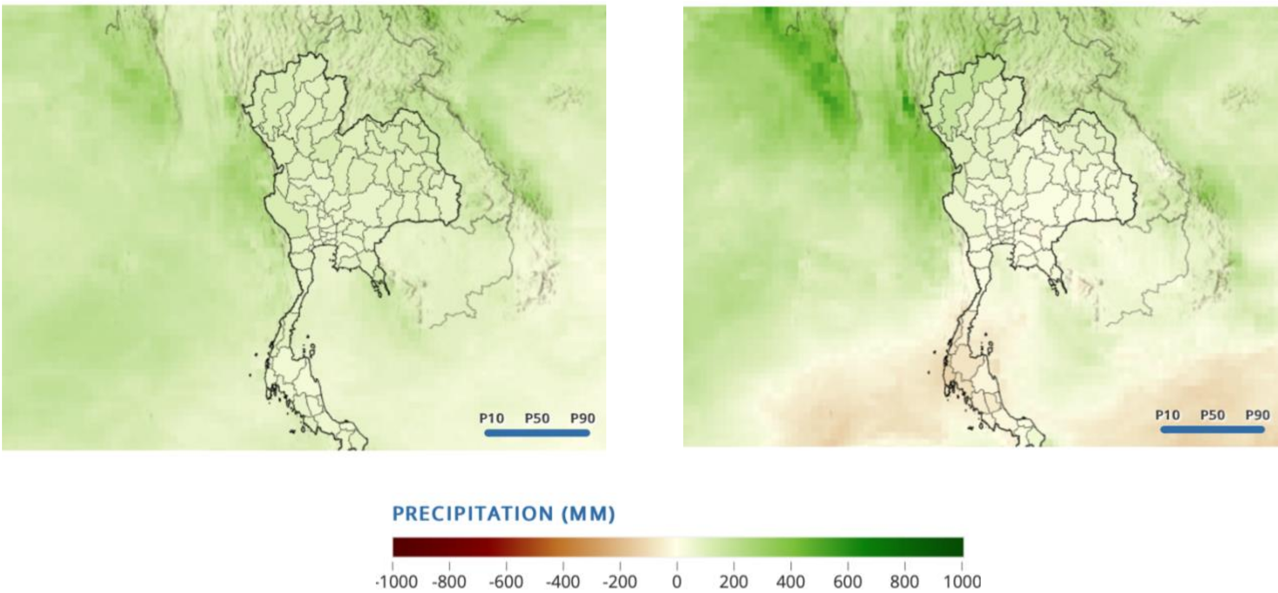

Figure 18: Projected average mean surface air temperature Thailand; (ref. period: 1995-2014), multi-model ensemble (World Bank Group, 2021)

While future precipitation patterns in Thailand remain uncertain, Figure 18 (World Bank Group, 2021) highlights the projected precipitation anomaly in the time period 2080-2099 under the SSP 1-2.6 and 5-8.5 scenarios. Furthermore, global trends suggest some clear shifts. Evidence from various parts of Asia indicates that the intensity of short-duration extreme rainfall events is increasing with rising temperatures (World Bank and Asian Development Bank (ADB), 2021). Additionally, the frequency of flooding, droughts, and other natural disasters is projected to grow (UNDRR, 2021).

Thailand is among the developing countries in the region that are particularly vulnerable to the effects of climate change. According to the Global Climate Risk Index (CRI) Report 2021, Thailand ranked as the 9th most affected country between 1999 and 2019, with losses equating to 0.82% of its GDP during this period (Eckstein et al., 2021). Between 2000 and 2019, the country endured 146 extreme climate-related events, including the large-scale floods of 2011, which impacted nearly 14 million people and caused an estimated USD 45.7 billion in damages (World Bank and ADB, 2021).

3.2 - Induced weather events

As described in Section 1.3 - Climate change trends and impact on agriculture, there are a series of risks associated with the agricultural sector that can arise owing to extreme weather events induced by climate change. Figure 19 below highlights the various disaster types (FAO, 2021), the total crop and livestock production loss in least developed countries (LDCs) and low- and middle-income countries (LMICs) between 2008-2018.

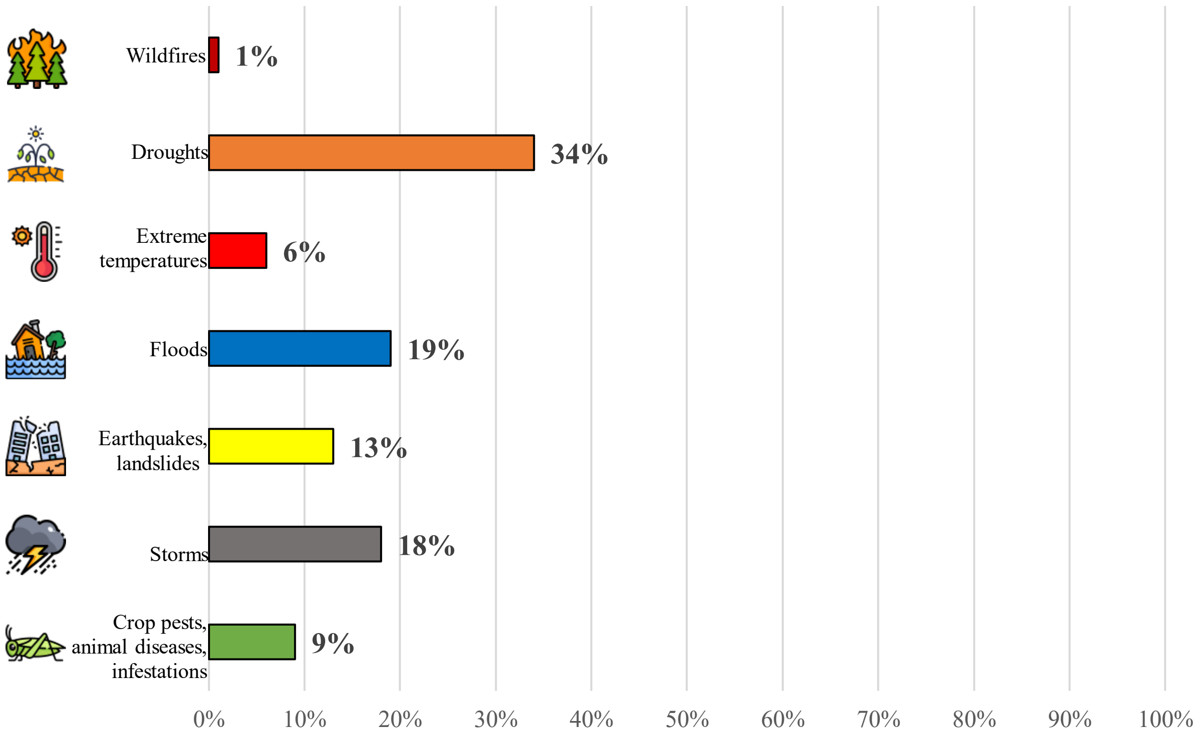

Figure 19: Total crop and livestock production loss per disaster type, LDCs and LMICs, 2008-2018 (source: FAO, 2021)

FAO projections indicate that Thailand's agriculture sector is highly vulnerable to the effects of climate change. Farmers are already experiencing the consequences of annual floods and droughts, which result in crop losses, reduced productivity, debt accumulation, and declining household incomes (World Bank and ADB, 2021).

Shifts in regional weather patterns could further destabilize the sector by disrupting critical stages of farming, from seeding to harvesting, leading to decreased yields (UNDP, nd). Additionally, rising temperatures and humidity are expected to exacerbate pest infestations, such as mealy bugs damaging cassava; or brown planthoppers (Nilaparvata lugens) attacking rice crops during the rainy season (UNDRR, 2020). Without sufficient adaptation efforts or new technologies, climate change could reduce rice production by 10-13%, sugarcane by 25-35%, and cassava by 15-21% by 2046-2055 (World Bank, 2022; Pititpukdee, 2020a; Pititpukdee, 2020b). Given Thailand's role as a major exporter of rice and cassava and the significant portion of the population employed in agriculture, these impacts are anticipated to have profound economic repercussions. Under a high-emissions scenario, the economic losses from reduced farmland value and output could surpass USD 94 billion by 2050, driven by changes in precipitation and temperature (UNDRR, 2020). While the impacts vary widely across provinces, with projected losses ranging from USD 0.27 billion to 19.43 billion, the overall consequences are severe for the Thai economy (ibid).

Changes in weather patterns, such as rising temperatures and unpredictable rainfall, pose increasing challenges for farmers' livelihoods. For instance, paddy rice is vulnerable to flooding during the rainy season, while upland rice can suffer from heat stress during harvest (UNDP, 2024). In aquaculture, increased temperatures can lead to the death of fish, crabs, and other seafood (ibid). Coastal erosion poses a significant challenge, particularly along the Gulf of Thailand coast, where it is more severe than on the Andaman Sea coast. This issue impacts local fishing communities, major seaports, and industrial estates along the shoreline. It heightens vulnerability to climate change effects, including extreme weather events like sea level rise, flooding, rising temperatures, and increased precipitation (World Bank and ADB, 2021). Similarly, livestock are affected by climate change, as heat impacts their health, growth, and reproduction. Pigs breed less in warmer conditions, chickens become more susceptible to diseases, and calves may even succumb to extreme heat (UNDP, 2024).

To assess more specifically current climate change risks in Thailand, for this analysis report, Arbol evaluated ERA5 temperature and precipitation data from 1970-2023 and International Best Track Archive for Climate Stewardship (IBTrACS) from 1950-2023 for typhoons at the provincial, regional, and national levels in Thailand. Over the past fifty years, Arbol's analysis shows that nationally yearly precipitation has decreased from 1,679.6 mm/year to 1,636.1 mm/year (Figure 20 and Table 3) while average daily temperatures have increased from 25.6 °C to 26.8 °C (Figure 21 and Table 4). While both daily average and maximum temperatures have increased for every month between 1970 and 2023 (Figure 22 and Table 5), precipitation has exhibited a non-uniformity that is especially concerning for the agricultural industry. Table 3 shows a substantial reduction in monthly rainfall during May and June with an increase for July. This is highly indicative of the monsoon season starting later which is especially detrimental to the main rice season. Furthermore, yearly rainfall over the past fifteen years has become notably volatile with years trending towards very dry or very wet. The increase in daily maximum temperatures (Figure 22 and Table 5) has also resulted in increased heat stress for both rice and palm oil in addition to livestock. This is discussed in more depth in the regional analysis section.

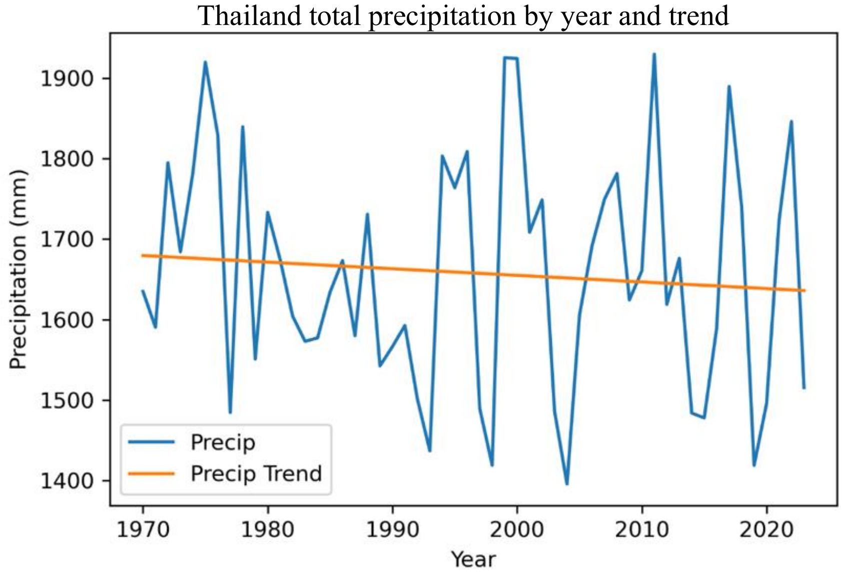

Figure 20: Thailand's yearly precipitation with 1970-2023 trend (Arbol, 2024)

	1970 precipitations (mm)	1970 to 2023 change (mm)	2023 precipitations (mm)
January	13.8	+13.8	27.6
February	19.9	+2.3	22.2
March	47.2	+3.1	50.3
April	91.8	+2.0	93.8
May	215.0	-28.6	186.4
June	238.8	-54.7	184.1
July	221.8	+27	248.8
August	280.0	-21.2	258.8
September	278.6	+1.1	279.7
October	174.6	+4.0	178.6
November	71.0	-1.1	70.0
December	27.2	+8.7	35.9
total =	1,679.6	-43.5	1,636.1

Table 3: Thailand's precipitation trend change in 1970-2023 by month (source: Arbol, 2024)

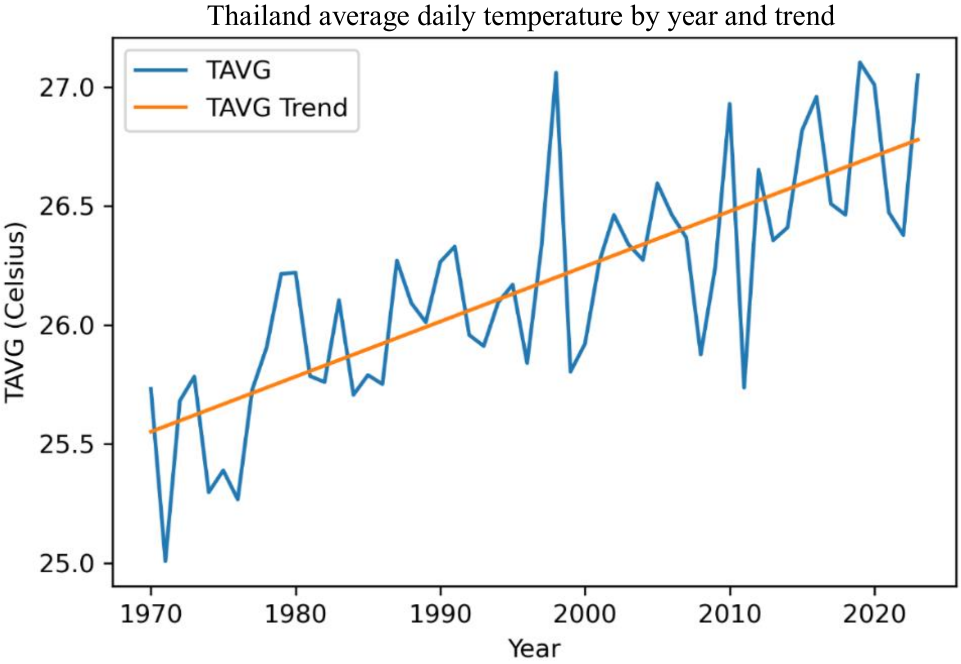

Figure 21: Thailand's daily average temperature with 1970-2023 trend (Arbol, 2024)

	1970 daily average temperature (°C)	1970 to 2023 change (°C)	2023 daily average temperature (°C)
January	22.5	+1.4	24.0
February	24.8	+0.8	25.6
March	27.0	+0.8	27.8
April	28.3	+0.7	29.0
May	27.5	+1.1	28.6
June	26.9	+1.3	28.1
July	26.5	+1.0	27.6
August	26.2	+1.1	27.3
September	26.0	+1.0	27.0
October	25.4	+1.2	26.6
November	23.6	+2.3	25.8
December	22.0	+1.9	23.9
average =	25.6	+1.2	26.8

Table 4: Thailand's average temperature trend change in 1970-2023 by month (Arbol, 2024)

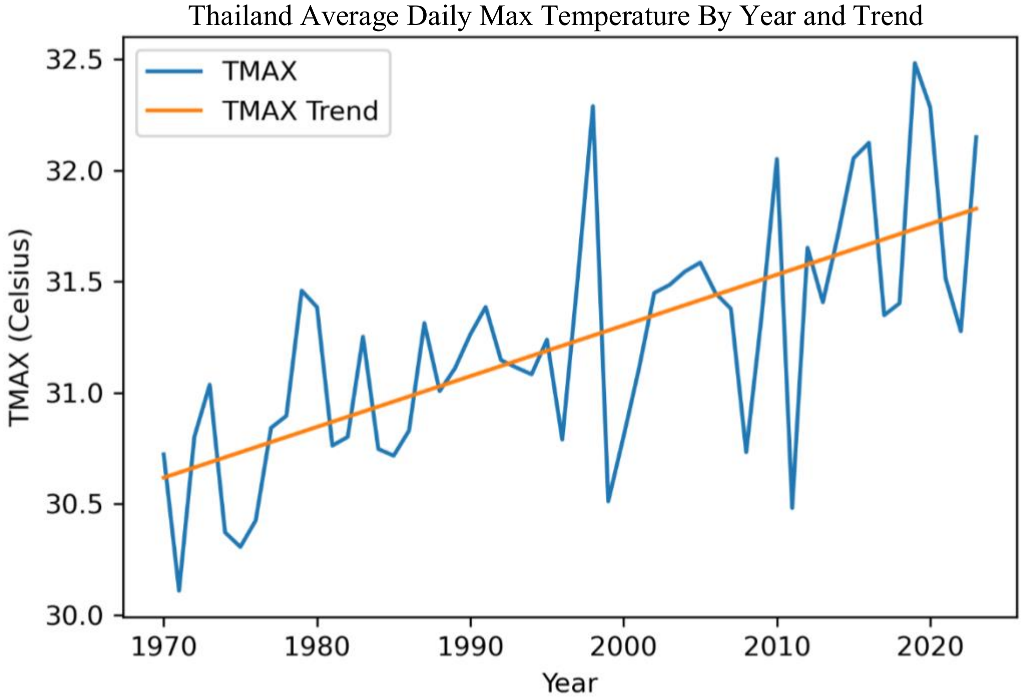

Figure 22: Thailand's daily maximum temperature with 1970-2023 trend (Arbol, 2024)

	1970 daily maximum temperature (°C)	1970 to 2023 change (°C)	2023 daily maximum temperature (°C)
January	29.2	+1.0	30.2
February	31.6	+0.5	32.1
March	33.5	+0.5	33.9
April	34.1	+0.6	34.7
May	32.1	+1.3	33.5
June	30.9	+1.5	32.4
July	30.5	+1.0	31.5
August	30.0	+1.3	31.2
September	30.0	+1.1	31.1
October	29.6	+1.3	30.9
November	28.3	+2.6	30.9
December	27.8	+1.8	29.6
average =	30.6	+1.2	31.8

Table 5: Thailand's average daily maximum temperature trend change in 1970-2023 by month (Arbol, 2024)

3.3 - Distribution by region

Over the past fifty years, Thailand has experienced significant climate changes impacting its agriculture and food security. Nationally, annual precipitation has decreased, while average daily temperatures have risen. These trends are accompanied by increased rainfall variability and a delayed monsoon onset, particularly affecting the main planting and harvesting periods. These climate trends underscore growing challenges to Thailand's agricultural systems, requiring urgent adaptive measures to ensure its food security.

Droughts, while less historically documented, are becoming more frequent and intensified, particularly in rain-fed agricultural areas, which rely heavily on consistent rainfall. As 80% of Thailand's agriculture depends on rain, water scarcity poses a significant threat to crop yields, food security, and the livelihoods of rural farmers (Waqas et al., 2024).

3.3.1 - Northern region

Containing 30% of rice production, 70% of corn production, and 80% of soybean production, the Northern region is key to food security in Thailand. The biggest risk associated with climate change in this region has been **drought**. Precipitation during the rainy season has decreased with early monsoon rainfall decreasing substantially from 1970 by 49.8 mm in May and 85.1 mm in June. The delayed onset of the monsoon coupled with the overall shortening of rainy seasons and increased maximum daytime temperatures have resulted in increased risk to the farmers' livelihoods in this region.

3.3.2 - Northeastern region

As the leading rice-growing region (approx. 40%) and the second largest producer of corn and soybean (approx. 20%), the northeastern region is essential to food security in Thailand. Over the past 50 years, an increase in daily maximum temperatures and a decrease in precipitation have combined to cause concern for the main food staples. A very pronounced threat is the delay in the monsoonal rains, which are key to rice planting and the health of other crops. The trend of average April and May rainfall each decreasing by nearly 30 mm since 1970 with the June rainfall decreasing an astounding 30% from nearly 250 mm in 1970 to 170 mm at present. With the climate trending drier and warmer during the planting and early growth periods, a clear risk has developed for the key cereal crops of the northeastern region.

The United Nations Development Programme reported that the most vulnerable provinces are in this region (Figure 24):

- Nakhon Ratchasima;
- Buriram;
- Khon Kaen;
- Roi Et;
- Si Sa Ket;
- Surin; and
- Ubon Ratchathani.

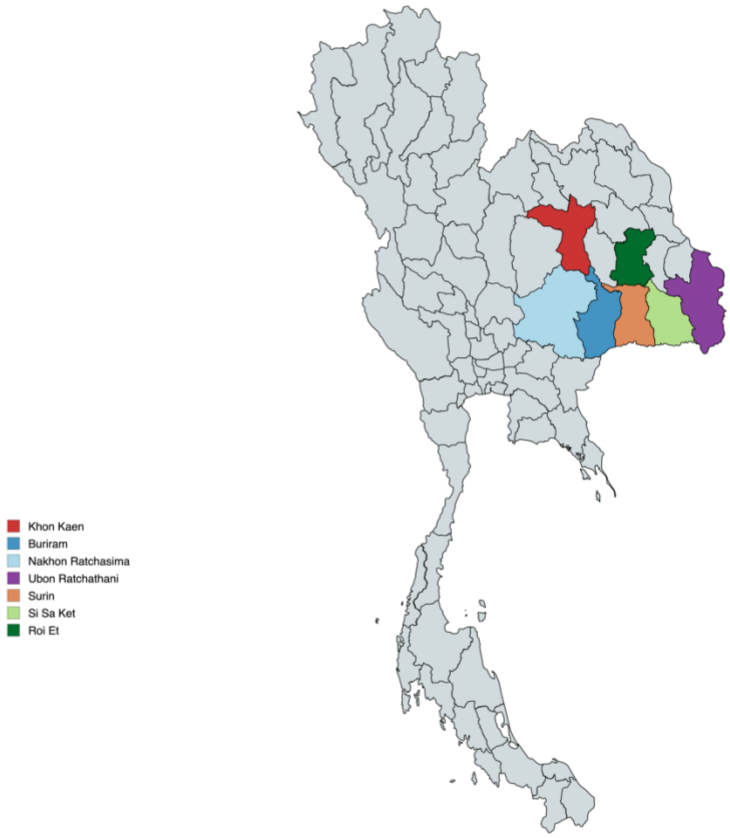

Figure 23: Northeastern provinces most vulnerable to extreme weather events (source: BCI, 2024)

These provinces in the northeastern region face the greatest combined risks from heat, drought, and flooding.

3.3.3 - Central region

In conjunction with the northern and northeastern regions, the central region is the other major producer of rice in Thailand (approx. 25%). Like the other two regions, the major threat associated with climate change is the delayed onset of the monsoon rains. Coincidentally, ERA5 data has shown rainfall trends increasing for months outside of May and June with only June exhibiting significant decreases since 1970. While this may lessen the risk to the farmers, it is noted that precipitation reliability has decreased in areas away from the Gulf of Thailand, resulting in key growing areas of the central plains experiencing similar precipitation issues as the north and northeastern regions. The warming trend in daily maximum temperatures during the growing season is tangible as they average near 32 °C with a stark increase in the number of days exceeding 35 °C. For instance, sugarcane yields are particularly affected by drought, with increasing reliance on groundwater intensifying the need for improved water management practices (Pitak Ngammuangtueng et al., 2023).

3.3.4 - Southern region

In contrast to the other regions of Thailand, our analysis has shown that the climate patterns tend to be wetter across southern Thailand. Yearly precipitation has increased by 240 mm since 1970 with slight indications of an increasing trend in typhoons starting in the 1990s. While the drought risk is of lower concern, an increased risk of flooding has been observed. As the primary palm-growing region of Thailand, the warming trend in temperatures is of concern. Daily maximum temperatures have climbed from around 30 °C in 1970 to nearly 32 °C today, resulting in more days exceeding 35 °C which is often seen as a critical threshold in palm growth.

4 - SOCIO-ECONOMIC IMPACTS OF CLIMATE CHANGE ON THE WIDER AGRICULTURAL SECTOR IN THAILAND

Climate change poses a significant risk to agriculture globally, affecting food security, livelihoods, and economic stability. In Thailand, where agriculture is a cornerstone of the economy and employs a large portion of the population, the effects of climate change are increasingly severe. The sector, which includes crops, livestock, and aquaculture, is particularly vulnerable to changing temperatures, rainfall patterns, and extreme weather events that have become more frequent in recent decades (Nakasu, 2017)(Wassmann et al., 2009)

Thailand's crop production is diverse, with key crops such as rice, maize, sugarcane, rubber, and palm oil—all of which rely on specific climatic conditions. The impacts of climate change, including prolonged droughts, unpredictable rainfall, and rising temperatures, have led to notable declines in crop yields and stressed essential water resources for irrigation. (David B Lobel & Christopher B Field, 2007). For instance, rice, Thailand's staple crop and a major export, is highly sensitive to fluctuations in climate. Shifts in temperature and erratic rainfall affect not only crop yields but also grain quality, threatening Thailand's global competitiveness in the rice market (Wassmann et al., 2009).The livestock industry is also vulnerable to climate-related stress, including heatwaves and water scarcity, which can decrease productivity and increase disease risks. Furthermore, rising temperatures and altered rainfall patterns influence the availability of feed and forage, adding pressure on farmers (FAO, 2020). Aquaculture, another vital component of Thailand's agricultural sector, faces the challenge of warming water temperatures and fluctuating salinity levels, which can reduce fish yields and disrupt ecosystems.

The socio-economic consequences are profound, therefore, especially in rural areas where agriculture is the primary livelihood. Smallholder farmers, who comprise the majority of Thailand's agricultural workforce, are the most vulnerable. They lack the resources to adapt to climate impacts effectively, leaving them exposed to income losses, food insecurity, and poverty (Warr & Suphannachart, 2021). Rural communities are already feeling the strain from reduced crop productivity, increased production costs, and the loss of arable land due to droughts and floods.

4.1 - Yield variability on major crops

Yield variability in Thailand's agricultural sector is heavily influenced by climate change, with crops such as rice, maize, cassava, and sugarcane showing marked sensitivity to fluctuations in temperature, erratic rainfall patterns, and extreme weather events. These crops are critical not only for domestic food security but also for exports. Recent data highlights varying production trends—while crops like oil palm fruit and potatoes have experienced yield increases, others, such as natural rubber and sugarcane, have shown declines, pointing to a complex interaction of climate effects, agricultural practices, and economic factors.

Rice—Thailand's primary staple and export crop—is particularly vulnerable to rising temperatures. Research shows that increasing night-time temperatures can lead to grain sterility, ultimately reducing yields (Wassmann et al., 2009). A mere 1-2 °C increase can decrease rice production by 10-20%, especially in Thailand's Central plains and Northern regions, where rice is extensively grown. This climate sensitivity is a critical factor in understanding long-term agricultural risks for Thailand.

Maize and cassava, key crops for both domestic consumption and export, also demonstrate yield variability driven by inconsistent rainfall. Droughts, particularly during maize's flowering stage, significantly reduce yields (Punyalue, 2020). While cassava is relatively drought-tolerant compared to other crops, severe droughts still negatively affect tuber size and overall quality. This resilience, however, is tested as extreme weather events become more frequent.

Sugarcane, a major cash crop, is highly dependent on consistent precipitation and adequate soil moisture during its growth phase. Variability in rainfall has resulted in fluctuating yields, with a particularly notable decline after 2018, likely due to adverse weather conditions and market-related factors.

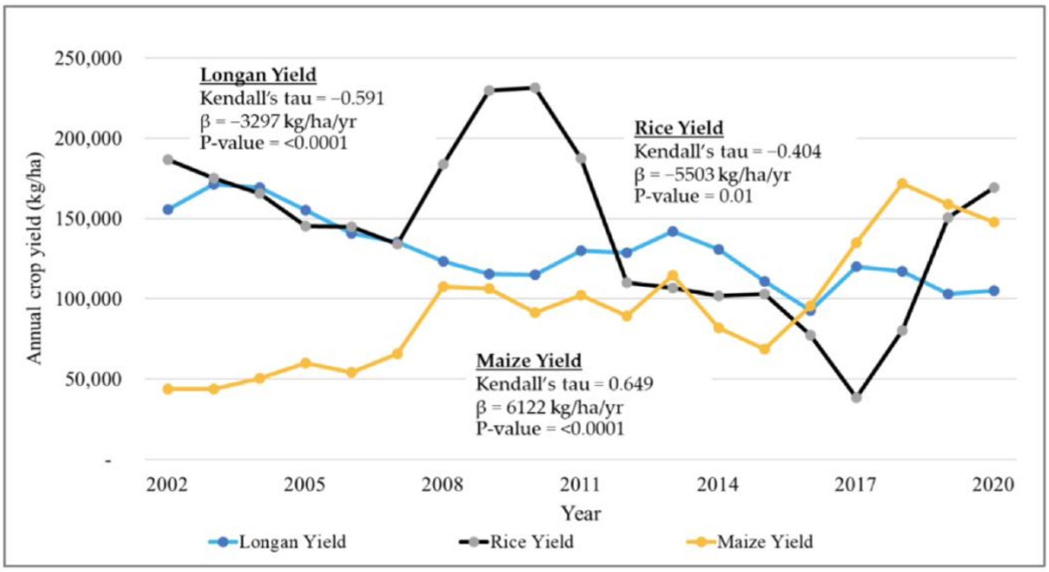

Figure 24: Temporal trends of crop yields between 2002 and 2020 in Chiang Mai province (source: Kyaw et al., 2023)

The figure above illustrates the variability in yields caused by climate change. Rice and longan yields are decreasing.

<u>4.2 - Variability on animal husbandry</u>

Animal husbandry in Thailand is increasingly impacted by climate change, which undermines livestock productivity through higher temperatures, erratic rainfall, and extreme weather events. These factors disrupt feed availability, animal health, and reproductive performance. Heat stress, in particular, is a critical concern, as rising temperatures reduce milk and meat production, affect growth rates, and impair fertility. In Table 6 below, livestock farmers in Thailand have experienced decreased yields in cattle and poultry due to elevated heat stress (Vongphet & Setboonsarng, 2020a).

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Cattle yields	100	98	95	92	90	87	85	83	80	78
Poultry yields	100	97	94	91	89	86	84	82	80	77

Table 6: Livestock yields in Thailand, impact of elevated heat stress (2010-2019) (source: Vongphet & Setboonsarng, 2020a)

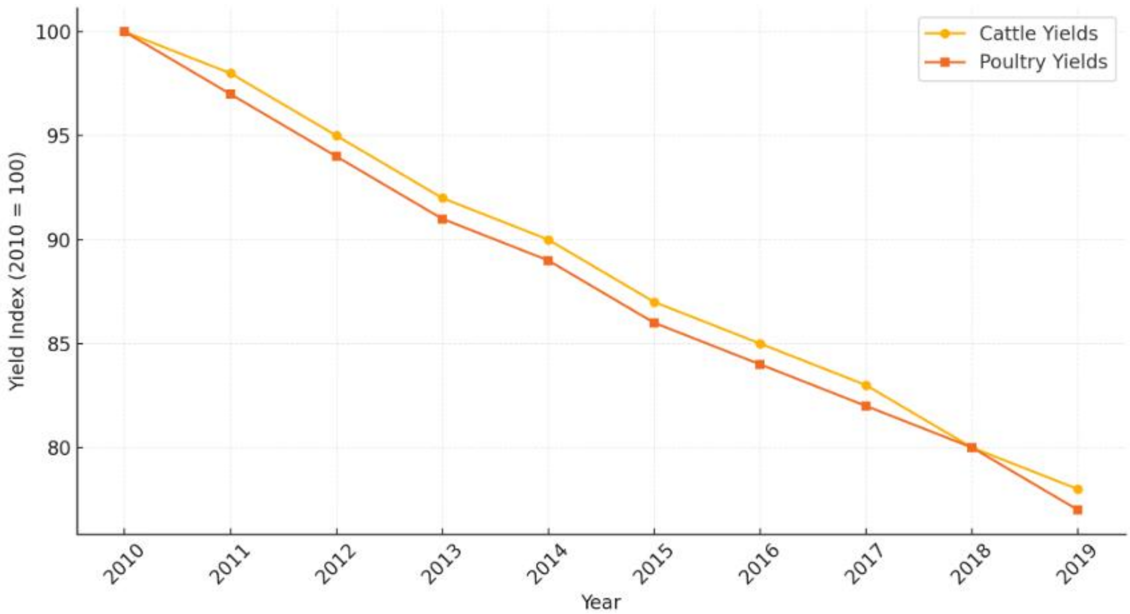

Figure 25: Trend of livestock yields in Thailand, impact of elevated heat stress (2010-2019) (source: Vongphet & Setboonsarng, 2020a)

More so, diseases pose another significant challenge, exacerbating yield variability. Outbreaks such as foot-and-mouth disease (FMD) and avian influenza, which are believed to be linked to changing climate patterns, have led to major economic losses and fluctuating livestock populations. Effective disease control measures, including vaccination programs and biosecurity enhancements, are essential to mitigate these risks. (Choe, 2019) highlights the importance of coordinated disease management strategies to stabilize yields and sustain animal husbandry.

Feed availability and quality also fluctuate due to seasonal variability and shifting climate patterns, affecting overall livestock productivity. For instance, prolonged droughts reduce the quality of natural forage, negatively impacting growth and the health of animals. (Amran, 2021) emphasize that improved feed management systems, such as enhanced forage cultivation and supplementary feeding during dry seasons, are critical for mitigating these productivity challenges.

Economic factors further contribute to yield variability, especially due to market fluctuations and price volatility for livestock products. (Boulanger et al., 2018) point out, price instability can influence farmer decisions regarding animal breeding, feeding investments, and disease management practices, affecting production outcomes. Additionally, global demand shifts for meat and dairy products are altering the focus of animal husbandry in Thailand.

4.3 - Socio-economic impacts by demography

Climate change is exacerbating socio-economic challenges in Thailand's agricultural sector, impacting not only crop yields but also livelihoods, employment, and rural poverty. The increasingly variable agricultural output, driven by extreme weather events, poses a direct threat to the income and food security of millions of smallholder farmers, who are particularly vulnerable due to their limited resources and reliance on subsistence farming. As a result, rural communities face a heightened risk of falling deeper into poverty (Kurukulasuriya et al., 2013). The cascading effects of climate change have compelled policymakers to prioritize adaptive strategies, such as sustainable farming practices, improved water management, and crop diversification (Intergovernmental Panel on Climate Change (IPCC), 2014). Indeed, to address these issues, the Thai government has implemented research and adaptive agricultural practices, such as altering planting schedules, adopting drought-resistant crop varieties, and investing in water management systems. These initiatives aim to stabilize yields and protect farmers' livelihoods despite growing climate challenges.

4.3.1 - Rural communities

The economic impact of extreme weather events, such as droughts and floods, disproportionately affects Thailand’s rural poor, as they are more likely to depend directly on agriculture for their livelihoods. Prolonged droughts and pest infestations reduce the quantity and quality of cereal crops, lowering farm revenues and forcing households to sell assets or seek off-farm employment to manage income losses (Norsuwan et al., 2021). While such strategies may help mitigate short-term income shocks, droughts are more difficult to manage and often leave farmers with few options for income recovery (Lertamphainont & Sparrow, 2016). Additionally, climate change-related events have escalated household vulnerability and food insecurity, especially for those with smaller landholdings.

Rural communities, particularly those reliant on natural resources for income, are bearing the brunt of climate-related impacts. (Waqas et al., 2024) suggest that food insecurity and income loss have worsened for smallholder farmers in Thailand’s vast rural regions. Rice farmers with small landholdings are particularly affected, experiencing diminished profitability as production costs rise, further worsening their economic plight (Isvilanonda & Bunyasiri, 2009). While wealthier, commercial farmers can invest in technologies that enhance climate resilience, smallholder farmers struggle to afford such improvements.

Local governments endeavor to introduce local adaptation initiatives for supporting underprivileged farmers. For example, local initiatives like small-scale farm reservoirs in the Northeast Mun River Basin have proven beneficial for some communities, but their impact is limited to those who can implement such systems (Prabnakorn et al., 2021). This unequal access to resources exacerbates the divide between wealthier farmers and the rural poor, hindering rural communities' capacity to adapt to climate change.

4.3.2 - Migrants

Climate change is contributing to migration flows, both within and beyond Thailand's borders. As agricultural conditions deteriorate, some rural families are forced to migrate to urban areas in search of alternative livelihoods, disrupting the social fabric of their communities. Meanwhile, those who remain often face even greater burdens due to labor shortages and diminished social support networks (Rigg & Salamanca, 2011). (Bennett, 2015) highlights that households with fewer financial resources are more likely to experience higher out-migration rates, further straining the rural economy.

For those who migrate, particularly informal or irregular migrant laborers, vulnerability to exploitation and discrimination increases, especially within agricultural labor markets. Women, in particular, often face disproportionate risks, as they are more likely to encounter exploitation in low-wage, precarious farming jobs (Musikawong et al., 2021). Migrants who remain in the agricultural sector are frequently exposed to harsh working conditions exacerbated by extreme weather, perpetuating cycles of poverty and vulnerability.

4.3.3 - Women and marginalized social groups

The effects of climate change on agriculture are also intensifying social inequalities, particularly among women, ethnic minorities, and marginalized rural communities. Research indicates that disadvantaged groups such as young women, girls, pregnant women and children face greater risks as climate change amplifies existing vulnerabilities (Boyland & Johnson, 2018). Thailand’s ageing agricultural workforce, combined with the fact that 80% of farm households control less than 3.2 hectares of land, underscores the sector’s dependency on disadvantaged social groups, who are less resilient to climate-induced shocks (Attavanich, 2023) .

Moreover, younger generations are increasingly moving away from agriculture, further intensifying the challenges faced by the remaining rural populations, as reflected in the declining proportion of agricultural employment in the national workforce as show in Figure 3.

Women, who were over-represented in the agricultural workforce in Thailand (Figure 26), particularly in rice cultivation, are disproportionately affected by the socio-economic consequences of climate change. We may conclude that harsh farm work conditions and too much revenue variability because of extreme weather events made women seek employment in services. As primary caregivers and agricultural laborers, women face a double burden: not only do they experience the direct effects of reduced crop yields and food insecurity, but they are also responsible for securing water, food, and income for their households (Bangkok Post, 2020).

The adverse effects of climate-related shocks on women are manifold. For instance, water scarcity increases the burden on women and girls, who are often responsible for water collection. Floods and other extreme weather events can block access to essential resources and disrupt agricultural activities, forcing women to take on additional responsibilities to compensate for lost household income (Boyland M & Johnson K., 2018). Moreover, this added stress leads to longer periods of unemployment for women compared to men, particularly in the aftermath of extreme weather events, further deepening gender disparities in rural Thailand (Hung, 2024).

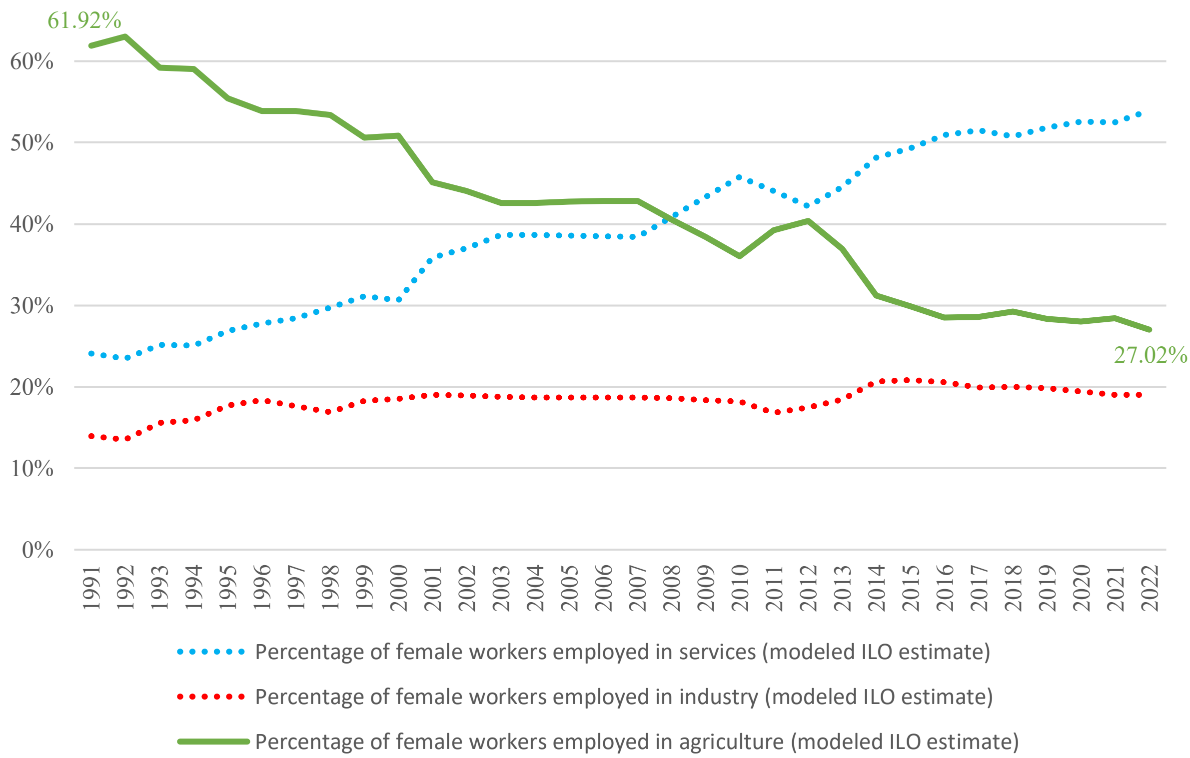

Figure 26: Repartition of female employment in Thailand (ILO, 2022)

5 - CLIMATE ADAPTATION STRATEGIES

Climate adaptation in Thailand’s agricultural sector has become increasingly urgent due to escalating climate risks such as droughts, floods, and temperature fluctuations. The country's heavy reliance on rain-fed agriculture, which accounts for approximately 78% of its agricultural land, makes it highly vulnerable to unpredictable rainfall patterns. These irregularities severely impact crop yields and disrupt agricultural stability (Pleerux, 2015). The resulting consequences extend beyond agriculture, affecting the economic stability of farmers and rural communities who depend on farming for both livelihoods and food security.

The adverse effects of climate change are particularly pronounced in food security and livelihood resilience, with extreme weather events like droughts and floods causing substantial crop losses. Droughts, in particular, have reduced agricultural productivity, endangering national food security (Waibel et al., 2017). This vulnerability is compounded by the socio-economic conditions of Thai farmers, many of whom lack secure land tenure. This insecurity limits their ability to invest in long-term adaptation measures, deepening their economic precariousness (Phromthep & Torut, 2024). Therefore, it is critical to develop comprehensive climate adaptation strategies to enhance the resilience of Thailand's agricultural systems.

Adaptation has emerged as a key response to these challenges. Evidence shows that farmers who adopt resilient practices are better equipped to cope with climate shocks (Saithong et al., 2022) (Waibel et al., 2017). Public policies that promote sustainable farming practices and improve access to resources for young farmers are also essential in boosting the adaptive capacity of agricultural communities (Faysse et al., 2019). Additionally, research suggests that farmers' perceptions of climate risks significantly influence their adaptation behaviors. Therefore, educational programs that increase climate awareness and provide skills for implementing resilience measures are invaluable (Menapace et al., 2015).

The unique challenges facing Thailand's agricultural adaptation strategies stem from the socio-economic profile of its farmers and the prevalence of smallholder farms. Limited access to resources, information, and technical support has traditionally hindered the widespread adoption of adaptive measures (Phromthep & Torut, 2024). However, recent initiatives, such as participatory guarantee systems, have empowered smallholder farmers by improving their access to local institutions and support mechanisms. These systems help strengthen collective bargaining power and foster collaboration between farmers, local governments, and institutions (Phromthep & Torut, 2024).

Adapting to climate change is essential for Thailand's agricultural sustainability. This requires developing and implementing more resilient agricultural practices, such as drought-tolerant crop varieties, improved water management systems, and diversification of crops to reduce dependency on climate-sensitive species (Vongphet & Setboonsarng, 2020b). Furthermore, crop- and region-specific adaptation strategies are needed to support farmers in adopting climate-smart agriculture, improving infrastructure for irrigation, and promoting early warning systems for extreme weather events.

Government support has been instrumental in facilitating these adaptation strategies. A cornerstone of this effort is Thailand's National Adaptation Plan (NAP), specifically the *Integrating Agriculture into National Adaptation Plans (NAP-Ag) program*. The NAP outlines the national circumstances, economic and social conditions, climate change trends, and climate risks across six sectors: water resource management, agriculture and food security, tourism, public health, natural resources management, and human settlements and security (DCCE, 2023b). The NAP-Ag program focuses on the agricultural sector, aiming to strengthen technical capacities, develop integrated adaptation roadmaps, improve evidence-based decision-making, and promote agricultural resilience through advocacy and knowledge-sharing (UNDP, 2024) (FAO, 2020b).

At the grassroots level, informal initiatives by farmers have been vital in building resilience. Two key strategies—ecosystem-based adaptation (EbA) and capacity building—have been particularly effective. Regarding EbA, farmers across Thailand have implemented various adaptive measures, such as alternative farming techniques, crop diversification, and advanced water management strategies (Waqas et al., 2024). For example, in Songkhla province, community-led construction groups built living weirs along the Khlong-La River to mitigate drought impacts. These bamboo weirs raised water levels upstream while regulating flow downstream, helping communities better manage water resources during dry periods (Cowan, 2023). Capacity building through farmer training programs and knowledge-sharing platforms is crucial for promoting climate-resilient practices. These programs offer training on efficient water use, crop diversification, and precision agriculture technologies. A study of 206 rice-growing households in Northeast Thailand showed that farmers actively engaged in local learning groups achieved higher yields and had better knowledge of climate change and advanced farming technologies than those who were not involved (Suwanmontri et al., 2018). However, while capacity building is essential, it requires sustained support from government and local authorities to be effective. Without adequate resources, short-term adaptation measures may lead to maladaptation, undermining long-term resilience (Pak-Uthai & Faysse, 2018). building through farmer training programs and knowledge-sharing platforms is crucial for promoting climate-resilient practices. These programs offer training on efficient water use, crop diversification, and precision agriculture technologies. A study of 206 rice-growing households in Northeast Thailand showed that farmers actively engaged in local learning groups achieved higher yields and had better knowledge of climate change and advanced farming technologies than those who were not involved (Suwanmontri et al., 2018). However, while capacity building is essential, it requires sustained support from government and local authorities to be effective. Without adequate resources, short-term adaptation measures may lead to maladaptation, undermining long-term (Pak-Uthai & Faysse, 2018)

Despite the implementation of various adaptation strategies, challenges remain. Limited resources, knowledge gaps, and inconsistent government support continue to hinder the widespread adoption of climate resilience measures (Waqas et al., 2024). Nevertheless, with sustained efforts to enhance collaborations among stakeholders and support grassroots initiatives, Thailand has the potential to secure its agricultural productivity and ensure long-term food security in the face of growing climate threats.

5.1 - Existing initiatives

Thailand has been proactively implementing a wide range of climate adaptation strategies in its agricultural sector to mitigate the growing impacts of climate change. These initiatives include government-led programs, climate-resilient farming practices, community-based adaptation projects, and collaborative public-private partnerships (PPPs). All these efforts represent Thailand's commitment to strengthening the resilience of its farming communities, which face increasing environmental threats and socio-economic challenges.

The country's climate adaptation strategies focus on several key areas: (i) agriculture; (ii) water resource management; (iii) infrastructure development; and (iv) disaster risk reduction. In agriculture, the promotion of climate-resilient crops—such as drought-tolerant and flood-resistant rice varieties—and the diversification of crops have been central strategies to reduce dependence on rice monoculture. Enhanced irrigation systems, expanded water infrastructure, and efficient water-saving techniques such as drip irrigation ensure a more reliable water supply during dry periods. Additionally, farmers benefit from early warning systems and crop insurance to mitigate risks associated with extreme weather events.

Effective water resource management is also crucial, as integrated, basin-wide approaches help balance the needs of agriculture, industry, and domestic water use. Traditional methods, such as the "monkey cheek" water retention system, continue to play a role in managing floods and droughts. Along the coast, mangrove restoration and seawall construction protect against storm surges and coastal erosion, while stricter land-use policies limit overdevelopment in vulnerable areas.

Thailand's disaster risk reduction programs focus on community-based preparedness and response efforts, supported by advanced meteorological systems and geographic information system (GIS) technologies for real-time monitoring. Urban adaptation measures include green infrastructure to combat urban heat islands and improve stormwater absorption, along with flood-resilient urban planning and energy-efficient building designs. Furthermore, ecosystem-based approaches like forest conservation, reforestation, and biodiversity protection contribute to stabilizing local climates and enhancing agricultural ecosystems.

Key policy initiatives, such as the *National Climate Change Master Plan (2015-2050)*, provide a comprehensive framework for both adaptation and mitigation, encouraging provinces and municipalities to develop localized strategies. Partnerships with international organizations, such as the UNDP and the Green Climate Fund (GCF), offer technical and financial support to enhance these efforts. Financial mechanisms, including subsidies for sustainable practices and crop insurance, help farmers adopt climate-resilient methods and provide safety nets for vulnerable populations. Despite these efforts, challenges such as resource constraints, coordination gaps, and the need for greater community involvement remain. Continued investment in funding, technology, and public awareness is essential for improving the effectiveness of Thailand's climate adaptation measures. This section will provide a SWOT analysis of three types of adaptation initiatives, including climate-resilient farming practices, community-based adaptation projects and crop insurance products.

5.1.1 - Climate-resilient farming practices

Farmers across Thailand are increasingly adopting climate-resilient farming practices as a frontline defense against climate variability (World Bank, 2021; FAO, 2020). These practices include crop diversification, the use of drought-resistant crop varieties, soil conservation techniques, and water-saving irrigation methods. For example, drought-resistant rice varieties have been developed and widely adopted, helping maintain yields under water-limited conditions (Amnuaylojaroen & Parasin, 2022). Additionally, water-efficient irrigation systems are now more commonly used in drought-prone areas, allowing for sustainable agricultural output with minimal water use (S. Chao-Amonphat et al., 2022). Additionally, water-efficient irrigation systems are now more commonly used in drought-prone areas, allowing for sustainable agricultural output with minimal water use (S. Chao-Amonphat et al., 2022).

These farming practices are most successful under conditions where farmers have access to adequate knowledge and resources, such as extension services, financial support, and appropriate technology. They thrive in areas with clear government support, such as subsidies or training programs for sustainable agriculture (National Agricultural Policy Office, 2023). Additionally, the practices are more suited to farmers who are open to adopting innovative techniques and those who have the financial means to invest in initial infrastructure, such as irrigation systems. Smallholder farmers, especially in communities with strong cooperative networks, benefit significantly as these networks often facilitate resource-sharing and collective learning. On the other hand, large-scale commercial farmers can also implement these practices effectively due to better access to capital and advanced technology.

The benefits of these practices extend beyond environmental resilience. Farmers who adopt diversified cropping systems report improved resilience not only to climate fluctuations but also to market instability. Diversification allows farmers to spread risk across different crops, stabilizing their incomes and strengthening food security in their communities (Yoshioka et al., 2022). By prioritizing sustainable agricultural practices, Thailand is advancing a model of resilience that integrates environmental sustainability with economic stability in rural areas.

STRENGTHS	WEAKNESSES
• Increased productivity and yield stability • Enhanced soil and water management • Sustainability and long-term viability • Diversification of crops • Long-term increase in livelihood	• High initial investment costs • Knowledge gaps and technical complexity • Limited access to resources • Short-term reductions in farmers' income
OPPORTUNITIES	**THREATS**
• Government and international support • Technological advancements • Market for sustainable and organic products • Complementarity with crop insurance • Climate finance	• Climate variability and unpredictability • Agricultural commodity prices instability • Land degradation and resource scarcity • Farmers' resistance to change • Pest and disease pressure

Table 7: SWOT matrix for climate-resilient farming practices (source: BCI, 2024)

5.1.2 - Community-based adaptation projects

Community-led adaptation projects have also gained momentum in Thailand, playing a critical role in fostering resilience at the grassroots level. These initiatives, such as farmer cooperatives and local water management groups, allow farmers to respond collectively to climate challenges by pooling resources and knowledge (Sereenonchai & Arunrat, 2019). Often supported by local governments, non-governmental organizations (NGOs), and international donors, these projects receive essential funding and technical assistance, helping ensure their long-term sustainability.

One notable example of community-driven adaptation is the improvement of local water management practices, which has significantly enhanced resilience to both flooding and droughts. Such collective efforts not only strengthen the capacity of communities to withstand climate impacts but also empower local populations by involving them in decision-making processes. Tailoring adaptation strategies to the specific needs of communities ensures more effective and inclusive outcomes (T. Chao-Amonphat et al., 2022). These community-based approaches provide a sustainable and inclusive pathway for building resilience, particularly in rural areas where social cohesion and resource-sharing are essential.

However, the success of these practices is contingent on several conditions. These projects thrive in environments where there is strong community participation, adequate funding, and sustained technical support. The presence of well-established social networks and effective leadership within communities further enhances their efficacy. Conversely, they often fail in areas lacking financial resources, technical expertise, or long-term government support. Social inequalities and dependence on external funding can also hinder their effectiveness, as these factors limit scalability and the ability to address broader systemic challenges. Furthermore, inadequate adaptation to local cultural and environmental contexts can lead to inefficiencies and a lack of community buy-in, undermining the project's sustainability.

STRENGTHS	WEAKNESSES
• Locally driven and inclusive • increased resilience to climate variability • Cost-effective solutions • Capacity building	• Limited financial resources • Lack of technical expertise • Limited scalability • Short-term focus
OPPORTUNITIES	**THREATS**
• Leveraging external support • Integration with government policies • Integration of technological innovations • New market opportunities for climate-resilient crops	• Increased climate uncertainty • Limited government support • Social inequalities • Dependence on external funding • Economic instability

Table 8: SWOT for community-based adaptation projects (source: BCI, 2024)

5.1.3 - Crop insurance products

The agricultural sector, particularly rice farming, plays a significant role in Thailand's economy but is highly vulnerable to extreme weather events. Crop insurance is critical for transferring most of the climate risks to the insurance companies and reducing financial losses for farmers due to climate change-related events, such as floods, droughts, and pest outbreaks, which are increasingly impacting Thailand's agricultural sector. Crop insurance is an essential tool to protect farmers' livelihoods, stabilize incomes, and encourage agricultural investment in the face of growing climate risks.

In the crop insurance product landscape, the key stakeholders include:

- Thai farmers: They are central to the success of crop insurance. They are the primary beneficiaries, depending on it for risk mitigation and income stability. Their needs and concerns shape product design, pricing, and distribution. Furthermore, their participation in claim processes and feedback mechanisms is crucial for improving the system's effectiveness and ensuring it remains relevant and responsive to their evolving needs.

- Government agencies: The Bank for Agriculture and Agriculture Cooperatives (BAAC) is the primary government body administering crop insurance, supported by the Ministry of Agriculture and Cooperatives (MOAC) and the Office of Insurance Commission (OIC);

- Insurance companies: Seven local insurance companies, such as Dhipaya Insurance, Bangkok Insurance, and Muang Thai Insurance, along with international reinsurers like Swiss Re, participate in the crop insurance scheme, offering policies to cover a range of natural disasters;

- Farmer cooperatives: Farmer cooperatives play a significant role in facilitating access to crop insurance by acting as intermediaries between farmers and insurance providers. They organize awareness campaigns, negotiate better terms with insurers, and ensure that smallholder farmers can benefit from available schemes. Individual farmers are the primary beneficiaries of these programs, especially those in high-risk areas prone to floods and droughts. Their participation and feedback are crucial in refining and expanding crop insurance products to meet on-the-ground needs.

- International organizations: Organizations such as the World Bank, Japan Bank for International Cooperation (JBIC), and GIZ (a German development agency) have been instrumental in providing technical and financial support for Thailand’s crop insurance programs.

The types of crop insurance products include:

(a) Traditional indemnity-based insurance: Traditional indemnity insurance policies, initiated in the 1970s, cover natural risks such as floods and droughts. Payouts are based on assessed damage, with rice, maize, and sorghum being the key crops covered.

(b) Parametric insurance: Parametric or weather index insurance uses specific weather conditions, such as rainfall levels, to trigger automatic payouts. This type of insurance, introduced in Thailand in 2005 with World Bank support, helps reduce delays in claim processing. Examples include insurance for maize and rice in drought-prone regions like northeastern Thailand.

Efforts continue to expand crop insurance coverage and improve the resilience of the agricultural sector through innovative insurance solutions and public-private partnerships. Below is a historical timeline (Table 9) that highlights the evolution of crop insurance in

Thailand, showcasing the efforts to protect farmers from natural disasters and enhance the resilience of the agricultural sector.

Early crop insurance initiatives (1978-1990s)	1978: The first crop insurance program in Thailand was introduced, covering cotton against natural risks such as floods and droughts. This was a traditional indemnity-based insurance(Hnin Ei Win, 2016).
	1990: The program expanded to include other crops like maize, sorghum, and soybeans, providing indemnity insurance for all natural risks. However, these early programs struggled due to high loss ratios, where premiums collected were lower than indemnity payouts (Hnin Ei Win, 2016).
Weather index insurance development (2005-2010)	2005: The World Bank introduced a pilot program for weather index insurance in Thailand. This was a significant shift from indemnity-based insurance to parametric models, where payouts were triggered based on specific weather conditions (e.g., rainfall levels). The pilot initially targeted maize farmers in the Pak Chong District of Nakorn Ratchasrima Province, focusing on drought risk (Gesellschaft für Internationale Zusammenarbeit, 2019).
	2006-2008: Weather index insurance for corn and rice was introduced. This type of insurance uses weather indices to determine payouts, making the process more efficient and transparent (Gesellschaft für Internationale Zusammenarbeit, 2019).
	2007: Weather index insurance for rice was introduced in collaboration with the Bank for Agriculture and Agricultural Cooperatives (BAAC) and Japan Bank for International Cooperation (JBIC). The program began in northeastern Thailand, a drought-prone region (Gesellschaft für Internationale Zusammenarbeit, 2019).
National rice crop insurance expansion (2011-2015)	2011: The government launched a national micro-insurance scheme for rice, covering natural disasters such as floods, drought, windstorms, frost, hail, and bushfires. This was developed to complement the government's disaster relief program (Gesellschaft für Internationale Zusammenarbeit, 2019).
	2014: The rice insurance program expanded significantly, covering up to 240,000 hectares (one-fourth of the total cultivated land throughout the country) by 2015. This accounted for approximately one-quarter of Thailand's total rice-cultivated land. The expansion was driven by increased government subsidies, making insurance more affordable for farmers (Gesellschaft für Internationale Zusammenarbeit, 2019).
Establishment of the National Catastrophe Insurance Fund (NCIF) (2012-2015)	2012: Following the devastating floods of 2011, Thailand established the National Catastrophe Insurance Fund (NCIF) to provide coverage for natural disasters. This fund also supported crop insurance programs by sharing the risks with private insurers and the international reinsurance market (Oxford Business Group, 2016).
	2015: By this time, the program had reached seven local insurers, covering a variety of crops, particularly rice. The program's success led to a continued increase in coverage (Oxford Business Group, 2016).
Recent developments and innovations (2016-present)	2016: The Thai National Crop Insurance Scheme (TNCIS) was introduced. This scheme required borrowers of seasonal credit from the Bank for Agriculture and Agricultural Cooperatives (BAAC) to purchase crop insurance, significantly increasing crop insurance penetration. The government also introduced additional programs aimed at expanding coverage, with significant efforts to reduce the cost of premiums by increasing insured areas and leveraging public-private partnerships (Gesellschaft für Internationale Zusammenarbeit, 2019).
	2017-present: Thailand has been exploring the use of blockchain-based insurance (BBPI) and smart contract solutions to improve the efficiency and transparency of crop insurance. These emerging technologies aim to enhance the claims process and increase accessibility, particularly for smallholder farmers (Gesellschaft für Internationale Zusammenarbeit, 2019).

	2018: Maize was added to the national crop insurance scheme under a PPP arrangement. This initiative was underwritten by a pool of local private-sector co-insurers managed by the Thai General Insurance Association (TGIA) (Gesellschaft für Internationale Zusammenarbeit, 2019).
	2020: Pilot projects for index-based crop insurance solutions were initiated. These projects aimed to develop and test new insurance products tailored to the specific needs of different crops and regions (Gesellschaft für Internationale Zusammenarbeit, 2019).

Table 9: Historical context of crop insurance in Thailand (source: BCI, 2024)

Crop insurance coverage and uptake are higher in regions where rice is predominantly grown, especially in flood-prone areas like central and northern Thailand. However, remote areas, such as parts of the south and the uplands, remain underserved due to infrastructure and awareness barriers.

Key challenges include the cost of premiums, lack of understanding of insurance benefits among farmers, and complex insurance products that do not always align with local cropping calendars. Despite expansions, many farmers remain uninsured due to affordability issues and lack of awareness. Programs like the BAAC subsidy aim to reduce these costs. Delays in assessments and payouts, especially for traditional indemnity-based insurance, have also led to mistrust among farmers.

Accurate and timely weather data is crucial for the effectiveness of parametric insurance. Limited access to such data in certain regions hinders the implementation of effective insurance programs.

There are opportunities for improvement and innovation:

- PPPs: Strengthening collaborations between the government, insurers, and international organizations can help expand crop insurance coverage and reduce premiums;
- Technological innovations: Integrating remote sensing, big data, and the Internet of Things (IoT) can improve the accuracy of risk assessment and streamline the claims process; and
- Expanding coverage: There is potential to expand crop insurance to cover a wider range of crops, such as cassava and sugarcane, and include other agricultural activities like livestock insurance.

	Early crop insurance initiatives (1978-1990s)	Weather index insurance development (2005-2010)	National Rice Crop Insurance (2011-2015)	National Catastrophe Insurance Fund (2012-2015)	Recent developments and innovations (2016-present)	Thai National Crop Insurance Scheme (TNCIS) (2016-present)	Other specialized insurance (e.g., Longan, Area-Yield)
Examples of products	- First Rice Crop Insurance Pilot (1978) - Multi-Peril Crop Insurance (MPCI) for Rice (1980s) - BAAC Crop Insurance Expansion (1990s)	- Drought Index Insurance for Rice Farmers (2006) - World Bank and BAAC Rice Insurance Pilot (2007-2010)	- Named Peril Crop Insurance (NPCI) - Weather Index Insurance - Subsidized Premium Insurance	- Catastrophe Insurance Policy for Households - Catastrophe Insurance Policy for SMEs and Industrial Sectors	- Weather Index Insurance for Maize - Microinsurance for Rice - Named Peril Crop Insurance (NPCI) - Compulsory Crop Insurance for Seasonal Credit Borrowers	- Weather Index Insurance for Maize - Microinsurance for Rice - Named Peril Crop Insurance (NPCI) - Compulsory Crop Insurance for Seasonal Credit Borrowers	- Longan Insurance - Area-Yield Insurance
Coverage of crop types	Cotton (1978); expanded to maize, sorghum, soybeans (1990)	Maize (2005); expanded to corn and rice (2006-2008)	Rice	Various crops, particularly rice	Rice, maize; exploring blockchain-based insurance; pilot projects for index-based solutions	Rice, maize, cassava	Longan (Chiang Mai); rice (pilot areas for Area-Yield Index Insurance); other crops in specific projects
Geographic coverage	Specific regions cultivating the insured crops	Pak Chong District, Nakhon Ratchasima Province; expanded to Northeastern Thailand	Nationwide, focusing on rice-cultivated areas	Nationwide	Nationwide; specific regions for pilot projects	Nationwide, focusing on disaster-prone provinces	Chiang Mai for longan; Suphanburi and Ubon Ratchathani for rice (AYII); targeted regions for specialized crops
Target audience	Farmers cultivating cotton, maize, sorghum, soybeans	Maize and rice farmers, particularly in drought-prone areas	Rice farmers, especially smallholders	Farmers affected by natural disasters	Smallholder farmers; BAAC loan recipients; exploring new technologies for broader farmer inclusion	Smallholders, BAAC loan recipients	Farmers of specific crops (e.g., longan and rice); smallholder farmers in specialized insurance pilots

	Early crop insurance initiatives (1978-1990s)	Weather index insurance development (2005-2010)	National Rice Crop Insurance (2011-2015)	National Catastrophe Insurance Fund (2012-2015)	Recent developments and innovations (2016-present)	Thai National Crop Insurance Scheme (TNCIS) (2016-present)	Other specialized insurance (e.g., Longan, Area-Yield)
Costs, terms, and conditions	Indemnity-based insurance covering natural risks; faced with high loss ratios	Parametric insurance with payouts triggered by specific weather conditions; aimed at efficiency and transparency	Micro-insurance scheme covering natural disasters; complemented government disaster relief; increased subsidies for affordability	Provided coverage for natural disasters; supported crop insurance programs by sharing risks with private insurers and reinsurers	Mandated insurance purchase for BAAC loan recipients; government programs to reduce premium costs; exploring blockchain solutions	Subsidized premiums (60% by government, 40% by BAAC for borrowers); adherence to crop registration	Fixed premiums (e.g., 299 Baht per unit for longan); rice premiums based on historical yields and coverage needs
Disbursement mechanism	Traditional indemnity payouts	Payouts based on weather indices, enabling objective and swift disbursements	Payouts complemented government disaster relief efforts	Coordinated with private insurers and international reinsurance market for disbursements	Leveraging technology for efficient claims processing; exploring smart contracts	Dual triggers: government-declared disasters and damage assessments; direct payouts	Parametric payouts (e.g., longan based on drought severity); Area-Yield Index Insurance based on yields below thresholds
Usage of data and automation/ level of digitalization	Limited data utilization; traditional methods	Utilized weather data and indices for determining payouts	Relied on disaster declarations and assessments for payouts	Engaged in risk-sharing with private insurers and international reinsurers	Integrates historical data, weather patterns, and machine learning; gradually digitalizing	Integrates historical data, weather patterns, and machine learning; gradually digitalizing	Uses advanced satellite and weather data (e.g., GSMaP for longan); machine learning for Area-Yield Index Insurance
Number of insured farmers	Data not specified	Data not specified	Covered up to 240,000 hectares by 2015, approximately one-fourth of Thailand's rice-cultivated land	Engaged seven local insurers by 2015	Significant increase in crop insurance penetration due to mandatory participation for	3.3 million farmers insured by 2020, covering 6.2 million hectares	Specific data varies by scheme; growing penetration in specialized crops

	Early crop insurance initiatives (1978-1990s)	Weather index insurance development (2005-2010)	National Rice Crop Insurance (2011-2015)	National Catastrophe Insurance Fund (2012-2015)	Recent developments and innovations (2016-present)	Thai National Crop Insurance Scheme (TNCIS) (2016-present)	Other specialized insurance (e.g., Longan, Area-Yield)
					BAAC loan recipients		
Level of insurance payments	High loss ratios led to financial sustainability issues	Aimed for efficient and transparent payouts; specific payment levels not detailed	Provided payouts aligned with disaster relief	Payments streamlined by NCIF through collaboration with insurers	Leveraging smart contracts for faster payouts and better accuracy	Claims exceeded THB 3 billion during severe disasters (e.g., 2019 floods); loss ratios around 150%	Longan payouts linked to drought index; Area-Yield schemes offer payouts based on deviation from trigger yield
Market size	A few thousand farmers	30,000 to 50,000 farmers – THB 100 to 150 million annually	1.5 million to 1.75 million farmers – THB 2 to 3 billion annually	500,000 policies – THB 1.5 to 2.5 billion annually	1.8 million farmers – THB 3 to 4 billion annually	2 million farmers (30-40% of Thailand's rice farmers) – THB 2.5 to 3.5 billion annually	10,000 to 15,000 farmers – THB 50 to 100 million annually

Table 10: Summary of crop insurance mapping in Thailand (source: BCI, 2024)

Table 10 below will map and analyze existing crop insurance products in Thailand regarding their coverage of crop types, geographic coverage, target audience, costs, terms and conditions, disbursement mechanism, usage of data (crop, weather, etc.) and level of automation/digitalization. The number of insured farmers, level of insurance payments and market size will also be presented, where available.

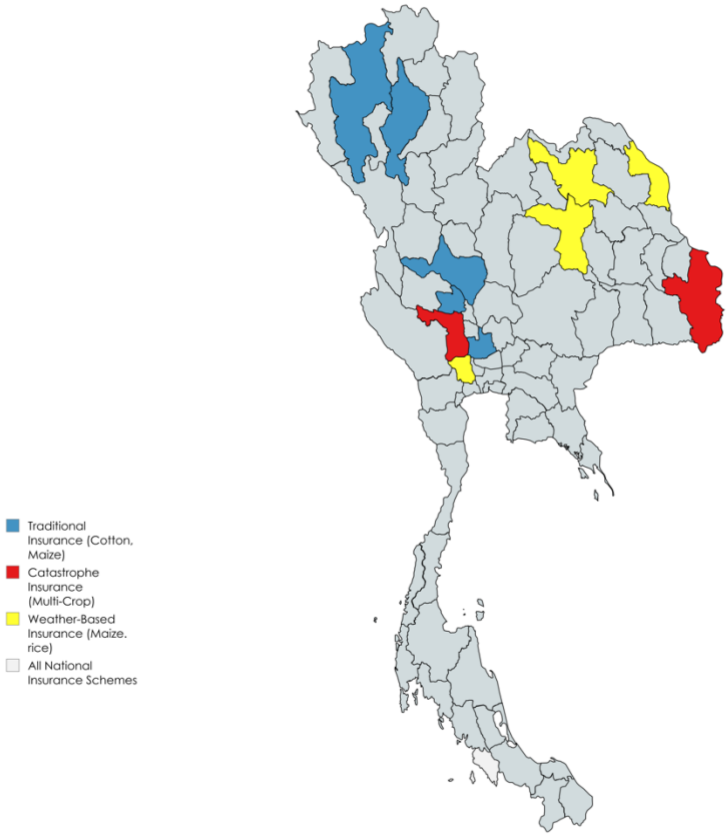

Figure 27: Crop insurance in Thailand (source: BCI, 2024)

STRENGTHS	**WEAKNESSES**
• Income stabilization • Government support • Encourages investment in modern agricultural techniques • Risk mitigation	• Limited coverage for cassava and sugarcane • Complexity and Lack of Awareness • Affordability for smallholder farmers • Delays in Traditional Claims Processing • Profitability
OPPORTUNITIES	**THREATS**
• Enhancement by blockchain technology • Expansion to other crops and regions • Public-private partnerships • Climate change adaptation	• Climate change uncertainty • Financial sustainability • Farmer mistrust • Dependence on government subsidies

Table 11: SWOT matrix for the crop insurance (source: BCI, 2024)

The mapping of Thailand's crop insurance product landscape reveals a dynamic yet fragmented sector that seeks to address the agricultural challenges posed by climate change. Figure 27 provides a visual representation of the current distribution of crop insurance products, highlighting the predominance of traditional indemnity-based schemes, and the recent shift towards parametric insurance models. This evolution reflects efforts to streamline claim processes, increase accessibility, and cater to a wider range of climate risks faced by farmers. Despite progress, gaps remain in coverage, particularly for crops like cassava and sugarcane, and in reaching remote regions, as evidenced by low participation rates in underserved areas.

Table 11 offers a SWOT analysis of the crop insurance sector, underlining its strengths in income stabilization and government support, while identifying critical weaknesses, such as limited farmer awareness and affordability concerns. Opportunities for technological advancements, such as integrating blockchain-based systems, and expanding coverage to include more crops and regions, present avenues for growth. However, persistent threats, including financial sustainability and dependence on subsidies, highlight the need for innovative funding mechanisms and partnerships.

In conclusion, enhancing Thailand's crop insurance framework requires a multifaceted approach. Strengthening public-private collaborations, investing in farmer education, and leveraging emerging technologies like blockchain can address existing inefficiencies and build a more resilient agricultural insurance ecosystem. By addressing these challenges, Thailand can better protect its farmers, ensure food security, and foster sustainable agricultural development in the face of increasing climate uncertainties.

5.2 - Potential initiatives

To further enhance Thailand's climate adaptation efforts in agriculture, several innovative initiatives could address existing gaps and capitalize on emerging technologies. Thailand has made significant progress in climate adaptation, but additional measures could further improve resilience, particularly in the agricultural sector. Large-scale vertical and indoor farming systems, for example, could reduce dependence on climate-sensitive outdoor cultivation, particularly in urban areas. Digital platforms providing real-time weather forecasts and market insights would empower farmers to make informed decisions, while innovative farming techniques like biochar application, hydroponics, and aquaponics can boost productivity, conserve water, and improve soil health.

For disaster preparedness, AI-driven risk mapping, migration plans for high-risk communities, and resilient communication networks would improve response capacities to extreme weather events. Ecosystem conservation efforts could focus on blue carbon projects to protect seagrasses and coral reefs, urban wetland creation for flood management, and rewilding programs to restore natural habitats. Policy innovations, such as carbon farming incentives, frameworks to address climate refugees, and cross-border climate agreements, could fill existing policy gaps. Advanced technologies, like blockchain for carbon credits, geoengineering research, and weather modification, could offer additional solutions to Thailand's climate challenges.

Farmer education programs would play a pivotal role in raising public awareness and fostering resilience. Integrating climate change education into school curricula and promoting citizen science initiatives could enhance understanding and engagement. Nationwide campaigns to reduce food waste, conserve water, and adopt renewable energy would further support sustainable practices.

In support of Thailand’s national adaptation goals, this section explores potential community strategies, including BBPI, precision agriculture technologies, climate-resilient infrastructure, and farmer education programs. These approaches hold substantial promise for strengthening climate resilience and sustainability in Thailand's agricultural sector. By implementing these forward-looking initiatives, Thailand can strengthen its adaptive capacity, safeguard vulnerable populations, and emerge as a leader in climate adaptation strategies.

5.2.1 - Blockchain-based parametric insurance

BBPI offers an innovative solution to mitigate the financial risks farmers face from climate-induced losses. Unlike traditional insurance, which relies on complex damage assessments, parametric insurance provides quick payouts based on predefined weather indices such as rainfall or temperature. By leveraging blockchain technology, this model ensures transparency, reduces fraud risks, and accelerates the claims process—crucial for farmers who need immediate financial relief after extreme weather events. Moreover, it improves traditional insurance products and can enhance the already existing crop insurance products.

While BBPI is not yet widely adopted in Thailand, similar models have been successfully piloted in regions like Africa, where smallholder farmers use them to manage risks associated with droughts and floods. Adapting this model to Thailand could provide farmers with a more reliable and efficient way to cope with economic shocks from climate variability. With its decentralized and secure nature, blockchain technology could also enhance trust between stakeholders in Thailand’s agricultural sector, where financial limitations often hinder the adoption of risk management strategies.

STRENGTHS	WEAKNESSES
• Income stabilization • Government support • Parametric and weather index insurance • Promotion of investment and modernization • Efficiency and speed • Transparency and trust • Reduced administrative costs • Accessibility	• Limited coverage • Complexity and lack of awareness • Affordability • Initial setup costs • Data requirements • Technical complexity
OPPORTUNITIES	**THREATS**
• Technological integration • Expansion to other crops and regions • PPPs • Climate change adaptation	• Climate change uncertainty • Financial sustainability • Farmer mistrust • Dependence on government subsidies • Adoption barriers

Table 12: SWOT matrix for the blockchain-based parametric insurance (source: BCI, 2024)

Nevertheless, the full (commercialization) potential of BBPI cannot be exploited unless other emerging technologies are employed to enhance the level of agricultural resilience and avoid maladaptation. Precision agricultural technologies, climate-resilient infrastructure and farmer education programs should become supportive measures to this end.

5.2.2 - Precision agriculture technologies

Precision agriculture technologies, including drones, soil sensors, and AI-driven platforms, offer transformative potential for optimizing resource use and boosting productivity in Thailand's agricultural sector. These technologies enable real-time monitoring of crop health, soil conditions, and water levels, helping farmers make data-driven decisions that reduce input wastage and improve yields. Drones, for example, can quickly identify early signs of crop stress, allowing farmers to intervene before losses occur.

In countries like Vietnam, precision agriculture has already led to significant gains in productivity and sustainability. Thailand could follow a similar path, enhancing food security and reducing the environmental footprint of conventional farming. Precision agriculture not only helps farmers adapt to climate change by improving efficiency but also supports broader sustainability goals. By investing in these technologies, Thailand can better equip its farmers to face the challenges of a changing climate while maintaining efficient production systems.

STRENGTHS	WEAKNESSES
• Automation and speed • Reduced administrative costs • Accessibility	• Technical infrastructure • Complexity and awareness • High initial set-up costs • Limited historical data
OPPORTUNITIES	**THREATS**
• Public-private partnerships • Integration with smart farming technologies • Expansion to more crops and regions • Climate change adaptation • Technical advancements • Climate finance	• Climate variability • Adoption barriers • Dependence on external funding • Economic instability

Table 13: SWOT matrix for precision agriculture technologies (source: BCI, 2024)

5.2.3 - Climate-resilient infrastructure

Developing climate-resilient infrastructure is essential for mitigating the impacts of extreme weather on Thailand's agricultural sector, especially in regions prone to floods and droughts. Improving flood defenses, expanding irrigation systems, and upgrading storage facilities for drought-resistant seeds are critical steps in safeguarding agricultural productivity. These infrastructure improvements can reduce the risks posed by climate variability and ensure that farming communities remain resilient in the face of environmental challenges.

Thailand has already experienced significant economic losses due to inadequate infrastructure during severe weather events. For example, failures in water management systems during heavy rainfall have exacerbated flooding, highlighting the need for robust investments in climate-resilient infrastructure. Strengthening infrastructure will not only protect agricultural outputs but also contribute to the long-term sustainability of rural livelihoods. These investments align with Thailand's broader goals of sustainable development, creating a more resilient agricultural system capable of withstanding future climate risks.

STRENGTHS	WEAKNESSES
• Protection against climate risks • Improved resource management • Long-term economic resilience • Job creation and local development	• High initial investment costs • Maintenance and sustainability issues • Slow implementation • Geographic disparities
OPPORTUNITIES	**THREATS**
• Government and international support • Technological innovations • PPPs • Climate Adaptation	• Climate change uncertainty • Funding constraints • Inadequate local expertise

Table 14: SWOT matrix for a climate-resilient infrastructure (source: BCI, 2024)

5.2.4 - Farmer education programs

Education is a cornerstone of building climate resilience. Comprehensive farmer education programs focusing on climate-smart agricultural practices and digital literacy can bridge knowledge gaps and accelerate the adoption of sustainable farming methods. These programs should cover areas such as sustainable resource management, climate risk assessment, and the use of digital tools to support decision-making in agriculture.

Evidence from other Southeast Asian countries shows that education initiatives significantly improve climate adaptation behaviors among farmers, leading to better resilience outcomes. Implementing similar programs in Thailand, which blend traditional farming knowledge with modern techniques, would empower farmers to respond more effectively to climate risks. By promoting climate-resilient practices and integrating innovative technologies, education programs can enhance the long-term sustainability of Thailand's agricultural sector.

STRENGTHS	WEAKNESSES
• Improved knowledge and skills: • Sustainability • Adaptation to climate change • Access to resources • Community building • Technological integration	• Limited reach and coverage • Lack of continuity • Low literacy and awareness levels • Cultural resistance • Insufficient resources • Resource constraint • Dependent on external funding • Variability in program quality
OPPORTUNITIES	**THREATS**
• Technology integration • Collaboration with NGOs and government • Climate-resilient crop varieties • Economic diversification • Climate adaptation • Trendy	• Unpredictable climate patterns • Economic constraints • Inadequate government support • Market instability • Dependence on external funding • Pest and disease outbreaks

Table 15: SWOT matrix for farmer education programs (source: BCI, 2024)

The mapping of Thailand's crop insurance landscape, as detailed in Figure 27 and Table 11, provides critical insights that directly inform the rationale and design of the farmer survey. The mapping highlights significant gaps in coverage and accessibility, particularly for smallholder farmers who dominate Thailand's agricultural sector. It underscores the challenges of limited awareness, affordability, and the complexity of insurance products, which contribute to the low adoption rates of crop insurance. These findings indicate a clear need to understand farmers' perceptions, experiences, and barriers to adopting both traditional and innovative insurance solutions.

The survey design is tailored to address these gaps by gathering firsthand insights from farmers across various regions and demographics. It seeks to capture their exposure to climate risks, their use and experience with existing insurance products, and their readiness to adopt advanced solutions such as blockchain-based parametric insurance. Specific questions targeting their understanding of insurance benefits, willingness to participate in such schemes, and preferred methods for premium payment are designed to uncover actionable insights. The results aim to bridge the disconnect between insurance providers and end-users, facilitating the development of more effective, accessible, and farmer-centric insurance solutions. By aligning the survey's objectives with the findings from the insurance mapping, this approach ensures that future policy and product designs are grounded in the real-world needs and challenges faced by Thai farmers.

6 - MAPPING OF BLOCKCHAIN-BASED CROP INSURANCE PRODUCTS INTERNATIONALLY

6.1 - Introduction

This project deliverable reviews some existing blockchain-based crop insurance products/initiatives globally, identifying their best practices and challenges, and provides recommendations by mapping their findings to the development of BBPI in Thailand. Through the mapping and analysis of both successful and not-so-successful projects, the report highlights factors contributing to their outcomes, as well as how the Thailand BBPI initiative can address their shortcomings and incorporate the best practices.

The analysis will examine products and services, geographic coverage, crop coverage, stage of development/operation, blockchain infrastructure, level of automation, and data usage. The key factors supporting blockchain-based system integrations in this crop insurance domain will also be explored. Reasons for the success or unsuccess of these products will be identified to create a catalogue of best practices. Through analyzing the best practices and findings from the international landscape, recommendations will be provided to support the design and execution of such blockchain-based crop insurance product models under this project.

6.2 - Methodology

The mapping of blockchain-based crop insurance products internationally follows a systematic and comprehensive approach. Its goal is to extract actionable insights by analysing both successful and unsuccessful projects. This methodology ensures a holistic understanding of the landscape, providing a foundation for adapting global best practices to Thailand's context. This methodology was developed based on several factors/rationales, including data collection, parameters of interest, categorisation of products/initiatives, comparative analysis, gap identification and best practices and applicability to Thailand. The following provides the specific areas considered under each of these method factors:

a. Data collection

Data was gathered from a diverse range of sources to ensure a robust and unbiased analysis. These include:

i. Academic publications: Peer-reviewed research on blockchain applications in agriculture and insurance;

ii. Industry reports: Insights from organizations like Climate Policy Initiative, World Bank, and insurance industry white papers;

iii. Case studies: Documented experiences of existing projects;

iv. Technical documentation: Blockchain architecture, platforms, and tools used in the initiatives; and

v. Stakeholder interviews (if applicable): Input from developers, policymakers, and farmers involved in these projects.

b. Parameters for analysis

Each identified initiative was evaluated based on the following parameters:

i. Products and services: The type of insurance product offered (e.g., parametric, indemnity-based) and its features;

ii. Geographic coverage: Countries or regions where the project operates, with attention to socio-economic and climate-related conditions;

iii. Crop coverage: Types of crops insured, categorized by staple, cash crops, or specific climate-sensitive varieties;

iv. Stage of development: Whether the initiative is in pilot, development, or operational phase;

v. Blockchain infrastructure: The blockchain platform used (e.g., Ethereum, Hyperledger), including smart contract implementation and scalability considerations;

vi. Challenges: Barriers encountered in implementation, adoption, and scalability; and

vii. Thailand project mitigation: Mitigation strategies applied in the Thailand Project;

c. Categorization of initiatives

Against the success criteria to be set out in 6.3.1 - Success criteria for blockchain-based parametric insurance products, projects were categorized into:

i. Successful (promising) initiatives: Projects that achieved operational scale, delivered intended benefits, and demonstrated replicability or scalability potential; and

ii. Not-so-successful initiatives: Projects that faced critical barriers, leading to limited adoption or termination;

d. Comparative analysis

A side-by-side comparison was conducted to:

i. Identify patterns of success and unsuccess;

ii. Highlight the influence of geographic, technological, and regulatory factors; and

iii. Assess how challenges in one project were resolved in other cases;

e. Gap identification and best practices

The analysis focused on understanding:

i. Factors that enabled success in operational projects;

ii. Common gaps or challenges across both successful and not-so-successful initiatives; and

iii. How these insights can be leveraged in the Thailand BBPI initiative;

f. Applicability to Thailand

To evaluate the applicability of every selected use case to the context of Thailand, the final step of the methodology involved aligning the findings with the specific needs and conditions of Thailand's agricultural sector. This included:

i. Local climate risks: Mapping findings to address Thailand's vulnerability to floods, droughts, and extreme weather;

ii. Target crops: Prioritizing insurance for economically significant crops like rice, cassava, and rubber;

iii. Infrastructure readiness: Leveraging Thailand's relatively advanced digital and the Internet of Things (IoT) infrastructure for blockchain deployment; and

iv. Regulatory context: Evaluating Thailand's legal and regulatory framework for blockchain and insurance to ensure compliance and scalability.

By following the above methodology, several important use cases of blockchain-based crop insurance products were mapped out and analyzed. The analysis focused on identifying the best practices and challenges in enabling the operationalization of such products, and exploring the key advantages brought in by integrating such products with blockchains.

6.3 - Mapping of blockchain-based crop insurance products

The development of BBPI represents a transformative shift in the insurance industry, leveraging the decentralized and transparent nature of blockchain technology to create more efficient, automated, and transparent insurance models. The blockchain-based crop insurance products tend to emerge globally with the rising interest in digitalization, automation and climate actions/financing across the globe (Jouini and Sethom, 2023). Countries from both the developing and developed worlds understand the need to collaborate nationally and internationally in achieving sustainable agriculture to combat the challenges against natural disasters/climate hazards, their quick recovery needs and other issues in the industry (Bank for International Settlements, 2023). As crop insurance is a major driver of helping the farmers in this journey, the technological advancements to resolve its challenges should be carefully studied. While industry 4.0 technologies enable the platforms for digitalization and automation in such systems, the blockchain plays a key role in providing trust, transparency, security and effective collaboration across distributed agents in such systems (Javaid et al., 2022).

6.3.1 - Definition of the blockchain-based parametric insurance product/services

The BBPI products are defined as insurance solutions for farmers that use distributed ledger technology (e.g. blockchain) to streamline, secure, and enhance the process of providing insurance coverage for crops. The services driven by such products could enable a range of benefits to the farmers from advising on best practices for combatting the climate challenges to automating fund distributions in the aftermath of natural disasters which destroy their crops and/or animal husbandry (Secretariat, 2022).

Understanding the blockchain-based parametric insurance

The BBPI is a merger of parametric-insurance systems with the blockchain and its supportive/integrative technologies which enables the automation of the entire process from monitoring real-world events/natural disasters via sensors/sensory sources, and processing event data against insurance criteria; to dispatching the benefit pay-outs to the insured. In brief, it contains two components: 1) parametric insurance; and 2) integration of blockchain (Khonje and Mitchell, 2019).

1. Understanding parametric insurance

Parametric insurance is a type of insurance that pays out a pre-defined amount based on the occurrence of a specific event, rather than relying on traditional claims assessments. The event is triggered by a defined parameter (e.g., wind speed, temperature, earthquake magnitude). Once this parameter is met, a payout is automatically triggered.

2. Integration of blockchain

Blockchain, a decentralized ledger system, ensures transparency, immutability, and security. When integrated into parametric insurance, blockchain can automate claims processing, verify parameters, and facilitate quicker pay-outs (Amponsah et al., 2021). Blockchain enhances parametric insurance through:

a. Smart contracts: Blockchain allows for the use of smart contracts, which are self-executing contracts where the terms of the agreement are directly written into code. In parametric insurance, smart contracts automatically trigger payouts when predefined conditions are met (e.g., a certain level of rainfall);

b. Decentralization and transparency: Blockchain's decentralized nature ensures that the data used to trigger a claim is stored across multiple nodes, reducing the risk of fraud or manipulation. Insurers, policyholders, and third-party data providers can all access the same information in real-time, ensuring transparency; and

c. Security and immutability: Blockchain provides a high level of security because once data is added to the blockchain, it cannot be altered, ensuring the integrity of the parameter data and the associated payouts.

Key technical components of blockchain-based parametric insurance

Given the needs of automatically detecting natural hazards and their geographic relevance in-time for deciding the distribution of insured funds to the farmers, a comprehensive and reliable form of sensing and feed-in those sensed-data/events-data to the decision-making blockchains are required in this context. This involves the integration of **data oracles** from numerous physical sources such as weather sensors, wind and seismic activity monitoring. The use of **smart contracts** and **tokenization** are two other components which enables the blockchain to automate the entire process of identifying the natural disasters, deciding which farmers affected and dispatching the relevant funds to the impacted insured/farmers (Jouini and Sethom, 2023). Each of these three main components are summarized as follows:

a. Data oracles: Oracles are external data sources that provide real-world information to the blockchain, such as weather data, seismic activity, or other predefined parameters. For example, an oracle might deliver data on rainfall or wind speed that determines whether a policyholder is entitled to a payout;

b. <u>Smart contracts:</u> The smart contract on the blockchain is programmed to automatically trigger a payout based on the data provided by the oracle. The contract contains pre-defined conditions, such as "if rainfall exceeds 100 mm in 24 hours," which can automatically initiate a transfer of funds to the policyholder; and

c. <u>Tokenization:</u> In some cases, parametric insurance policies may be tokenized on the blockchain, allowing for easy transfer of ownership, fractional ownership, or liquidity in the insurance market.

To illustrate a blockchain-based parametric insurance product, we can break it down into four key technical components and their interactions: (a) the insurer (investor); (b) insuree (client/farmer); (c) the remote/IoT sensing agents; and (d) the intermediary insurance system (the platform/solutions providing the insurance service), as shown in Figure 28, *as* the key components in these use cases. In most cases, the investors/ funding agencies keep the finances in escrow and utilize the blockchain-based smart contracts to effectively discharge the claims when the crops are impacted by natural disasters. Automating the data flow to identify when the crops are impacted is enabled by integrating data oracles into the blockchains from numerous remote sensing sources as predefined triggers (weather oracles, seismic oracles, satellite or IoT data). The deployment/enablement of such sensing sources is carefully localized based on ground-level details and the types of crops insured. This form of insurance relies on pre-defined triggers and automatically pays out claims when specific conditions are met, without the need for lengthy assessments or claims processes. Blockchain enhances this system by adding transparency, automation, and immutability. Figure 28 shows an overall architecture with such high-level components.

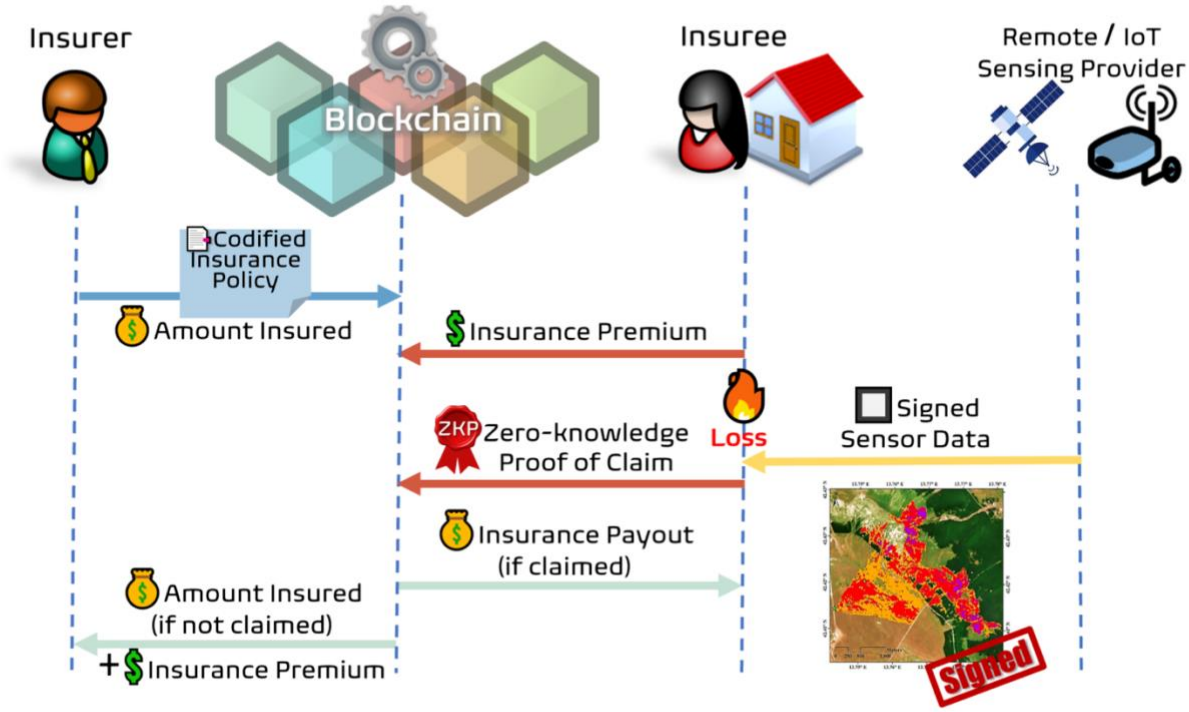

Figure 28: An illustration of blockchain-enabled parametric insurance system (source: BCI, 2024)

Benefits of blockchain-based parametric insurance

To elaborate on the SWOT analysis matrix (Table 12), this section presents several important benefits of BBPI compared to its conventional insurance solutions available for the farmer to cover similar disaster situations (Secretariat, 2022) (Arbol, 2018):

- Faster payouts: Since blockchain automates the claims process, payouts can be made almost instantly once the triggering event occurs. Traditional insurance models can take weeks or even months for claims to be processed;
- Reduced costs: Blockchain reduces administrative costs, fraud, and overhead by automating the claims process and eliminating the need for manual interventions in validating claims;
- Greater transparency and trust: Blockchain's immutable ledger ensures that the terms of the insurance contract, as well as the data used for claims, are transparent and verifiable by all stakeholders; and
- Global reach and accessibility: Blockchain can democratize access to insurance, particularly for underserved populations in remote areas where traditional insurance systems are inefficient or non-existent.

Challenges in adopting blockchain-based parametric insurance

Our previous studies (Secretariat, 2022) have identified several key challenges in implementing BBPI, which are summarized below:

- Data reliability and accuracy: The effectiveness of parametric insurance is entirely dependent on the accuracy of the data provided by oracles. If an oracle provides faulty data, it can lead to incorrect pay-outs or disputes;
- Regulatory hurdles: Blockchain-based insurance models may face legal and regulatory challenges, especially in regions where insurance is heavily regulated. The use of smart contracts and decentralized systems may require new legal frameworks to ensure that these policies are enforceable; and
- Adoption and integration: Insurers and other stakeholders in the ecosystem may face challenges in adopting and integrating blockchain technology into their existing systems. This includes both technological and operational hurdles, such as upgrading legacy systems and ensuring industry-wide cooperation.

Real-world use cases

In mapping out the blockchain-based parametric insurance products internationally, we have identified several significant real-world use cases that align with the definition of BBPI outlined earlier (i.e. in Glossary). These use cases were selected for their relevance to the objectives of the Thailand project, as they address similar markets and problem domains, including smallholder farmers, climate resilience, and agricultural risk management. Each example demonstrates innovative applications of blockchain technology to solve pressing challenges such as delayed insurance payouts, lack of trust in traditional systems, and inefficiencies in claims processing. By focusing on initiatives targeting regions vulnerable to climate change and agricultural challenges - markets analogous to Thailand's - we can draw valuable lessons and best practices. These examples not only highlight the potential of BBPI to transform traditional insurance models but also underscore the importance of tailoring solutions to the unique socio-economic and environmental contexts of their target regions.

- Etherisc is a decentralized insurance protocol built on blockchain that offers parametric insurance solutions, including flight delay insurance and weather-related insurance (e.g., crop insurance). Etherisc uses smart contracts to automatically trigger payouts when flight delays or specific weather parameters are met (Etherisc, 2016).

- Lemonade Crypto Climate Coalition is a blockchain-based initiative launched by the Lemonade Foundation to provide affordable crop insurance to smallholder farmers in Sub-Saharan Africa. Leveraging blockchain technology and parametric insurance models, the coalition automates payouts based on predefined weather indices, such as rainfall and drought conditions, ensuring timely financial relief without the need for traditional claims processes (Lemonade, 2022).

- Arbol is a blockchain-based parametric insurance platform designed to provide climate risk solutions for farmers, agribusinesses, and other industries worldwide. By leveraging smart contracts and decentralized oracles, Arbol automates payouts based on predefined weather conditions, such as rainfall, temperature, or wind speed, ensuring transparency and efficiency in claims processing. With a global presence across 15+ countries, Arbol integrates data from trusted sources like NASA, NOAA, and IoT devices to offer scalable and precise risk management solutions tailored to diverse crops and climates (Arbol, 2018).

- AgriBIoT is an innovative platform that combines blockchain technology with IoT devices to provide real-time, data-driven parametric insurance solutions for farmers. By integrating soil moisture sensors, weather monitoring systems, and blockchain-based smart contracts, AgriBIoT automates insurance claims and policy adjustments with high precision. This approach enhances transparency, reduces fraud, and ensures timely payouts, making it particularly effective for addressing the unique challenges of climate variability and agricultural risk management in diverse global regions (Jouini and Sethom, 2023).

- AgriSure is a blockchain-based crop insurance initiative piloted in Southeast Asia, targeting staple crops such as rice and cassava. Using Hyperledger Fabric, the project aimed to automate claims processing and improve transparency in agricultural insurance. However, AgriSure faced significant challenges, including integration issues with traditional insurance models and resistance from farmers due to limited awareness and trust in blockchain technology, ultimately limiting its success ("AgriSure," n.d.).

- Sprout Insure is a blockchain-based parametric insurance initiative piloted in Sub-Saharan Africa to provide affordable coverage for farmers vulnerable to climate risks. Built on Ethereum, it aimed to automate claims and enhance transparency by linking payouts to weather indices, such as rainfall thresholds. Despite its innovative approach, Sprout Insure struggled with high implementation costs, data reliability issues, and a lack of local technical expertise, which ultimately hindered its scalability and adoption ("Sprout Insure," n.d.).

	Product model	**How it meets the definition (defining components)**	**Region**
Etherisc	Etherisc offers weather-indexed insurance where payouts are automated through blockchain-based smart contracts triggered by meteorological data such as drought or rainfall thresholds	Smart contracts for automation and weather data as a parametric trigger	Kenya, Ghana, Sri Lanka
Lemonade Crypto Climate Coalition	The coalition provides low-cost parametric insurance that automatically issues payouts based on predefined weather indices, such as rainfall or drought levels, to protect subsistence farmers	Automated claims processing, affordability, and predefined weather data triggers	Sub-Sharan Africa, Kenya
Arbol	Arbol delivers customizable parametric insurance solutions for various industries, using decentralized oracles and smart contracts to automatically settle claims based on climate data like temperature, rainfall, and wind speed	Real-time data from IoT and satellites and transparent blockchain automation	Global
AgriBIoT	AgriBIoT integrates IoT-enhanced parametric insurance, combining real-time sensor data on soil and weather conditions with blockchain-based smart contracts for precise and timely payouts	Precision IoT data integration and blockchain automation for transparent claims settlement	Sub-Sharan Africa, South and South-east Asia

AgriSure	AgriSure provides weather-based crop insurance, using Hyperledger Fabric to automate payouts tied to specific weather events, such as floods or droughts, affecting staple crops	Blockchain infrastructure for automation and weather-based parametric triggers	Thailand, Vietnam, Indonesia
Sprout Insure	Sprout Insure offers rainfall-indexed parametric insurance, leveraging Ethereum-based smart contracts to trigger payouts when rainfall falls below predefined levels	Automation through smart contracts and reliable parametric weather indices	Kenya, Uganda, Ethiopia, Tanzania

Table 16: BBPI real-world use cases (source: BCI, 2024)

Success criteria for blockchain-based parametric insurance products

The success of BBPI products/services depends on a range of factors from multiple domains such as technological, economical, legal, local and social ones. Depending on how the BBPI systems are implemented and integrated into the underlying physical infrastructures; how they interact with its actors (both farmers/insured and insurers/insurance-agencies); and how well they are accepted within their legal and economical means, the level of success and long-term existence of BBPI will be evaluated (Khonje and Mitchell, 2019) (Omar et al., 2023).

This sub-section presents a list of factors that can be used to determine the level of success of the identified use cases of BBPI products/projects:

a. Technological domain:

   i. Transparent claim settlements: The product should ensure trust and clarity for all stakeholders through transparent claim settlement processes. By implementing blockchain technology, which serves as an immutable and transparent ledger for all transactions and claims, the product ensures that all stakeholders can verify the authenticity and status of claims in real-time.

   ii. Reduced fraud through monitoring: Implementing advanced monitoring technologies, such as IoT sensors and drones, gathers real-time data on crop conditions and weather events, this reduces the likelihood of fraudulent claims and ensures accurate assessments.

   iii. Scalable parametric models: Continuously updating and refining parametric models using machine learning algorithms and real-time data improves accuracy and scalability, this ensures that the models remain responsive to changing environmental conditions.

b. Economical domain:

i. Affordable coverage for subsistence farmers: Introducing tiered insurance plans that offer varying levels of coverage to accommodate different financial capabilities, this ensures that even the most financially constrained farmers can afford basic protection.

ii. Rapid claims settlement: Utilizing smart contracts to automate the claims process, triggering immediate payouts based on predefined parameters such as weather data, this reduces the time required for manual verification and processing, ensuring rapid settlement of claims.

c. Legal domain:

i. Mobile-friendly access: Facilitating easy policy management and claims processing through user-friendly mobile platforms with multilingual support and offline capabilities, this ensures that farmers in remote areas with limited internet access can still manage their policies and file claims.

ii. Precision policy management: Leveraging data analytics and satellite imagery to offer highly customized policies that reflect the specific risks and needs of individual farms, this enhances the relevance and effectiveness of coverage.

d. Local and social domains:

i. Local partnerships: The product should enhance accessibility and trust as well as facilitate better communication and support for farmers by establishing strong local partnerships with groups such as local agricultural cooperatives, NGOs, and community leaders.

Considering the interdependencies of most of these factors contributing to the success or unsuccess of the products/projects, in most cases. Based on their performance against each of the criteria above, this report uses the above criteria to determine the “successful (promising) initiatives” and “not-so-successful initiatives”. The key to the benchmarking or mapping exercise is to examine whether the BBPI products manage to reach real-world deployments and exist longer within the relevant localities gaining enough trust and acceptable rate of uptakes within actors.

Reviewing the use cases of blockchain-based crop insurance around the world provides important insights into designing integrated insurance systems to accommodate both the investors and claimants demands effectively (Javaid et al., 2022).

6.3.2 - Successful projects

Over the past decade, several successful blockchain-based crop insurance products/projects have been located across the world from Asia, Sub-Saharan and globally. As described, Etherisc from Asia, provides a platform that automatically triggers insurance policies and payout to the affected in the event of extreme weather events. It uses local weather parameters integrated into “an innovative parametric crop insurance built on top of a Generic Insurance Framework (GIF) on Ethereum”. It makes use of Chainlink’s oracle network which provides a reliable connection to external weather data sources. Lemonade Crypto & Arbol provide other evidence from Sub-Saharan and global contexts, for providing automated crop insurance over numerous adverse weather events such as drought and flood. Arbol is operational in over 15 countries tackling the pressing issues in climate risk management with a data-driven, technology-centric approach, harnessing AI and blockchain for precise risk assessment and transparent transactions.

Based on the parameters of analysis and comparative analysis approach as set out under the methodology section (6.2 - Methodology), Table 16 and Table 17 provide an analysis of these use cases. Further, Figure 30 and Figure 31 shows the geographic distribution of successful projects using the DLT-based parametric insurance and assistance systems.

	Region	Crop	Data	Stage of development	Blockchain
Etherisc crop insurance (Etherisc, 2016)	Kenya, Ghana, Sri Lanka	Weather-sensitive (maize, rice)	Meteorological data	Operational	Ethereum (“Avalanche,” n.d.; Ethereum Foundation, 2018)
Lemonade crypto climate coalition (Lemonade, 2022)	Sub-Saharan Africa	Staple crops (drought, flood-prone)	Meteorological data	Pilot	Avalanche
Arbol	15+ countries	Diverse (e.g., rice, coffee)	IoT sensors and meteorological Data	Operational	Ethereum
AgriBIoT (Jouini and Sethom, 2023)	Global pilots	Maize, wheat, rice	IoT sensors	Development	Hyperledger fabric

Table 17: Success project categorization (source: BCI, 2024)

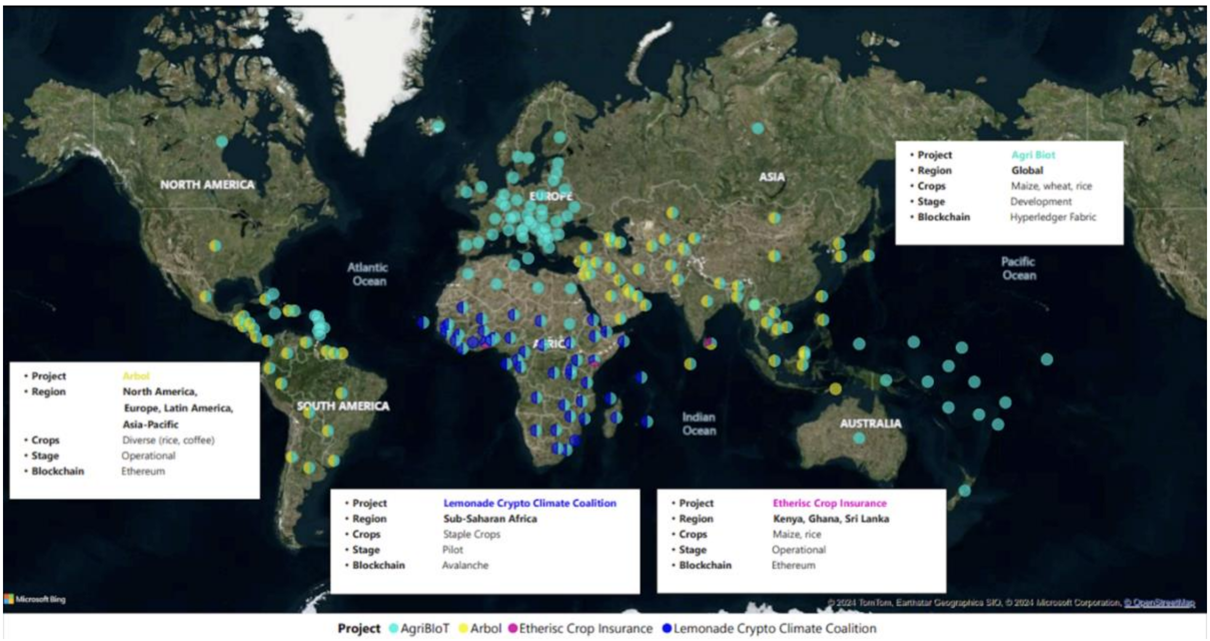

Figure 29: Success project categorization (source: BCI, 2024)

Figure 30: Success project categorization - Thailand zoom-in (source: BCI, 2024)

	Satisfaction of success criteria (Success factors)	Challenge	Potential mitigation plans for Thailand BBPI projects
Etherisc crop insurance	• Transparent claim settlements • Local partnerships enhance accessibility	Limited digital literacy among farmers	Incorporating farmer training programs to improve digital literacy and blockchain adoption
Lemonade crypto climate coalition	• Affordable coverage for subsistence farmers • Mobile-friendly access	Limited mobile and internet penetration	Leveraging Thailand's relatively strong digital infrastructure to ensure connectivity and adoption
Arbol	• Rapid claims settlement • Scalable parametric models	High costs for IoT and blockchain integration	Partnering with government and international funds to subsidize infrastructure and implementation costs
AgriBIoT	• Precision policy management • Reduced fraud through monitoring	High initial costs and technical training requirements	Conducting localized training programs and leveraging Thailand's existing IoT ecosystems

Table 18: Success factors, challenges and mitigation strategies (source: BCI, 2024)

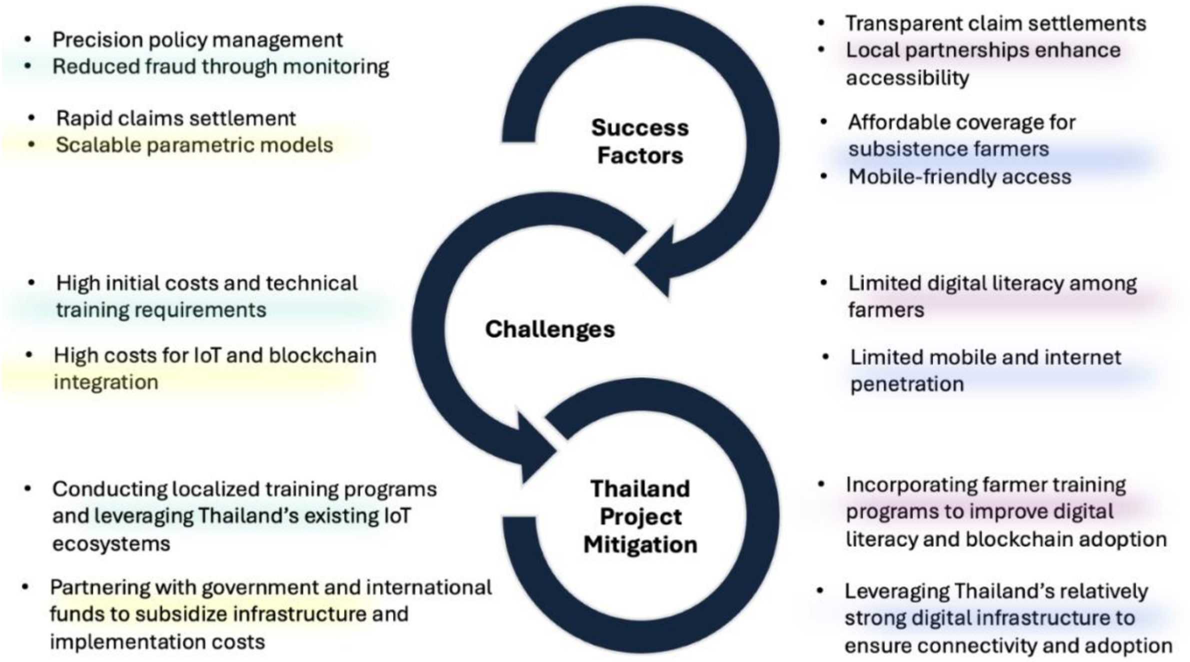

Figure 31: Success factors, challenges and mitigation strategies (source: BCI, 2024)

Etherisc achieved success largely by excelling in multiple domains. In the technological domain, it provided transparent claim settlements through its Ethereum-based blockchain, allowing all stakeholders to verify claims in real-time, while its scalable parametric models ensured accuracy and adaptability to local conditions. The economic domain was addressed through affordable insurance products tailored to subsistence farmers and rapid claims settlements enabled by smart contracts that triggered automatic payouts based on weather data. In the legal domain, *Etherisc* leveraged mobile-friendly platforms to make policy management and claims accessible even in remote areas. Finally, in the local and social domains, *Etherisc* partnered with local cooperatives and NGOs to build trust, enhance accessibility, and ensure effective communication with farmers, contributing to its widespread adoption and success.

The Lemonade Crypto Climate Coalition excelled in meeting the success criteria by targeting subsistence farmers in vulnerable regions with innovative blockchain-based parametric insurance. In the technological domain, it provided transparency through smart contracts and reduced fraud by linking payouts to reliable weather indices. The coalition addressed the economic domain by offering affordable, at-cost insurance plans and automating rapid payouts triggered by predefined parameters like rainfall or drought data. In the legal domain, its user-friendly, mobile-compatible platform enabled policy management and claims filing for farmers with limited internet access. In the local and social domains, Lemonade collaborated with local organizations to strengthen its reach and trust within communities, ensuring high uptake and scalability.

Arbol demonstrated significant success across the defined domains. In the technological domain, it used blockchain-enabled smart contracts and decentralized oracles to ensure transparent and automated claim settlements, supported by IoT and satellite data for fraud prevention. *Arbol* addressed the economic domain by designing flexible, scalable parametric insurance solutions that provided rapid claims settlements, catering to both smallholder farmers and large agribusinesses. Its legal domain strength lay in creating mobile-accessible platforms that allow seamless policy management and customization based on individual needs. In the local and social domains, Arbol emphasized partnerships with stakeholders in each target region, fostering trust and ensuring that its solutions met the specific challenges of diverse agricultural landscapes.

AgriBIoT successfully met the success criteria by integrating IoT and blockchain technologies to provide precise and reliable parametric insurance solutions. In the technological domain, it utilized real-time data from IoT sensors and blockchain smart contracts to enable transparent claim settlements and reduce fraud through accurate monitoring. The economic domain was addressed by creating affordable and scalable solutions tailored to farmers' financial constraints while automating rapid payouts based on real-time environmental data. In the legal domain, its mobile-friendly platforms allowed farmers to manage policies and file claims seamlessly, even in regions with limited connectivity. In the local and social domains, *AgriBIoT* established partnerships with agricultural cooperatives and local leaders to improve accessibility, trust, and community engagement, ensuring its relevance and scalability.

6.3.3 - Not-so-successful projects

There are many challenges to these types of complex digital platforms which need effective integrations over distributed entities or monitoring sites, predictive and identification-based event triggering and scalability over the volumes of both data and users in the system. Several use cases may be classified as not-so-successful ones yet due to such issues in their products. Table 3 provides a summary of these unsuccessful projects.

	Region	**Crops**	**Blockchain**	**Reasons for unsuccess**
AgriSure	Southeast Asia	Rice, cassava	Hyperledger fabric	• Integration issues with traditional insurance models • Farmer resistance due to limited awareness
Sprout Insure	Sub-Saharan Africa	Various	Ethereum	• High implementation costs; insufficient data reliability • Lack of local expertise

Table 19: Not-so-successful project categorization (source: BCI, 2024)

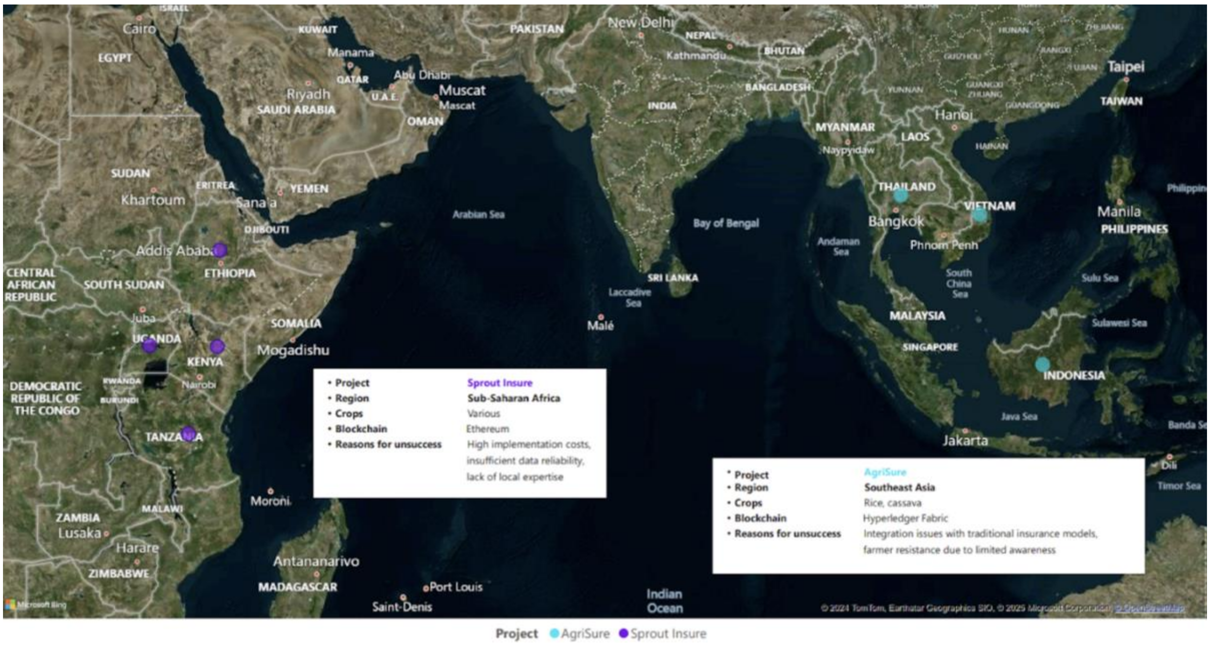

Figure 32: Not-so-successful project categorization (source: BCI, 2024)

AgriSure failed to meet the success criteria across multiple domains. In the technological domain, the initiative struggled with integrating blockchain into traditional insurance systems, resulting in inefficiencies and a lack of transparency in claims settlements. Additionally, its parametric models were not well-adapted to local environmental conditions, limiting scalability. In the economic domain, the product failed to provide affordable coverage for financially constrained farmers, reducing its accessibility and adoption rates. In the legal domain, *AgriSure* lacked user-friendly platforms for managing policies, making it difficult for farmers in remote areas to participate. Finally, in the local and social domains, *AgriSure* did not establish strong local partnerships or effectively communicate its benefits, leading to low trust and limited uptake among farmers. These shortcomings collectively undermined its success and sustainability.

Sprout Insure faced significant challenges in meeting the success criteria, particularly in the technological domain, where unreliable weather data and insufficient monitoring capabilities compromised the accuracy of its parametric models and reduced trust in claims settlements. In the economic domain, high implementation costs made the product financially unsustainable, and it failed to offer affordable plans tailored to subsistence farmers. In the legal domain, the lack of a mobile-friendly interface and inadequate policy management tools further alienated farmers in rural areas. In the local and social domains, Sprout Insure struggled to form meaningful partnerships with local stakeholders, such as cooperatives and community leaders, which hindered trust and adoption. These cumulative deficiencies prevented Sprout Insure from achieving the necessary uptake and operational longevity to be considered successful.

6.4 - Key findings and best practices

The analysis of blockchain-based crop insurance products globally highlights several recurring themes in both successful and unsuccessful initiatives. In the interest of identification of knowledge gaps and best practices as stated in the methodology section (6.2 - Methodology), the project team has drawn from the findings in the preceding section and presents an array of implications and actionable insights for designing robust and scalable BBPI solutions in Thailand in Table 20 and Table 21: Common best practices of successful BBPI projects (source: BCI, 2024) below.

Success factors	Key findings	Implications to Thailand BBPI projects
Technology fit	Blockchain technology is instrumental in enhancing transparency, reducing fraud, and automating claims processing. Platforms like Ethereum and Chainlink (Chainlink, n.d.) are commonly used due to their scalability and flexibility.	Selecting a blockchain platform that aligns with Thailand's infrastructure and crop insurance requirements is critical. A balance between technical capability and cost-effectiveness is needed.
Data reliability and integration	High-quality data (weather, IoT, satellite imagery) is central to the success of parametric insurance. Projects like Arbol and AgriBIoT demonstrate how real-time data integration improves accuracy and trust.	Strengthening meteorological infrastructure and leveraging existing IoT systems will be essential for real-time monitoring and accurate payouts.
Cost barriers	High implementation costs for IoT devices, blockchain integration, and training are common challenges, particularly for projects in early stages like AgriBIoT.	Leveraging international climate funds and government support can offset these costs, making the initiative economically sustainable.
Farmer engagement and literacy	Limited digital literacy and scepticism about new technologies hinder adoption. Etherisc and AgriSure faced challenges in gaining farmer trust and participation.	Tailored farmer training programs and community outreach will be critical to building trust and ensuring adoption.
Regulatory compliance	Blockchain-based solutions often face regulatory hurdles, particularly in jurisdictions without clear frameworks for digital technologies.	Collaborating with policymakers to establish clear regulatory guidelines for blockchain-based insurance will be a priority.
Scalability	Projects that achieve scalability (e.g., Etherisc, Arbol) demonstrate flexibility in adapting to diverse crops and regions. However, scalability requires robust infrastructure and stakeholder alignment.	Designing scalable insurance products tailored to key crops (e.g., rice, cassava, rubber) and regional vulnerabilities will ensure widespread impact.

Table 20: Identification of BBPI knowledge gaps (source: BCI, 2024)

Foreshadowed under the last step ('Applicability to Thailand') in the methodology section (6.2 - Methodology), Table 21 presents some common best practices, derived from successful projects, which may offer actionable guidance for the Thailand BBPI initiative:

Common best practices	Viable models	Action items applicable to Thailand
Leverage technology for automation and transparency	Use of smart contracts for claims automation, as demonstrated by Etherisc and Lemonade Crypto Climate Coalition, reduces delays and enhances transparency.	To implement smart contracts to automate policy issuance and claims processing, ensuring timely payouts for Thai farmers affected by climate risks
Invest in data infrastructure	Integrating IoT, satellite imagery, and weather data improves accuracy and efficiency. AgriBIoT and Arbol excel in this aspect.	To partner with local and international meteorological agencies to strengthen data collection and integrate IoT devices for real-time monitoring
Tailor solutions to local contexts	Projects like Etherisc partnered with local cooperatives to address specific regional needs, enhancing adoption and trust.	To engage local farmer cooperatives and community organizations to design insurance models tailored to Thailand's agricultural landscape
Enhance farmer adoption through education	Community training programs to improve digital literacy and explain parametric insurance concepts have shown promise.	To develop multilingual training materials and interactive workshops to demystify blockchain technology and its benefits for farmers
Promote policy and regulatory alignment	Early engagement with policymakers to establish supportive legal frameworks.	To work with Thai regulators to create clear guidelines for blockchain-based insurance, ensuring compliance and scalability
Focus on scalability and replicability	Projects with modular and adaptable designs (e.g., Arbol) have scaled to multiple regions and crop types.	To design flexible insurance products that can be adapted to other Southeast Asian countries, positioning Thailand as a regional leader in BBPI

Table 21: Common best practices of successful BBPI projects (source: BCI, 2024)

The mapping of blockchain-based crop insurance products globally provides valuable insights into the opportunities and challenges associated with implementing such initiatives. Successful projects, such as *Etherisc*, *Lemonade Crypto Climate Coalition,* and *Arbol*, demonstrate the transformative potential of blockchain in enhancing transparency, automating claims, and improving access to insurance for smallholder farmers. However, these initiatives also highlight critical barriers, including high implementation costs, limited farmer adoption due to low digital literacy, and regulatory complexities.

In parallel, not-so-successful projects, such as *AgriSure*, further underscore the importance of addressing integration issues, scalability challenges, and stakeholder engagement. These lessons emphasize that the success of blockchain-based insurance depends on robust data infrastructure, tailored solutions, and strong collaborations with governments and local communities.

Thailand's BBPI initiative is uniquely positioned to leverage these insights. By integrating advanced blockchain technology with real-time data, conducting farmer training programs, and accessing diverse funding sources, the initiative can overcome common pitfalls and set a new standard for climate-resilient agricultural insurance. This comprehensive approach ensures the scalability, sustainability, and relevance of the solution, not just for Thailand but as a potential model for other countries in the region and beyond.

By examining both successful and failed cases, BCI identifies key factors that contribute to their outcomes and highlighted best practices for future implementations.

The findings underscore the transformative potential of blockchain technology in the crop insurance sector. Blockchain can enhance transparency, efficiency, and accessibility, offering significant benefits to farmers and insurers alike. However, the challenges faced by failed initiatives highlight the importance of careful planning, investment in technology, and comprehensive data management.

The results of this mapping exercise are subject to change as the project team is conducting a more in-depth study on the technicality of their underlying blockchain infrastructure during the technical feasibility study.

7 - FARMER SURVEY

7.1 - Purpose

A comprehensive farmer survey was conducted as part of this exploratory study to gain insights into farmers' exposure to climate-related risks, their experiences with crop insurance products, and their readiness to adopt blockchain-based parametric crop insurance. The survey aims to gather detailed information on several key areas:

(a) Exposure to climate hazards: The survey assessed the types of crops farmers cultivate and mapped their exposure to various climate-related hazards such as droughts, floods, or extreme weather events. This helps in understanding the climate risks farmers face depending on their geographical location and crop type.

(b) Experience with crop insurance: Farmers were asked about their past experiences with crop insurance products, focusing on the perceived and actual benefits they received, as well as any limitations they encountered. For those without crop insurance, the survey explored the reasons behind their decision not to purchase it, providing insights into potential barriers to adoption.

(c) Readiness for blockchain-based parametric insurance: The survey explored farmers' preparedness to engage with innovative BBPI. Factors such as ownership of a bank account, access to mobile phones and mobile money, and their capacity to manage finances in times of climate-induced risks were examined to determine their readiness for such technology-driven insurance solutions.

(d) Willingness-to-buy/pay: After the assessment of awareness of crop insurance solutions, the survey asked farmers their willingness to purchase this solution.

The findings from this survey provide valuable insights into the challenges and opportunities within the agricultural sector's crop insurance market, contributing to the development of more effective and accessible insurance solutions for all farmers.

7.2 - Sample and data collection

Farmers were interviewed based on the results of the analysis and mapping above. The selected villages should be in:

- A province located in a rice-producing region (Figure 9): These provinces are at the core of Thailand's agricultural economy and understanding farmer attitudes and readiness in these regions will provide valuable insights for implementing innovative insurance solutions.

- A province most impacted by extreme weather events: Thailand is highly vulnerable to extreme weather events such as floods, droughts, and storms, which significantly impact the agricultural sector. A survey in a province facing these challenges will provide valuable insights into farmers' needs, challenges, and their potential for adopting innovative insurance solutions.

- A province experienced in implementing crop insurance (Figure 27): Provinces where farmers have already interacted with traditional crop insurance products offer a valuable opportunity to understand their level of familiarity, trust, and attitudes towards new, blockchain-based solutions.

With regard to the above, potential sites were identified in October and November 2024. The target provinces in which the survey was conducted are:

(i) Nakhon Phanom; and
(ii) Chiang Mai.

The following map demonstrates the geographical diversity crucial to having more robust results.

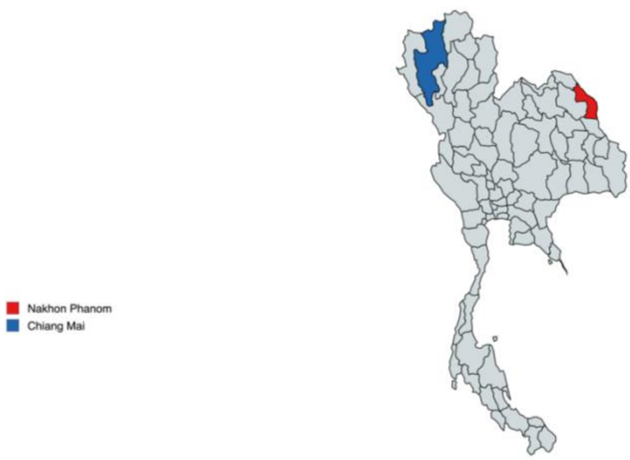

Figure 33: Location of interviewees (source: BCI, 2024)

The interviews were conducted between December 2024 and January 2025. It is noteworthy that interviewees in remote locations may be contacted by telephone or may fill in an online questionnaire. The farmer survey utilised transparent and replicable data collection processes, ensuring that the methodology could be reproduced in similar contexts.

Furthermore, the survey incorporated multiple ethical considerations to ensure the protection of respondents and the integrity of the data:

- Farmers were informed of the survey's purpose, procedures, and potential benefits, ensuring informed consent was obtained prior to participation;
- Interviewers followed the guidelines and protective measures of Thammasat University, our local partner that conducted the survey, and Nakhon Phanom University regarding voluntary participation and right to withdraw; and
- Anonymised data to protect personal and sensitive information to respect the respondents' privacy and confidentiality.

Additionally, a particular attention was paid to the specific experiences, interest, and requirements of female farmers, with a representative number of female farmers (59%) included to ensure their voices were heard, aligning with ethical research practices and gender inclusivity principles.

Preliminary results were delivered for the first workshop in January 2025.

Representativeness of the sample

This study involved 150 respondents from two provinces in Thailand, each representing distinct agricultural regions. Nakhon Phanom, located in the northeastern region (Isaan), is characterized by rice and cassava farming and is frequently affected by drought. Chiang Mai, in the northern region, boasts diverse agricultural activities, including fruit and vegetable cultivation. Selecting these regions captures a wide spectrum of climate risks and farming practices, offering a comprehensive representation of Thailand's agricultural sector.

The geographic and agricultural diversity of these provinces ensures the survey findings reflect a broad range of climate vulnerabilities and insurance needs. This diversity enhances the accuracy of insights into Thai farmers' preparedness for a blockchain-based parametric crop insurance (BBPI) solution.

As an exploratory study, the research aims to gather initial insights into the feasibility of implementing BBPI. The survey results highlight key challenges—such as awareness of blockchain technology, willingness to adopt insurance, and financial capabilities—and inform decision-making for potential implementation. **A sample of 150 respondents is sufficient to identify patterns, preferences, and barriers that can guide further research and policy development.** According to the renowned Japanese statistician Taro Yamane, a sample size of 150 is often considered adequate for descriptive statistics and exploratory analysis, with a 95% confidence level and a 5–10% margin of error. Moreover, Thai farmers share a degree of homogeneity in variables central to this study, such as crop types, exposure to climate risks, and access to technology. This homogeneity ensures the sample size provides a representative and reliable assessment of the farming community, allowing valid generalizations.

The structured approach of this study offers statistically meaningful insights into crop insurance awareness and readiness. For example, it identifies patterns, such as whether smallholder farmers are aware of crop insurance products. While the sample size may not detect minor subgroup differences, it is sufficient to reveal broader trends. The survey findings remain reliable and comparable, supporting both the current study and future research initiatives.

Adequacy of survey design for general insights

The questionnaire was structured in a manner to address critical issues such as farmers' experiences with climate impacts, their knowledge of crop insurance, and their readiness to adopt BBPI. It included various aspects such as farming business performance, income levels, climate risk assessments, and interest in blockchain insurance, ensuring a comprehensive view of farmers' situations and expectations. The rigorous design of the questionnaire enabled the collection of relevant, high-quality data, allowing for an in-depth analysis of the surveyed farmers' needs and readiness for modern insurance solutions.

The data collected from the 150 respondents were rigorously analyzed to provide a clear understanding of farmers' perceptions and needs. The data analysis process included:

- cross-checking responses for consistency;
- segmenting respondents based on geographic location, gender, and farming practices;
- using the frequency analysis method (count the number of respondents who selected each answer option for each multiple-choice question then converting frequency counts into percentages to make comparisons easier) to identify patterns and trends; and
- further validating the survey findings by comparing them with external climate and agricultural datasets (rainfall patterns, drought and flood data, farmer income data, etc.) to ensure alignment with real-world scenarios.

The data collected were cleaned, categorized and contextualized. This comprehensive approach allowed for meaningful insights to be drawn, enhancing the credibility of the survey results and providing a strong foundation for further analysis in the context of blockchain-based parametric crop insurance.

Cost and feasibility considerations

Considering that surveys in rural or agricultural settings can be expensive and time-consuming, a sample of 150 farmers balances practical feasibility with statistical power. While larger sample sizes provide more precise estimates, diminishing returns often set in after a certain point. In many cases, increasing the sample size beyond 150 may not lead to significantly different conclusions but will increase costs disproportionately.

It is worth noting that a privileged relationship between local experts and Thai agricultural sector actors is responsible for a high response rate of 97,40% minimizing cost and maximizing quality. Survey results were regularly monitored to ensure data completeness and accuracy, and any discrepancies or incomplete responses were addressed during data collection. Additionally, the use of a digital platform to track and store responses enabled efficient validation and verification, contributing to the overall data integrity and reliability of the survey outcomes.

Avoidance of bias

By involving farmers from two representative provinces, the survey avoids *geographical bias* and ensures that the data reflects a broad spectrum of experiences and challenges faced by Thai farmers.

Additionally, the survey targeted a representative share of female farmers to ensure gender inclusion, which helps mitigate *gender bias* in the results. This approach ensures that the perspectives of various segments within the farming community, including small-scale farmers and agricultural entrepreneurs, are well-represented, contributing to a balanced and unbiased understanding of the overall readiness for blockchain-based parametric crop insurance.

7.3 - Results

To assess the exposure of Thai farmers to climate-related risks, their experiences with crop insurance products, and their readiness for adopting a blockchain-based parametric crop insurance system, we analyzed the data from 150 completed questionnaires. The following results provide critical insights:

1. Demographics: As requested in the terms of reference of this technical assistance, a representative share of female farmers was targeted in this survey. 62 male respondents (41%) and 88 female respondents (59%) were interviewed.

2. Farmers' awareness and understanding:

   - Knowledge of crop insurance: Only 21 out of 150 respondents were cognizant of agricultural crop insurance.

     The fact that only 14% of the respondents were aware of agricultural crop insurance suggests a significant knowledge gap among farmers regarding the availability and benefits of crop insurance products. Such a low awareness rate implies that many farmers may not have access to critical information about risk mitigation tools, leaving them vulnerable to climate-related risks. This could be due to limited outreach or education efforts from insurers, government programs, or other intermediaries, highlighting a key area for improvement in promoting crop insurance products to farmers in rural and remote areas.

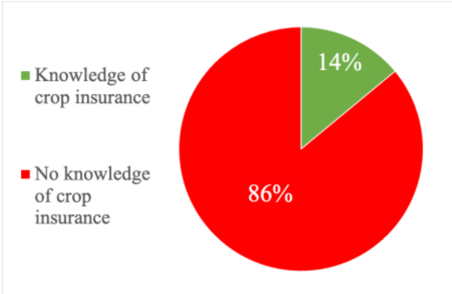

Figure 34: Farmer survey - knowledge of crop insurance

- Experience with crop insurance: 19 out of 150 farmers interviewed (or 13% of respondents) had purchased crop insurance over the past 5-10 years, indicating low engagement with available products.

  This low engagement rate suggests that even among farmers who are aware of insurance products, adoption remains limited. We can suppose that the reasons for this low uptake may include:

  - Perceived cost barriers: Farmers might consider premiums too high relative to their income or the perceived value of coverage.
  - Limited product accessibility: Farmers may find the insurance products complex, difficult to access, or not adequately tailored to their specific crop types or climate risk exposures.
  - Mistrust or dissatisfaction: Farmers who have experienced delays in claims processing or inadequate payouts in the past may be reluctant to repurchase insurance.

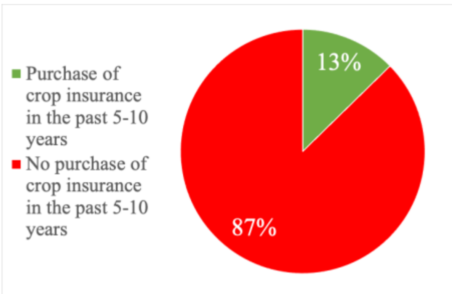

Figure 35: Farmer survey - experience with crop insurance

The low level of both awareness and engagement with crop insurance reflects broader challenges in Thailand's agricultural sector. It signals the need for targeted education and awareness campaigns, as well as a re-evaluation of the accessibility, affordability, and perceived value of existing crop risk insurance products.

Given these results, it is crucial to address such inadequate awareness and adoption as part of any strategy aimed at introducing blockchain-based parametric crop insurance. Blockchain technology has the potential to simplify and improve the insurance process by offering:

- Faster payouts: Automated, transparent payouts triggered by predefined weather events;
- Greater trust: Transparent smart contracts can reduce mistrust in the claims process; and
- Simpler access: Digital platforms could lower administrative barriers, making it easier for farmers to enroll and manage insurance policies.

However, for this potential to be realized, substantial efforts must be made to increase awareness and provide clear, accessible education about both traditional and blockchain-based crop insurance. The low engagement with insurance may also suggest a need for products that better address the specific needs of farmers, such as more affordable premiums, simpler processes, and more reliable payouts.

Additionally, as blockchain adoption may require access to technology (such as mobile phones and mobile wallets), further surveys and outreach should assess and address potential barriers to digital literacy and technology access among farmers, particularly in rural areas.

3. <u>Sources of financing:</u> Agricultural production activities (commodity cultivation, livestock farming, etc.) were predominantly financed through personal savings (78 households), followed by bank loans (30 households) and other means.

   Around 52% of respondents rely predominantly on personal money to finance their agricultural activities. Many farmers operate on self-funded systems, potentially due to limited access to formal financial services. Meanwhile, 20% of respondents reported financing their agricultural activities through bank loans, indicating that formal financial institutions are not the primary source of capital for most farmers, not to mention the availability of formal financing sources for crop risk insurance products.

   This may be attributed to barriers such as limited credit access, complex loan application processes, or high interest rates. The remaining households used other forms of financing, such as borrowing from informal sources or community cooperatives.

   These findings highlight a possible financial vulnerability among farmers, especially when faced with unexpected expenses such as crop losses due to climate-related impacts. Farmers may be reluctant to take on formal loans, perhaps due to uncertainty about their ability to repay or the high risk of crop failure, which further increases the importance of accessible and affordable crop insurance options.

4. <u>Impact of changing climate patterns:</u> A staggering 148 households reported experiencing crop damage due to climate-related impacts, emphasizing the need for adequate crop insurance.

   An overwhelming majority of respondents (99%) reported experiencing crop damage due to climate-related impacts. This overwhelming percentage emphasizes the critical need for effective risk management tools, such as crop insurance, to mitigate the financial losses associated with extreme weather events, droughts, floods, and other climate risks. **These results clearly underscore the urgency for insurance solutions that can offer timely payouts and protection against climate-induced crop damage.**

The high incidence of climate-related damage among farmers indicates that they are highly vulnerable to the unpredictability of weather patterns. **However, given the earlier findings that only 14% of households had purchased crop insurance, it becomes evident that there is a disconnect between the high exposure to risk and the low engagement with available risk mitigation products.** This could point to financial barriers, lack of trust, or limited knowledge of existing insurance schemes.

5. Readiness for blockchain-based parametric crop insurance: Most farmers (115 households) own mobile phones, primarily using 4G (66 households) and 5G (49 households) standards.

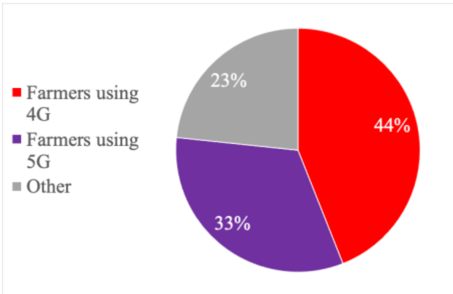

Figure 36: Farmer survey - readiness for blockchain insurance

Approximately 77% of respondents own mobile phones. This is a positive finding as mobile phone ownership is a critical enabler for accessing blockchain-based parametric crop insurance, which is expected to operate through mobile platforms for registration, monitoring, and payouts. The high rate of mobile phone ownership suggests that most farmers already possess the basic infrastructure required to engage with digital insurance products. However, for effective use of a blockchain-based platform, factors such as digital literacy, awareness of mobile applications, and comfort with financial technology may need to be assessed in greater detail to ensure that farmers are not only equipped with the necessary tools but are also capable of utilizing them effectively.

Moreover, most farmers are using relatively modern mobile network standards, with strong connectivity and faster internet speeds. This is highly favourable for the implementation of blockchain-based insurance, as it requires consistent and reliable access to the internet for real-time updates, smart contract executions, and the use of decentralized platforms. 4G and 5G networks are more than adequate for supporting mobile-based blockchain applications. Farmers with these networks should be able to seamlessly access and interact with the platform, check weather data, receive payouts, and manage their insurance policies without significant connectivity issues.

6. Understanding of crop insurance: Only 54 households understood crop insurance's advantages, with many (96 families) lacking this understanding.

Only 36% of respondents were aware of the advantages of crop insurance, while the remaining 64% lacked a clear understanding of how crop insurance can benefit them. This low level of awareness about the specific benefits of crop insurance—such as protection against crop loss due to climate events, income stabilization, and financial security—points to a significant gap in farmer education on risk management tools.

The fact that 64% of respondents are unfamiliar with the advantages of crop insurance suggests that many farmers may not fully appreciate how such products can safeguard their livelihoods. This knowledge gap could also contribute to the low uptake of insurance observed in other survey findings, where only 13% of farmers had purchased crop insurance in the past.

7. Needs and willingness to purchase:

(a) Reasons for not purchasing insurance: Of the respondents who had not purchased any crop insurance, the most common barriers to insurance uptake include a lack of awareness (81 households), followed by high premiums and complicated processes.

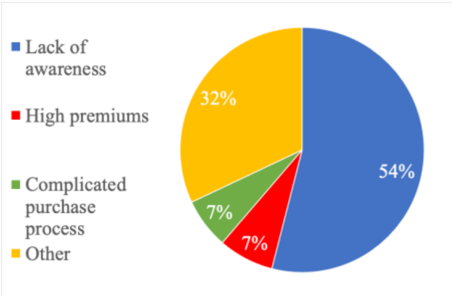

Figure 37: Farmer survey - reasons for not purchasing a crop insurance

Around 54% of respondents indicated that they had not purchased insurance due to a lack of awareness about its availability, advantages, and benefits. This confirms that educational outreach is a major hurdle in preventing the widespread adoption of crop insurance among Thai farmers. The lack of information likely leaves many farmers unaware of how insurance can protect them from crop losses due to climate risks.

(b) High premiums: Some farmers also cited high premiums as a barrier, reflecting concerns about the affordability of insurance products. This indicates that current pricing is perceived as being beyond the financial reach of many farmers, particularly those with smaller farms or lower income levels.

(c) Complicated processes: Another factor discouraging insurance uptake is the perception of complex processes involved in purchasing or managing crop insurance policies. Farmers may find existing procedures for enrollment, claims, or payouts to be too complex or time-consuming, which can deter participation.

(d) Willingness to purchase: A significant majority - 123 households - expressed willingness to purchase crop insurance if it is priced reasonably and accompanied by better educational processes.

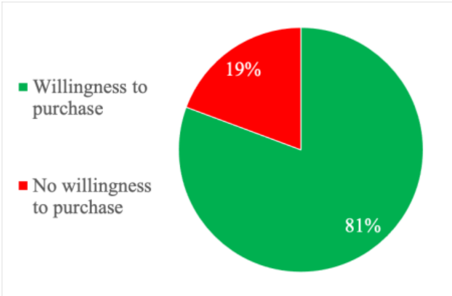

Figure 38: Farmer survey - willingness to purchase

Despite these barriers, 81% of respondents expressed willingness to purchase crop insurance, provided that the premiums are reasonable, and the processes are simplified. This indicates a clear demand for crop insurance among farmers, as they are aware of the risks posed by climate impacts and are open to adopting insurance products that offer affordable protection and easy-to-navigate systems. This high level of willingness is an encouraging sign, suggesting that if the right conditions are met, farmers are ready to invest in crop insurance to protect themselves from financial losses due to unpredictable weather events and climate risks.

8. Affordable premiums: Most farmers (116 households) believe they can afford less than 2% of their crop value premiums. Approximately 77% of respondents believe they can afford premiums amounting to less than 2% of their crop value. For example, farmers could afford up to THB 71/rai (1 rai = 0.16 hectare). This finding highlights the price sensitivity among farmers when it comes to purchasing crop insurance. Most farmers seem to have limited financial flexibility and are only willing to invest in insurance if it is offered at a relatively low cost.

   The fact that such a large proportion of farmers have set their affordability threshold at under 2% of crop value underscores the need for insurance products that are not only effective in protecting against climate-related risks but also affordable enough for widespread adoption. If premiums exceed this threshold, many farmers may find it financially unfeasible to purchase insurance, leaving them vulnerable to climate-related crop losses.

9. Desired coverage: The key risks which farmers demand insurance to cover include droughts (125 households), floods (117 households), insect infestations (116 households), and price fluctuations (113 households).

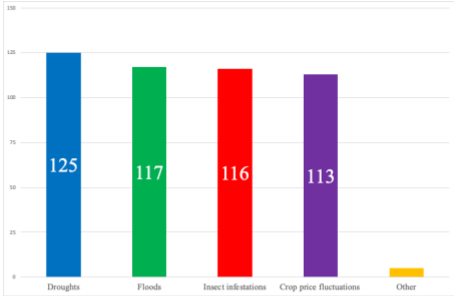

Figure 39: Farmer survey – desired coverage

- 83% cited droughts as a major risk for which they need coverage. This suggests that drought is a widespread and significant climate-related hazard in Thailand's agricultural sector, likely exacerbated by changing weather patterns due to climate change. Farmers recognize the devastating impact that droughts can have on crop yields, leading to financial instability and food insecurity. Therefore, drought coverage is a top priority for most respondents.

- 78% identified flood risk as another key area where insurance is needed. Floods, like droughts, are highly disruptive, causing direct crop damage and potentially destroying entire harvests. Thailand, being prone to seasonal flooding in certain regions, especially during monsoons, makes it crucial for farmers to protect their livelihoods against this risk.

- 77% expressed interest in insurance coverage for insect infestations. Pests can severely damage crops, leading to reduced yields and increased costs for pest control. Insect infestations are another significant threat, particularly in a warming climatic pattern where pest populations can become more widespread and harder to control. Farmers, therefore, see the value in protecting themselves against this unpredictable risk.

- 75% also wanted coverage for price fluctuations in agricultural markets. Market volatility can significantly impact farmers' income, even if their crops are unaffected by climate risks. Prices of crops can fluctuate due to supply and demand factors, market conditions, and even global economic trends. Farmers appear concerned about their ability to maintain a stable income amid such fluctuations and seek insurance solutions that offer protection against financial losses due to falling crop prices.

10. <u>Recommendations for improvement in the crop insurance program:</u>

- Farmers suggested simplifying the process (125 households), lowering premiums (99 households), and enhancing awareness campaigns (122 households) as key recommendations for improving any crop insurance program.

  - 83% of respondents recommended simplifying the crop insurance process. This indicates that many farmers perceive the current process of enrolling in crop insurance, submitting claims, or understanding the policies as overly complicated. This complexity likely discourages participation and could explain why only a small percentage of the surveyed farmers have purchased crop insurance in the past. Streamlining processes—through simpler policy terms, easier claims filing procedures, and more user-friendly platforms—could greatly enhance the program's accessibility and appeal.

  - 66% of respondents suggested lowering premiums as an important improvement. This feedback aligns with the earlier finding that a significant proportion of farmers can only afford premiums of less than 2% of their crop value. The current pricing structure may be unaffordable for many farmers, especially those with smaller farms or lower incomes. By addressing the cost barrier through more affordable premiums or introducing subsidies, more farmers might be encouraged to purchase insurance and benefit from the protection it provides.

  - 81% of respondents stressed the importance of enhancing awareness campaigns. The survey revealed that many farmers lack sufficient knowledge of crop insurance and its benefits, which limits uptake. Improved education and outreach efforts—such as workshops, informational brochures, and mobile-based campaigns—could help farmers better understand how insurance works, its advantages, and how to enroll. By increasing awareness and knowledge, farmers would be more likely to make informed decisions about protecting their crops.

- A total of 119 households were supportive of the call for faster claim payments.
  - 79% of respondents expressed a need for faster claim payments. Slow payouts can be a major issue for farmers, especially after suffering a climate-related disaster. Timely payments are critical to helping farmers recover quickly and minimize financial losses. The delay in payouts might discourage farmers from purchasing insurance, as they may feel that it does not provide the immediate assistance they need after a loss. Implementing a more efficient claim.

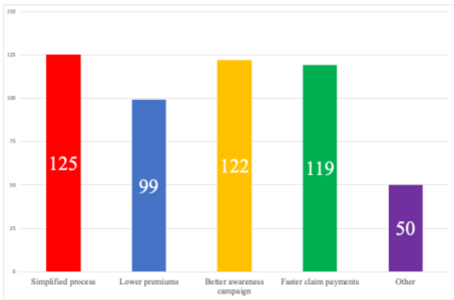

Figure 40: Farmer survey - desired improvements in crop insurance

11. Recommendation among peers: A substantial majority (129 households) would recommend crop insurance to other farmers, indicating a potential for positive word-of-mouth if the product offerings improve.

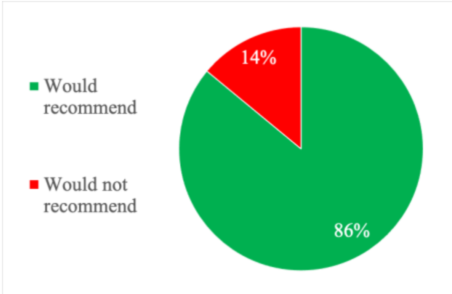

Figure 41: Farmer survey - recommendation among peers

- 86% of respondents would recommend crop insurance to their fellow farmers. **This finding is significant because it demonstrates a generally positive perception of crop insurance, even though current participation rates are relatively low.** This suggests that, despite existing barriers such as complex processes, high premiums, and lack of awareness, farmers recognize the potential value and importance of insurance in protecting their livelihoods from climate risks.

- The high level of willingness to recommend crop insurance indicates that, if improvements are made to the product offerings (as outlined in previous recommendations), the adoption of crop insurance could increase significantly through positive word-of-mouth among the farming community. Farmers are more likely to trust and follow the advice of their peers, especially when it comes to financial products like insurance. A strong peer recommendation network could be an effective tool for expanding the reach of crop insurance programs.

7.4 - Key takeaways from the survey findings

The high prevalence of climate-related risks among farmers underscores the urgent need for an effective and accessible crop insurance solution. A BBPI system, which automates payouts based on pre-defined triggers like rainfall or temperature thresholds, offers a promising way forward. Its transparency, speed, and ability to streamline claims address key shortcomings of traditional insurance, such as delays and bureaucratic complexity. However, affordability remains a critical barrier, as many farmers rely on personal funds. Financial inclusion measures, such as subsidized premiums or government support, will be essential to make insurance accessible to all.

Farmers in surveyed regions are technologically ready for blockchain solutions, given high mobile phone ownership and widespread 4G/5G networks. A mobile-first approach aligns well with this population, but successful adoption will require addressing digital literacy, ensuring inclusive design, and building trust through pilot programs and transparent communication. Additionally, the limited understanding of crop insurance benefits poses a significant challenge. Targeted education campaigns, tailored messaging, and hands-on training are crucial to raising awareness and demonstrating the value of parametric insurance in mitigating climate risks.

A blockchain-based system can effectively address farmers' key barriers: lack of awareness, cost concerns, and complex processes. Automating claims through smart contracts, it simplifies processes and enables faster payouts, while reduced administrative costs can lower premiums, making insurance more affordable. Customizable coverage options—such as protection against drought, floods, pests, and price fluctuations—allow farmers to tailor policies to their specific needs, enhancing relevance and appeal.

Finally, the willingness of farmers to recommend crop insurance presents a valuable opportunity to drive adoption. Leveraging positive word-of-mouth, building trust through peer networks, and showcasing farmer testimonials can accelerate uptake. By addressing affordability, simplifying processes, and enhancing awareness, a blockchain-based parametric crop insurance system has the potential to transform agricultural risk management, providing farmers with timely, reliable, and accessible protection against climate-related uncertainties.

8 - CONCLUSION

Thailand's agricultural sector faces increasing threats from climate change, including more frequent and severe droughts, floods, and temperature fluctuations. These risks endanger millions of farmers' livelihoods, food security, and the country's economic stability. To address these challenges, Thailand needs a comprehensive approach involving legislative reforms, technological innovations, financial mechanisms, and international collaboration.

Key priorities for the Thai government include enhancing climate resilience policies, promoting climate-resilient crops, and improving disaster risk management. Expanding insurance coverage, particularly weather-indexed insurance, and leveraging technologies like precision agriculture, drones, and BBPI will help optimize resource management and financial protection for farmers. Weather-indexed insurance, unlike traditional crop insurance, provides payouts based on specific weather conditions—such as rainfall or temperature—rather than waiting for damage assessments. This approach accelerates payouts, offering quick financial relief to farmers when they need it most (Sugiarto et al., 2017).

While Thailand and other Southeast Asian countries have piloted weather-indexed and crop insurance programs with some success, adoption remains low among smallholder farmers. High premiums, limited understanding of insurance products, and a general mistrust of insurance providers are common barriers (Takahashi et al., 2016). To increase uptake, Thailand could subsidize premium costs for small-scale farmers and implement financial literacy campaigns to raise awareness of the benefits and mechanics of insurance schemes. By expanding access to affordable insurance, Thailand can provide its farmers with a critical safety net against climate risks, promoting long-term resilience.

Moreover, blockchain technology offers an opportunity to enhance transparency and efficiency in climate risk insurance. BBPI can automate claim processing, allowing farmers affected by extreme weather events to receive payments promptly. Using blockchain-stored weather data ensures fair and equitable compensation for farmers, improving their financial resilience to climate disasters.

The global mapping of blockchain-based crop insurance products offers valuable insights into the opportunities and challenges of implementing such initiatives. Successful projects like *Etherisc, Lemonade Crypto Climate Coalition,* and *Arbol* showcase blockchain's transformative potential in enhancing transparency, automating claims, and improving insurance access for smallholder farmers. However, these initiatives also highlight critical barriers, including high implementation costs, limited farmer adoption due to low digital literacy, and regulatory complexities. Conversely, less successful projects like AgriSure emphasize the importance of addressing integration issues, scalability challenges, and stakeholder engagement. These lessons underscore that the success of blockchain-based insurance hinges on robust data infrastructure, tailored solutions, and strong collaborations with governments and local communities.

Thailand's BBPI initiative is uniquely positioned to leverage these insights. By integrating advanced blockchain technology with real-time data, conducting comprehensive farmer training programs, and accessing diverse funding sources, the initiative can overcome common pitfalls and set a new standard for climate-resilient agricultural insurance. This comprehensive approach ensures the scalability, sustainability, and relevance of the solution, not only for Thailand but also as a potential model for other countries in the region and beyond.

Key conditions for the success of BBPI include addressing the low awareness and adoption of insurance, improving farmers' readiness for blockchain-based solutions, and tackling affordability concerns. Farmers expressed a strong preference for simplified insurance processes, lower premiums, and quicker claim settlements. With 77% of respondents being tech-ready, owning smartphones, and using mobile banking, there is potential for leveraging mobile platforms to deliver insurance services. However, achieving success will require targeted awareness campaigns, training programs to enhance digital literacy, and partnerships with government and local cooperatives to promote trust in the system and ensure it meets the specific needs of Thai farmers.

Indeed, though a significant majority of Thai farmers are vulnerable to climate risks such as drought and flooding, yet only 14% are aware of crop insurance, and 16% have ever purchased it. These findings underscore a substantial gap in insurance coverage and awareness, highlighting the need for more accessible and transparent insurance products tailored to the needs of farmers. The survey also found that 52% of households rely on personal funds for farming, while 99% reported crop damage from climate-related events in recent years.

In addition to blockchain technology, the use of AI in precision agriculture technologies offers transformative potential for optimizing resource use and boosting productivity in Thailand's agricultural sector. Technologies such as drones, soil sensors, and AI-driven platforms enable real-time monitoring of crop health, soil conditions, and water levels, helping farmers make data-driven decisions that reduce input wastage and improve yields. For example, drones can quickly identify early signs of crop stress, allowing farmers to intervene before losses occur.

By investing in these technologies, Thailand can enhance food security, reduce the environmental footprint of conventional farming, and better equip its farmers to face the challenges of a changing climate.

Capacity-building programs, such as farmer education initiatives, are also crucial for improving climate adaptation behaviors among farmers. Evidence from other Southeast Asian countries shows that education significantly enhances resilience outcomes. Implementing similar programs in Thailand, which blend traditional farming knowledge with modern techniques, would empower farmers to respond more effectively to climate risks. By promoting climate-resilient practices and integrating innovative technologies, education programs can enhance the long-term sustainability of Thailand's agricultural sector. These initiatives, combined with blockchain-based insurance and precision agriculture technologies, can create a comprehensive and robust framework for climate adaptation in Thailand.

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ANNEXES

SURVEY QUESTIONNAIRE

General

1. Could you please tell us about your household?
    a. Please tell us of your household members living together with you in your house.
    b. Please tell us about the children who are not living in your house.

Farming activities

2. Could you please tell us about your house and land?
    a. How large is your house land here (including the land occupied by other houses)?
    b. Do you own the land?
    c. What are the details of the house?
3. Could you please tell us about your farmland?
    a. How many plots of agricultural land does your household own during the last crop year [2022.4-2023.3]?
    b. How much surface of the paddy field is enough for self-sufficiency?
4. Could you tell us about your farming activity?
    a. Are you a member of a large-scale community rice production company?
    b. Are you a member of Krum Khao?
    c. Can you give details about the wet season paddy cultivation?
5. What is your utilization of fertilizers and other agricultural chemicals?
6. What is the yield and disposal of paddy and other crops during the last crop year 2022.04-2023.03?
7. Do you have other farm-based livelihoods?
8. What is your rice consumption?
9. What is your income?

a. How much did each of your household members earn from agriculture and other work during the last crop year [2022.4-2023.3]?

10. Specific questions for women:

    a. What is your status?

    b. Are you the decisionmaker in household spending and investment?

    c. Did you have equal opportunity to attend school?

    d. Do you have access to family resources for learning?

Finance

11. Do you know about the agricultural crop insurance program?
12. How do you finance your farming activities?
13. In the past 5-10 years, has your crop been damaged by drought, flood, pest, heat (high temperature)?

Crop insurance

14. In the past 5-10 years, have you paid for crop insurance?
15. If you paid for crop insurance, for which crop did you buy insurance?
16. If you paid for crop insurance, how did you learn about it?
17. If you paid for crop insurance, how long did you wait for the payout?
18. If you paid for crop insurance, have you spent a lot of time and energy on paperwork for the payout?
19. Regarding blockchain-based crop insurance, what is your readiness level?
20. Do you know the benefits of crop insurance?
21. Are you aware of any government schemes for crop insurance?
22. Have you ever purchased crop insurance?
23. If you never paid for crop insurance, what are the reasons?
24. Would you be willing to purchase crop insurance if it were affordable?
25. What premium amount would you consider affordable?
26. What type of risks would you like crop insurance to cover?
27. How would you prefer to pay for the premium?

28. What improvements would you like to see in crop insurance schemes?

29. Would you recommend crop insurance to other farmers?

30. Any additional comments or suggestions regarding crop insurance?

Access to digitalization

31. Do you own a mobile phone?

32. If you own a mobile phone, what type of mobile phone?

33. What is your mobile phone operator?