ADB

JFPR Japan Fund for Prosperous and Resilient Asia and the Pacific

From the People of Japan

ADB TA-9993 THA: Climate Change Adaptation in Agriculture for Enhanced Recovery and Sustainability of Highlands

Documentation of Climate-Smart Agriculture (CSA) Demonstration Process

AIT Asian Institute of Technology

NIPPON KOEI

TEAM GROUP

TA 9993-THA: Climate Change Adaptation in Agriculture for Enhanced Recovery and Sustainability of Highlands

Knowledge Product

Documentation of Climate-Smart Agriculture Demonstration Process

February 2025

Project Name: Climate Change Adaptation in Agriculture for Enhanced Recovery and Sustainability of Highlands
Project No.: TA 9993-THA
Recipient: Asian Development Bank (ADB) and Office of Agricultural Economics (OAE)
Document Type: Knowledge Product - KP6
Version: 3
Date: 6 February 2025
Contributing Authors: Nathsuda Pumijumnong

Foreword

Improper farming practices in the highlands have caused continual and severe degradation of natural resources. Additionally, unpredictable climatic conditions have negatively impacted agricultural production in these regions, further exacerbating the issue. One promising solution is climate-smart agriculture (CSA), which promotes sustainable farming practices tailored to highland areas.

The Bua Yai Subdistrict in Na Noi District, Nan Province, is a demonstration site where various CSA techniques have been implemented. These include solar-powered irrigation systems, keyline plowing, and the use of biochar. Preliminary evaluations show that solar-powered irrigation systems can reduce greenhouse gas emissions by up to 3,067 kg CO2e per hectare. These systems also help farmers adapt to climate change by enabling year-round crop cultivation and improving food security in highland areas. Keyline plowing, in particular, has proven effective in retaining soil moisture for extended periods, especially in areas with gentle slopes. Demonstration plots have shown that soil moisture levels can be up to 1.5 times higher with keyline plowing compared to untreated areas, depending on the slope and water availability. Additionally, combining solar irrigation, biochar, and microbial fertilizers have been shown to double soil moisture retention compared to areas without CSA practices, increasing plant growth in height and diameter by 1.2 times.

An economic analysis comparing CSA and conventional cacao cultivation examined three discount rates. The net present value (NPV) of net profits for CSA cacao is 1,899,235.30, 1,376,206.89, and 1,175,998.73 THB at discount rates of 3.5%, 5.0%, and 8.0%, respectively. The internal rate of return (IRR) values exceeds the corresponding discount rates, indicating significant net benefits from CSA cacao cultivation. The NPV represents the total net profit after accounting for the time value of money.

The benefit-cost ratios (BCRs) for CSA cacao cultivation range from 4.12 to 4.38, suggesting that for every 1 THB invested, there is a return of approximately 4.12 THB at an 8.0% discount rate. A BCR more significant than 1 confirms the financial viability of CSA cacao cultivation. The payback period for CSA cacao cultivation is four years, meaning cumulative net returns become positive in the fourth year, fully recovering the initial investment.

Similarly, an economic analysis comparing CSA and conventional avocado cultivation at three discount rates shows that the NPV for CSA avocados is 1,595,901.68, 1,165,251.01, and 480,473.82 THB at discount rates of 3.5%, 5.0%, and 8.0%, respectively. The IRR values exceed these discount rates, highlighting the profitability of CSA avocado cultivation. The BCRs for CSA avocado cultivation range from 7.68 to 8.58, indicating that every 1 THB invested yields approximately 7.68 THB at an 8.0% discount rate. The payback period for CSA avocado cultivation is three years, as cumulative net returns become positive in the third year.

While CSA practices can reduce greenhouse gas emissions, enhance resilience to climate change, and boost farmers' productivity, their adoption in other highland agricultural areas remains limited. This is mainly due to high initial investment costs and low market confidence. To address these challenges, we advocate for incorporating climate-smart agriculture into Thailand’s agricultural adaptation plans for climate change. Relevant agencies must continuously evaluate the implementation of CSA practices to ensure tangible and measurable outcomes.

Contents

Tables

Figures

1. Situational Assessment

1.1 Unique Challenges in the Highland Regions

According to the Royal Decree on the Establishment of the Highland Research and Development Institute (Public Organization) B.E. 2548, a highland is defined as "a mountainous area or an area with an elevation of 500 meters or more above sea level, or an area located between highland areas as determined by the committee."[1]

Thailand's highlands span approximately eight provinces: Chiang Mai, Chiang Rai, Mae Hong Son, Phayao, Phrae, Nan, Lampang, Phetchabun, and Loei. Most highland communities are situated within watershed forest areas. About 88% of these villages face transportation challenges, making it difficult for government agencies to access and work in these regions. Moreover, the highlands face persistent issues such as shifting cultivation and forest encroachment.

1.2 Challenges Facing Thailand's Highland Areas

Thailand's highland areas face several critical issues that affect the livelihoods and well-being of local communities. Key challenges include:

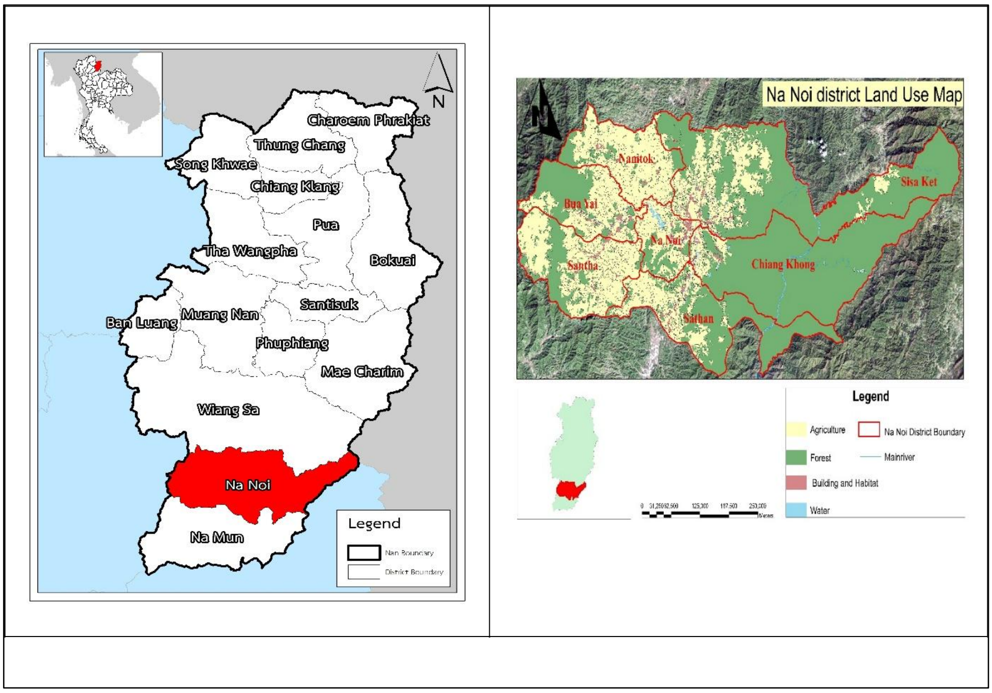
(1) **Deforestation and Land Degradation**. The conversion of forest land to agricultural use, particularly for cash crops, has resulted in significant deforestation and soil erosion. These activities harm biodiversity and disrupt ecosystems.
(2) **Climate Change Vulnerability**. Highland regions are increasingly affected by climate change, including unpredictable weather patterns, droughts, and soil degradation, which have adverse impacts on agricultural productivity and food security.
(3) **Poverty and Economic Challenges**. Many highland communities experience poverty and have limited access to markets, healthcare, and education. Dependence on subsistence agriculture often perpetuates this cycle of poverty.
(4) **Cultural and Social Issues**. Ethnic minority groups in the highlands often face marginalization and discrimination, limiting their access to resources, participation in decision-making, and support services.
(5) **Infrastructure Deficiencies**. Poor infrastructure, including inadequate roads and limited access to essential services, hinders economic development and restricts these communities' access to markets, education, and healthcare.
(6) **Biodiversity Loss**. Agricultural encroachment and urbanization have caused habitat loss and degradation, threatening the rich biodiversity found in Thailand's highland ecosystems[2, 3].

1.3 Addressing the Needs of Target Communities

Nan Province, located in northern Thailand, is one of the 77 provinces in the country. It spans approximately 12,000 square kilometers and is characterized by its elongated shape and mountainous terrain, except for the southern region. Identifying and understanding the needs of target communities in Nan Province is essential for developing sustainable solutions to the challenges faced in Thailand's highlands.

[1] https://www.hrdi.or.th/about/Highland
[2] IUCN Report: (https://www.iucn.org/content/highland-peoples-and-conservation-thailand)
[3] UNDP Report: (https://www.th.undp.org/content/thailand/en/home/library/environment_energy/highland-communities.html)

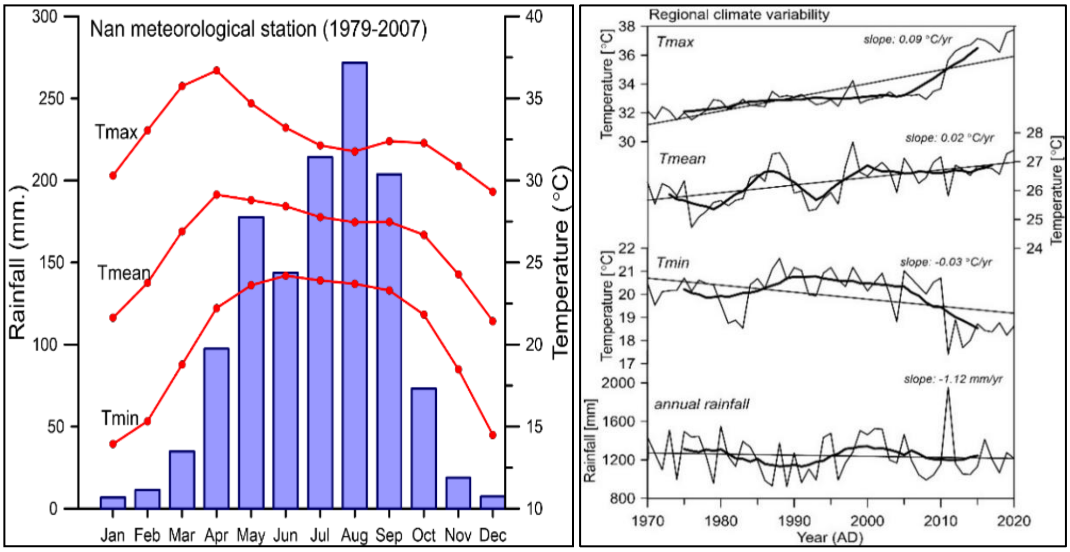
Figure 1:
Project area map.



1.3.1 Topography and Climate

Nan Province accounts for one-third of the Nan River Basin, which flows from north to south and joins the Ping, Wang, and Yom Rivers to form the Chao Phraya River in Nakhon Sawan Province. The lowlands (< 400 m) occupy about 18% of the province's area, while elevations greater than 800 m cover approximately 40%. The highest altitude of 1,980 m above mean sea level is in Doi Phu Kha National Park. Nan Province has a tropical savanna climate. Winters are relatively dry and very warm. Temperatures rise until April, which is very hot, with the average daily maximum reaching 37.0°C. The monsoon season runs from late April through October, with heavy rain and somewhat cooler temperatures during the day, although nights remain warm (Figure 2)[4].

Figure 2:
Climate diagram of Nan Province during 1979–2007.



[4] Nan Meteorological Station, 2020

1.3.2 Provincial Government

The province is divided into 15 districts. These are further divided into 99 sub-districts and 848 villages. The districts are: 1) Mueang Nan, 2) Mae Charim, 3) Ban Luang, 4) Na Noi, 5) Pua, 6) Tha Wang Pha, 7) Wiang Sa, 8) Thung Chang, 9) Chiang Klang, 10) Na Muen, 11) Santi Suk, 12) Bo Kluea, 13) Song Khwae, 14) Phu Phiang, and 15) Chaloem Phra Kiat.

1.3.3 Population

The 2019–2020 population of Nan Province was 478,227 persons[5], comprising approximately 170,000 households across 924 villages/communities, 99 sub-districts, and 15 districts, with an average of three members per household. Fifty-five percent of households were engaged in agriculture.

The agricultural sector contributed about 32% of the Gross Provincial Product (GPP)[6]. The mean population density was low (39 persons/km²) compared to the national population density (130 persons/km²), primarily due to mountainous topography, considered a barrier to economic development. Poverty continues to be a significant social problem in the province. In 2015, 28.8% of Nan's population lived under the poverty line (USD 1,057 per person per year in 2015), significantly higher than the national proportion of 8.6%[7]. A higher density of households living in poverty was observed in steeper terrains due to low agricultural incomes and a lack of job opportunities.

1.3.4 Economy

In 2019, the gross domestic product (GDP) of Nan Province was valued at 34.63 billion baht. This total comprised 9.953 billion baht from the agricultural sector and 24.677 billion baht from the non-agricultural sector. The agriculture, forestry, and fisheries sectors were the primary contributors to the provincial economy, accounting for 28.7% of the GDP. This was followed by wholesale and retail trade and vehicle repair, which contributed 12.3%. Education represented 10.8%, financial and insurance activities accounted for 9.1%, and administration, defense, and compulsory social security made up 8.7%. Other sectors collectively contributed 30.4%.

The crop sector produced the largest amount of agricultural goods, accounting for 80.5% of the farming GPP. The livestock sector accounted for 9.0%, agricultural services for 7.5%, fisheries for 1.9%, and forestry for 1.1%.

Nan Province's average annual income is significantly lower than the national average. Estimates suggest a median household income of around THB 67,000–85,000 per year, primarily due to the province's reliance on agriculture and rural economic activities.

In contrast, the average annual income across Thailand was approximately THB 125,000–150,000 in 2023, varying depending on regions and urban centers. Bangkok and major cities like Chiang Mai tend to have higher income averages due to their diversified economic activities. This income gap highlights the challenges faced by rural provinces like Nan, which depend on less diversified and seasonal income sources compared to urbanized regions[8].

1.4 Climate Data and Trends

1.4.1 Climate in Thai Highlands

The climate in the Thai highlands is typical of tropical mountains, characterized by a decrease in temperature with an increase in altitude. There is a clear distinction between the dry and wet seasons. Nan's average dry season rainfall is 153.4 mm, while the wet season rainfall is 1,110.8 mm (1985–2014). Meanwhile, the average dry and wet season temperatures are 24.4°C and

[5] Official statistics registration systems, 2019
[6] National Statistical Office, 2017
[7] Office of National Economic and Social Development Board, 2015
[8] https://www.worlddata.info/average-income.php#google_vignette

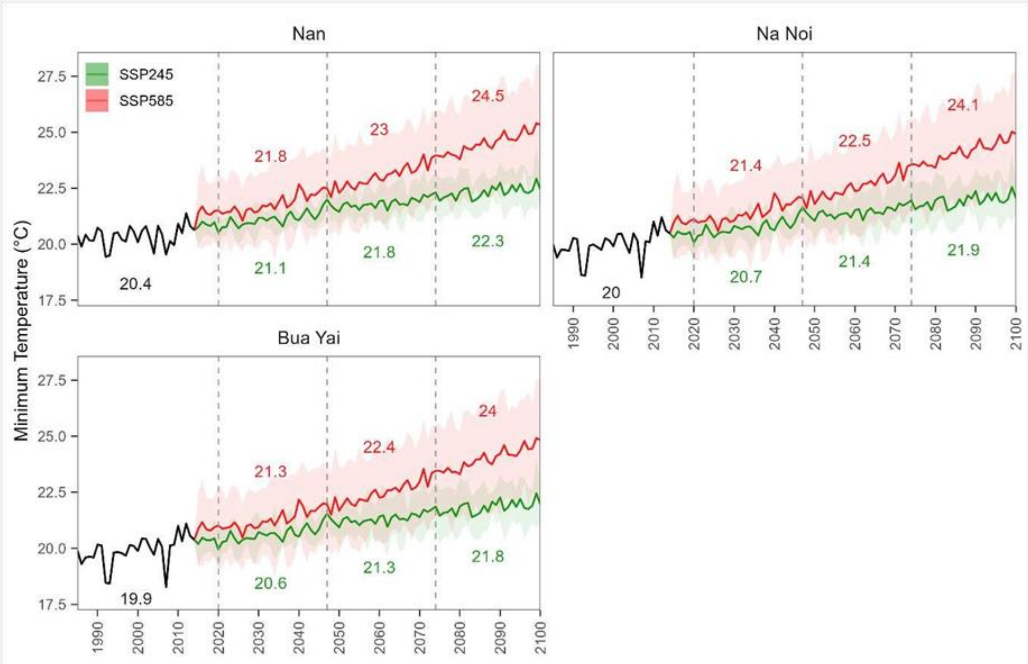
28.3°C, respectively. It was observed that Na Noi and Bua Yai receive less annual rainfall than the overall province while remaining approximately 0.4°C cooler, suggesting a cooling effect due to the rise in elevation. The maximum fluctuation in daily temperature (diurnal range) occurs in February (17.7°C), while August has the minimum daily range of 7.5°C.

1.4.2 Future Climate[9]

Nan Province is anticipated to be hotter, with an average annual temperature increase between 1.8°C and 3.6°C by the end of the century. Figure 3 and Figure 4 show an increasing trend in minimum and maximum temperatures throughout the 21st century. The minimum temperature in Nan Province is expected to increase more (i.e., 1.9–4.1°C) than the maximum temperature (i.e., 1.7–3.0°C), suggesting a decrease in the diurnal temperature range. There was little to no spatial variation in the temperature increment within the province. However, slight variations of around 0.5°C were observed in some areas, likely due to the sparse gauge stations, which could not capture the micro-climate.

Future temperatures are likely to change differently between seasons. The dry season minimum temperature is expected to rise by around 0.4°C more than the wet season minimum, suggesting less seasonal variation in minimum temperature. However, the change in maximum temperature is relatively consistent across seasons. These findings align with the IPCC (2013) estimate of an average global temperature increase between 1.1°C and 4.8°C.

Figure 3:
Temporal change in minimum temperature during 1985–2100. Future values are from the mean of six GCMs under SSP245 and SSP585 emission scenarios.



[9] KP2: Vulnerability of Highland Agriculture Current and Future Climate Change Scenarios

Figure 4:
Temporal change in maximum temperature during 1985–2100. Future values are from the mean of six GCMs under SSP245 and SSP585 emission scenarios.

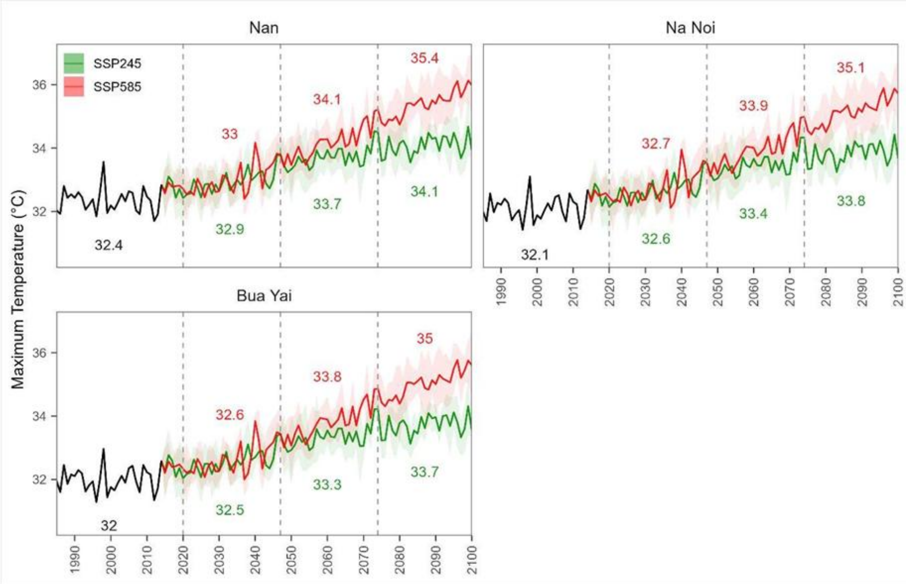
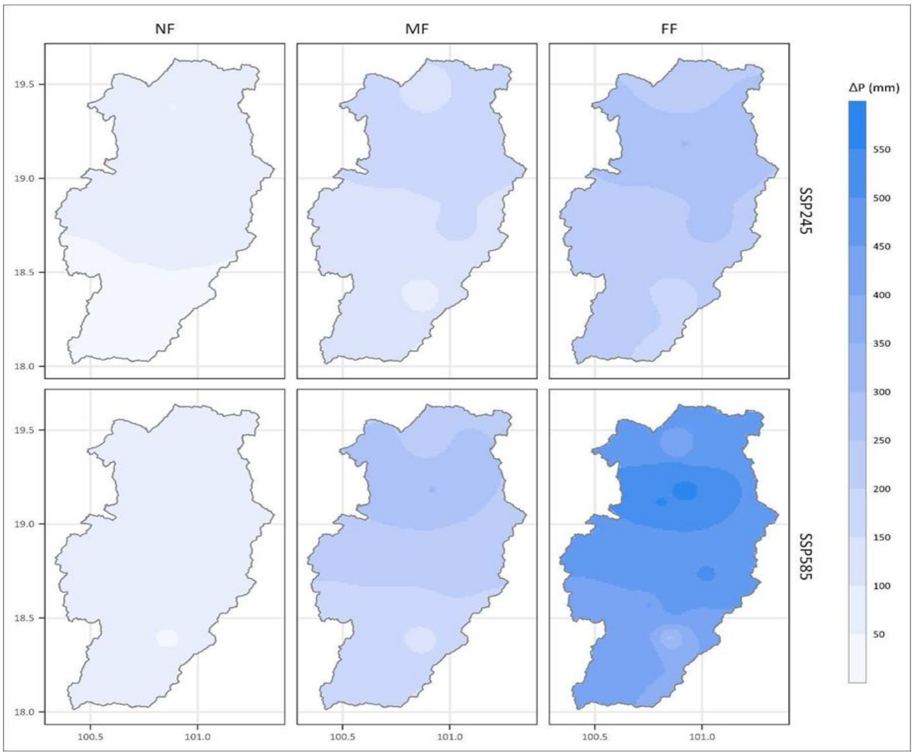


Figure 5 shows significant spatiotemporal variation in the absolute change in future rainfall. Compared to the overall Nan Province, Bua Yai and Na Noi are expected to receive less rainfall in the future. Both dry and wet seasons are projected to experience an increase in rainfall. However, the percentage increase in dry season rainfall (a maximum of 40–60% in the far future) is higher than that in the wet season (a maximum of 16–34% in the far future).

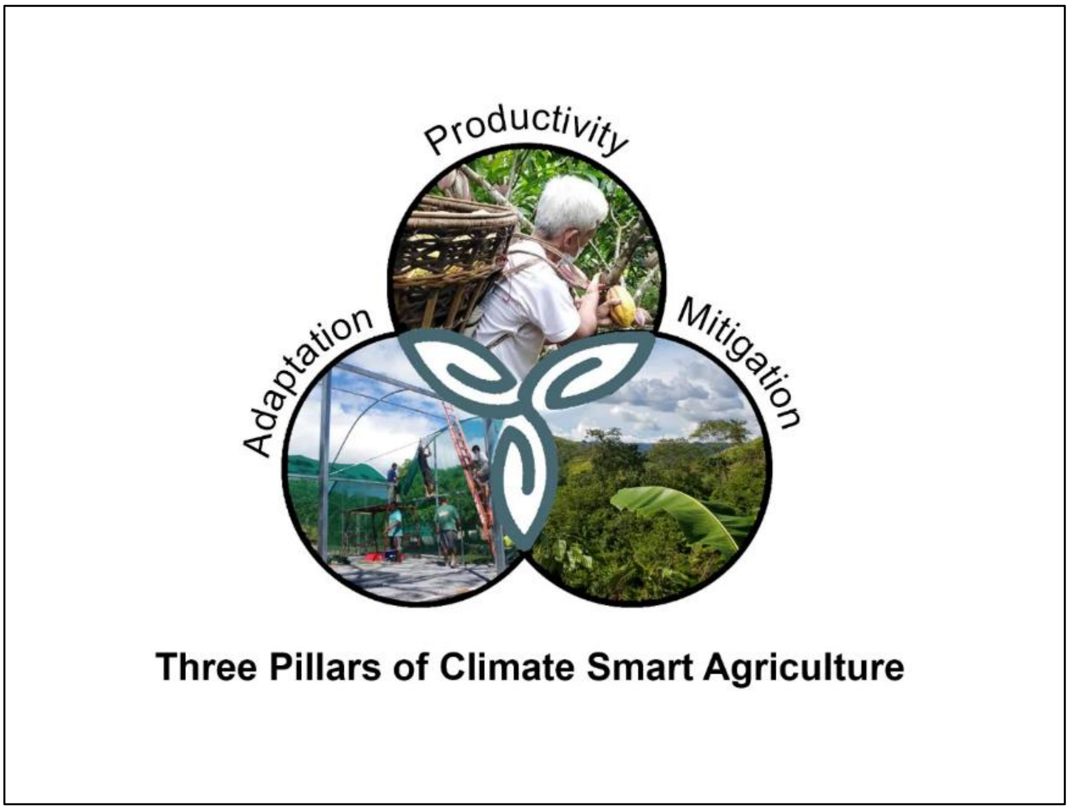
Figure 5:
Spatiotemporal distribution of absolute change in precipitation in Nan province during near (NF), mid (MF), and far (FF) future compared to the baseline period (1985–2014). Results are from the mean of six GCMs under SSP245 and SSP585 emission scenarios.



2. Climate-Smart Agriculture

Climate-smart agriculture (CSA) is an approach that helps guide actions to transform agri-food systems toward green and climate-resilient practices. CSA supports achieving internationally agreed goals, such as the SDGs and the Paris Agreement. CSA activities aim to achieve three main objectives: sustainably increasing agricultural productivity and incomes, adapting and building resilience to climate change, and reducing and removing greenhouse gas emissions, where possible (Figure 6).

Figure 6:
Pillars of Climate-Smart Agriculture.



Source: https://spsbiota.co.nz/pages/climate-smart

Solar irrigation, keyline plowing, and biochar application to improve soil fertility are three CSA initiatives suitable for highland areas subject to soil degradation, water shortages, and climate change impacts.

2.1 Solar Irrigation

Solar irrigation systems in highlands are an innovative and sustainable solution to address water scarcity for agricultural purposes in elevated terrains. These systems leverage solar-powered pumps to draw water from wells, rivers, or reservoirs, ensuring reliable irrigation even in remote areas without grid electricity.

2.1.1 Case Studies

Ethiopia: The Green World project introduced solar-powered irrigation technologies, combining results-based financing models with Pay-As-You-Go (PAYGO) systems. These approaches empowered farmers by decentralizing water access and reducing dependency on centralized systems[10].

Malawi: Smallholder farmers using solar pumps reported significant benefits in increased income and agricultural productivity. While initial costs were shared among cooperative groups, many farmers noted a doubling of their income due to year-round irrigation[11].

Nepal: Over 1,900 SIPs have been installed, with subsidies playing a critical role. However, targeted support is needed for marginalized farmers, as wealthier landowners capture many subsidies[12].

2.2 Keyline Water Management

Keyline plowing has been effectively applied in highland areas to improve water management, enhance soil fertility, and reduce erosion. A notable case study is from the C-B Ranch in northern New Mexico, where keyline design was implemented on a 3% slope to address soil erosion, poor water infiltration, and loss of native vegetation[13].

2.3 Climate-Adaptive Soil Management with Biochar

Biochar is a stable, carbon-rich material produced through the pyrolysis of organic matter, such as agricultural residues and biomass. Its use in agriculture can improve soil fertility, enhance resilience to climate change, and significantly mitigate greenhouse gas emissions.

Biochar has been shown to significantly enhance soil health and fertility through its unique properties as a soil amendment. A couple of notable case studies highlight its effectiveness:

2.3.1 Case Study 1: Tomato Production in Sandy Loam Soil, Texas

Researchers at Texas A&M studied the impact of wheat-based biochar on soil health and tomato production. Biochar improved the diversity and activity of beneficial soil microbes, enhanced nitrogen cycling, and reduced the prevalence of pathogenic fungi in organically grown soils. While it did not significantly affect yields in this trial, biochar improved soil structure and nutrient availability, suggesting its potential for broader horticultural applications[14].

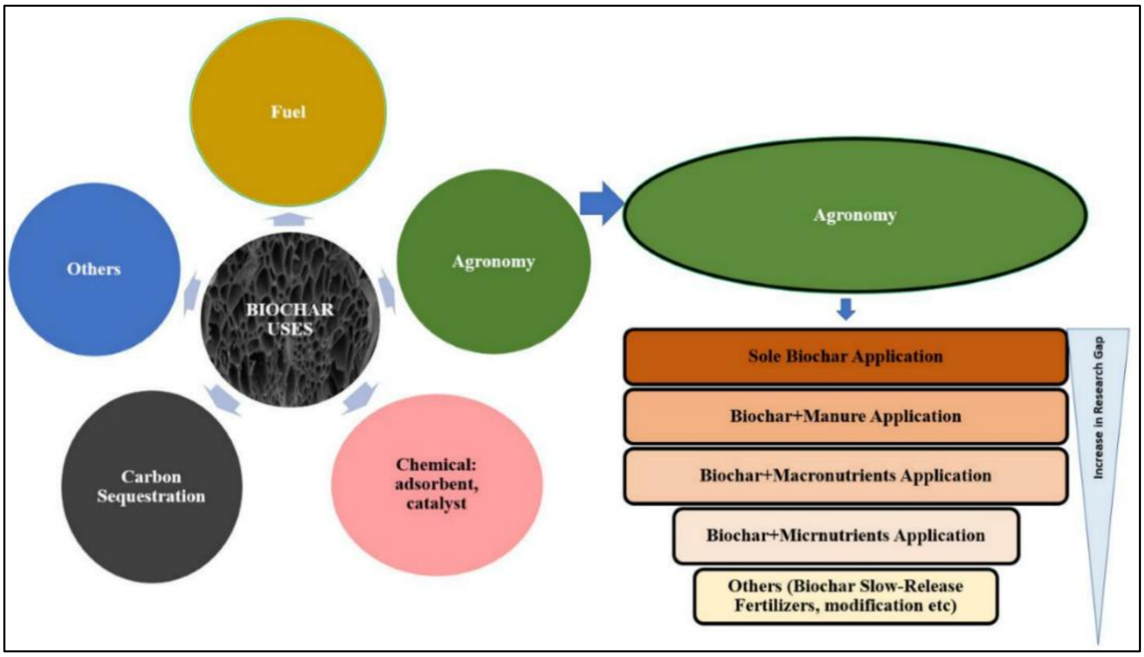
2.3.2 Case Study 2: Agricultural Fields in Nigeria

Biochar applications in Nigeria demonstrated enhanced soil fertility and crop performance in degraded soils. It improved cation exchange capacity, water retention, and reduced nitrogen leaching, which is critical for semi-arid and humid regions. Combinations of biochar with macronutrients and organic fertilizers yielded the most significant benefits. However, scaling biochar use is challenged by production costs and resource constraints[15].

---

[10] https://www.snv.org/library/green-world-a-case-study
[11] https://regeneration.org/sites/default/files/2023-11/Solar%20Pump%20Case%20Studies%202023-11-11-%20reduced_0.pdf
[12] https://solar.iwmi.org/wp-content/uploads/sites/43/2021/09/NEPAL-SITUATION-ANALYSIS-REPORT_final-version-3.pdf
[13] Yeomans, P. A. (2000). Water for a Healthy Country: Keyline Design and Water Harvesting. This book outlines the principles, applications, and benefits of keyline design and plowing for sustainable agriculture.
[14] https://agrilifetoday.tamu.edu/2023/12/14/soil-health-enhancement-biochar/
[15] https://doi.org/10.3390/soilsystems7040105

Figure 7:
Biochar utilization for improving soil health.



Source: Zubairu et al. (2023), https://doi.org/10.3390/soilsystems7040105

3. Demonstration Implementation in Bua Yai Subdistrict, Na Noi District, Nan Province

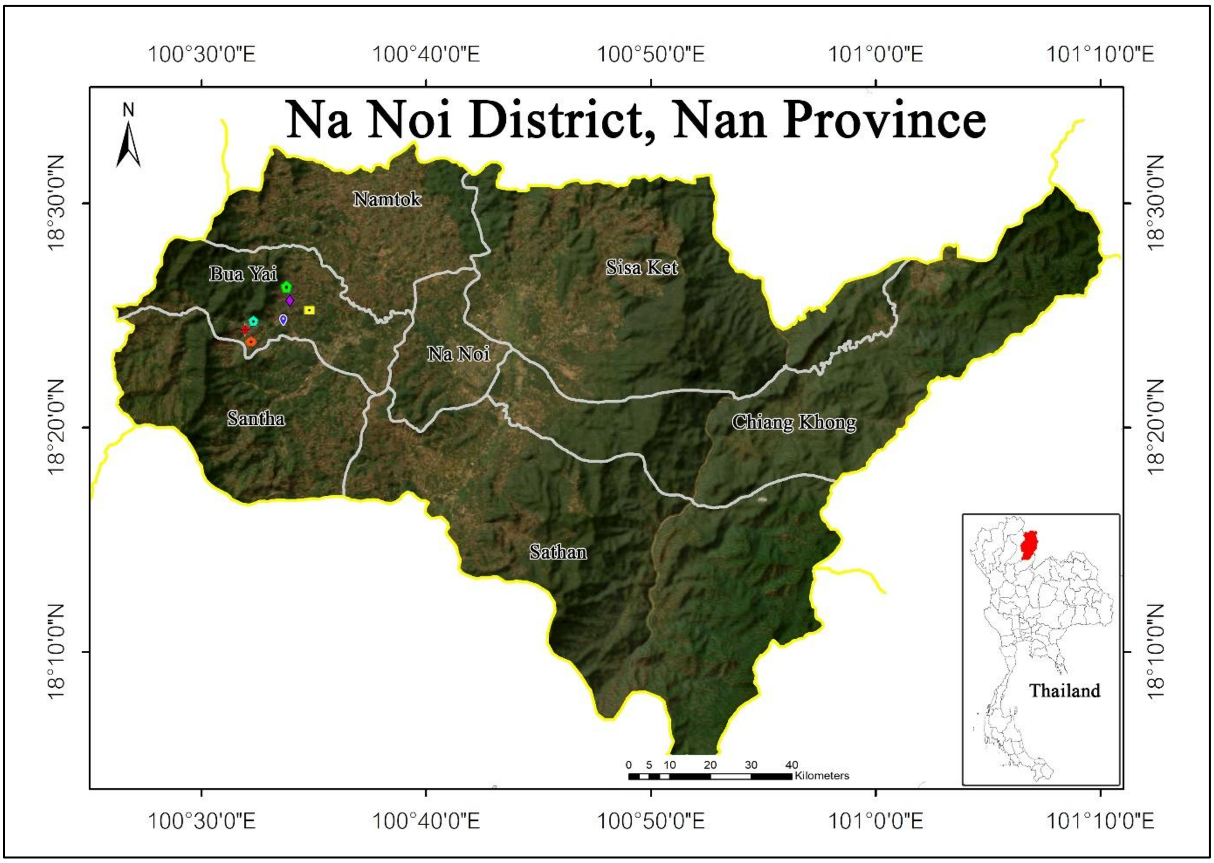
3.1 Information on Bua Yai Subdistrict

The information on Bua Yai Subdistrict was collected from primary and secondary sources. Primary data was gathered through interviews with community leaders and 107 villagers using structured questionnaires in eight villages[16]. Secondary data was obtained from the Nan Provincial Agriculture and Cooperatives Office. The details of the subdistrict are as follows:

3.1.1 Location

Bua Yai Subdistrict was officially separated from Santana Subdistrict in 1982. It comprises eight villages, with the Bua Yai Subdistrict Administrative Organization (Bua Yai SAO) located in Village 2, Ban Mai Mongkol. The subdistrict is situated 72 kilometers from Nan Province (Figure 8).

Figure 8:
Map of Nan, Na Noi, and Bua Yai Sub-district[17]



3.1.2 The Territory of Bua Yai Subdistrict

Bua Yai Subdistrict covers an area of approximately 131.1 km² or 81,939 rai (1 rai = 1,600 m²). It is bordered by:

[16] Baseline survey, 2021
[17] Source: Land Development Department, 2020

(1) North: Namtok Subdistrict, Na Noi District, Nan Province
(2) West: Rongkaew District, Phrae Province
(3) East: Na Noi Subdistrict, Na Noi District, Nan Province
(4) South: San Tho Subdistrict, Na Noi District

3.1.3 Topography

Most of Bua Yai Subdistrict lies within a national reserved forest zone and features a mix of mountainous terrain and plains. The altitude ranges from 600 to 1,000 meters above sea level. The Haeng River originates from the mountain range in this area. The terrain is generally classified into three types:

(1) Flat areas, comprising 4.78% of the subdistrict
(2) Foothill areas, comprising 19.03%
(3) Mountainous areas, comprising 76.19%

3.1.4 Settlement Pattern

The subdistrict has been inhabited for approximately 100 years. Settlements are organized in clusters within each village, with farming activities conducted outside the residential areas.

3.1.5 Demography

As of April 2019, the total population of Bua Yai Subdistrict was nearly 4,000, distributed across 1,346 households, with an average of three persons per household (Table 1). The population density is low, at approximately 30 persons per km², with a gender ratio of 1.01 (women to men). The entire population identifies as Northern Thai and practices Buddhism.

Table 1:
Demographics of Bua Yai Subdistrict.

Name of Village	Village No.	# Households	Male Population	Female Population	Total
Ban Oi	1	205	330	323	654
Ban Mai Mongkol	2	150	228	247	475
Ban Na Haen	3	214	302	293	595
Ban Tabman	4	186	272	276	548
Ban Nakai	5	199	293	293	586
Ban Tong Muang	6	83	114	129	243
Ban San Phayom	7	94	106	113	219
Ban Nong Ha	8	214	327	327	655
Total of all villages		**1,346**	**1,972**	**2,001**	**3,973**

Source: Registration Administration Office, Department of Provincial Administration, April 2019

The average landholding size in Bua Yai Subdistrict varies across villages, ranging from 15 to 30 rai per household. Only a small portion of the land is situated in lowland areas with secure title deeds. Most areas in Villages 1, 2, 6, 7, and 8 fall under the Agricultural Land Reform Area and are managed with Sor Por Kor 4-01 (SPK 4-01)[18] documents and "NTC" (Ko-To-Cho)[19] certifications.

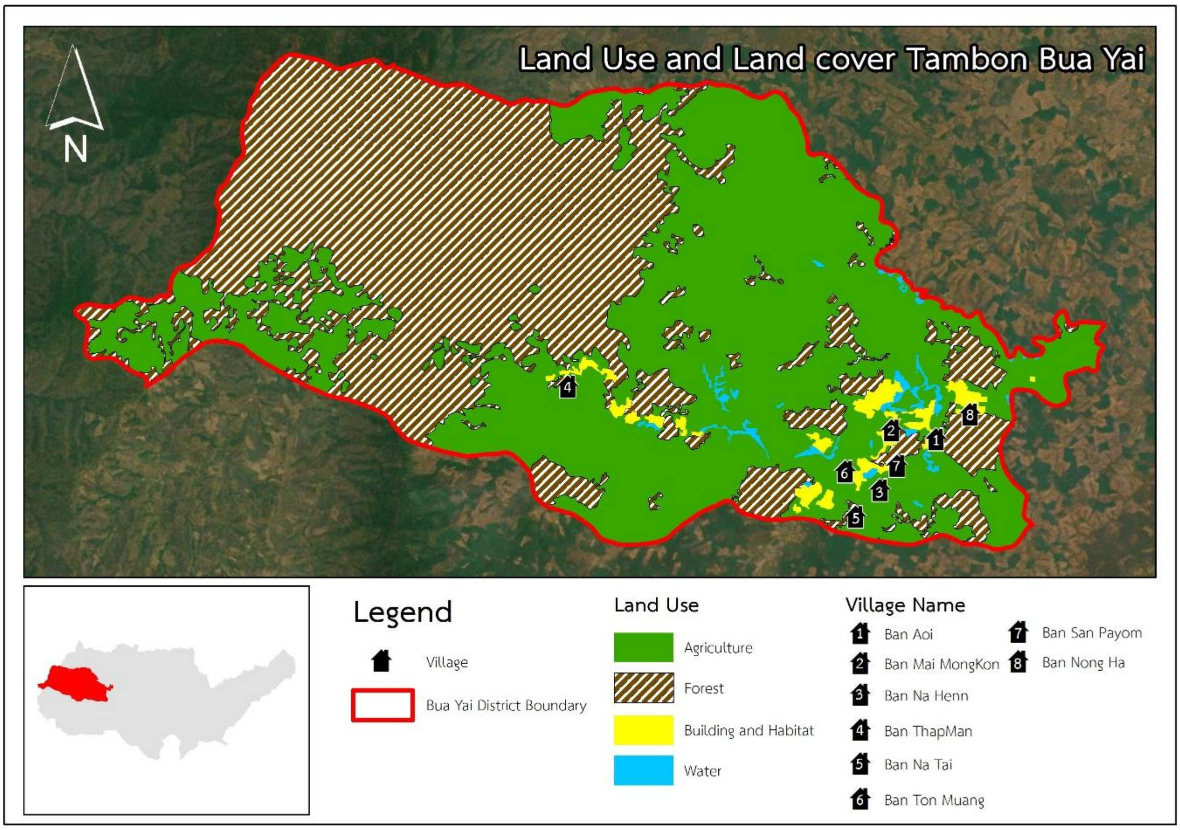
Residents of Ban Mai Mongkol (Village 2) primarily live within the subdistrict, but often own agricultural land located in other subdistricts. It is noteworthy that the majority of farmland in Village 5 and approximately half of the farmland in Village 4 is situated within forest areas. These lands

[18] Sor Por Kor 4-01 (SPK 4-01) is a document entitled for people to take advantage of the land reform area, which began with the Agricultural Land Reform Act 2518.
[19] "NTC" (Ko-To-Cho) is initiated by The National Land Policy Committee Act B.E. 2562 which was enacted to have the National Land Policy Committee or "NTC" (Ko-To-Cho)

are regulated under the condition of "no more encroachment," limiting further land expansion or forest clearing.

Land use and land cover details for Bua Yai Subdistrict are illustrated in Figure 9[20].

Figure 9:
Land use and cover in Bua Yai Subdistrict.



3.1.6 Occupation

Agriculture is the predominant livelihood in Bua Yai Subdistrict, with crop cultivation being the primary focus. Livestock raising plays a minimal role, with only a few households keeping pigs and buffaloes in small numbers. Most households rear free-range chickens primarily for household consumption.

3.1.7 Crop Cultivation

Maize and rubber are the major crops grown in the subdistrict. Bamboo, cashew nuts, pumpkin, and tamarind are cultivated in limited quantities in Villages 1, 2, 4, and 8. Village 4 also supports small plantations of teak, durian, and rambutan, with the potential for increased bamboo cultivation due to the presence of a processing factory.

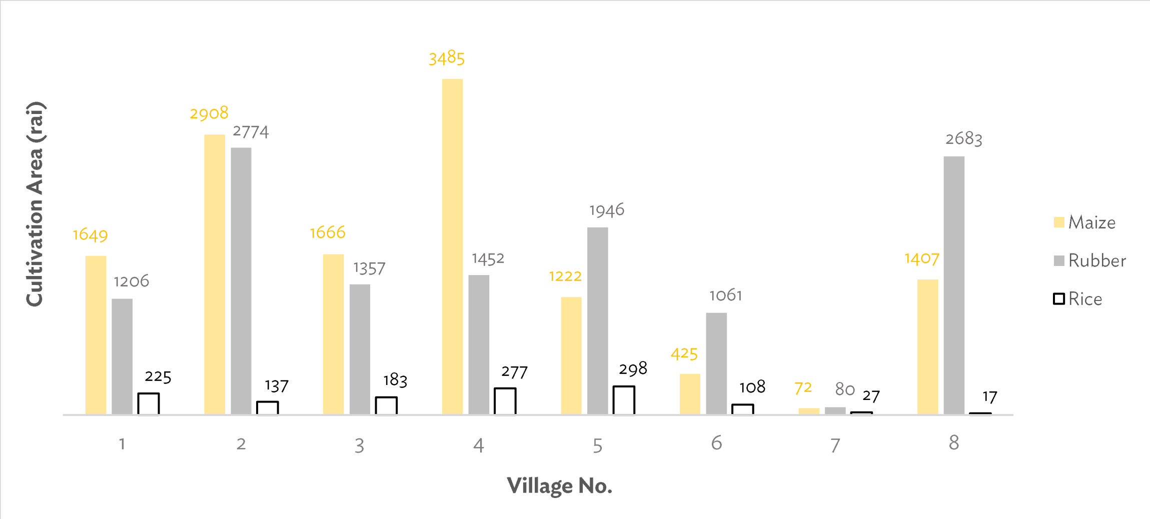
In Village 1, ten farmers have initiated cocoa cultivation, although the crop has yet to yield results. Rice cultivation is restricted to small lowland areas across all villages, while kitchen gardens in most households produce vegetables for local consumption.

A comparative analysis of the cultivation areas for major crops in 2020 (Figure 10) highlights that maize occupies more land than rubber in Villages 1, 2, 3, and 4. In contrast, rubber plantations

[20] Source: Land Development Department 2020

dominate in Villages 5, 6, and 8. This distribution reflects varied agricultural practices influenced by local conditions and land suitability.

Figure 10:
Cultivation area of maize, rubber, and rice by village.[21]



3.1.8 Cultivation Practices

Land preparation in Bua Yai Subdistrict is mainly mechanized, except for vegetable cultivation, which typically occurs on smaller plots. Farmers use a mix of inorganic fertilizers, bio-fertilizers, and pig manure for growing maize and rubber. Some rubber farmers also apply dolomite. Herbicide usage is significant for maize cultivation but is limited in rubber production. Bamboo, teak, and tamarind are mostly left to grow naturally. Animal manure is commonly applied to rice, vegetables, and cashew nuts. Farming operations primarily rely on family labor, though additional labor is sometimes hired for specific tasks such as herbicide spraying. After maize harvesting, crop residues are left on the fields and later tilled into the soil before the next cultivation cycle.

3.1.9 Water Sources for Agriculture

Agriculture in the region is heavily dependent on rainfall, with limited supplemental water sourced from nearby creeks. Certain villages have access to natural water bodies—Village 1 utilizes “Nong Puan,” and Village 5 accesses “Huay Mapoo.” Similarly, Village 2 has a reservoir named “Huay Pha Lat,” which is unsuitable for agricultural use. Advanced irrigation infrastructure is scarce, with only one computer-controlled watering system installed on a vegetable plot in Village 8, supported by the Digital Economy Promotion Agency (DEPA).

3.1.10 Socio-Economic Conditions

Rubber and maize farming are the primary income sources for most villagers, with rubber generating relatively higher earnings. Major household expenditures include agricultural investments, children's education, and vehicle financing, while consumption expenses are comparatively lower. Many families are burdened with debt, highlighting the economic challenges faced by the community.

3.1.11 Problems in Agriculture

The most pressing issue for farmers in Bua Yai is water scarcity, which significantly reduces crop quality and yields, leading to lower market prices. These challenges, coupled with high input costs, exacerbate farmer indebtedness. Pest damage also affects household health, while Village 3 faces additional challenges related to insecure and restricted land rights in reserved forest areas.

[21] Source: Nan Provincial Agriculture and Cooperatives Office 2020

3.1.12 Recognition of Climate Change

Over the past decade, villagers have observed changes in seasonal patterns and durations, with warmer temperatures. Extreme weather events have been reported, including severe storms, frequent forest fires, and significant temperature fluctuations between day and night. Rainfall patterns have become erratic, with lower overall rainfall, extended droughts, and occasional heavy downpours causing massive flooding. These climatic changes have profoundly impacted agricultural practices and outputs.

3.1.13 Adaptation to Climate Change

Maize and rubber, the two primary crops of the region, exhibit a degree of drought resilience, enabling farmers to persist with their cultivation. However, reliance on inorganic pesticides and fertilizers remains high, as farmers prioritize consistent production to address pressing financial needs such as debt repayment and educational expenses. Despite growing concerns about health and environmental impacts, most farmers find transitioning to climate-smart or organic farming daunting due to the intensive care and stable water supply these practices require. Nevertheless, community leaders have identified potential opportunities for expanding organic agriculture, particularly in Villages 1, 2, 4, 5, and 8. They have expressed interest in cultivating alternative crops such as cocoa, avocado, fruit trees, pumpkin, cashew nuts, and giant tamarind—provided adequate water resources can be secured.

3.2 Prioritization of the Most Effective CSA Practices

Bua Yai Subdistrict, located in Na Noi District, Nan Province, has been designated as an experimental area for applying climate-smart agriculture (CSA). The region faces several challenges, including prolonged cultivation of animal-feed maize on highland areas, water scarcity for agriculture, soil erosion, contamination of water and soil by chemicals and herbicides, and the overarching impacts of climate change.

Implementing CSA in such areas requires careful consideration of factors like topography, available agricultural resources, and farmer practices. For Bua Yai, prioritizing the most effective CSA practices necessitated evaluating their impact on productivity, sustainability, resilience to climate change, and alignment with the local socio-economic context. The following steps and criteria were employed for this prioritization:

A multi-criteria analysis was conducted to identify and select suitable CSA practices objectively. This process calibrated farmer preferences and perceptions with the insights of experts and staff from agricultural agencies.

Farmer Participation: Fifty-one farmers (28 women and 23 men) from eight villages in Bua Yai were interviewed to gather their preferences and perceptions regarding seven proposed CSA practices. These practices were evaluated across ten key variables:

(1) Input cost savings
(2) Water savings
(3) Labor savings
(4) Soil improvement
(5) Increased production
(6) Increased income (profitability)
(7) Long-term sustainability
(8) Prior knowledge
(9) Adaptation potential
(10) Mitigation potential (GHG emissions reduction)

3.2.1 Scoring and Ranking

Farmers rated each CSA practice on a scale of 0 to 3, where:

(1) 0 = Not Sure
(2) 1 = Low
(3) 2 = Medium
(4) 3 = High

The numerical scores from all 51 farmers were aggregated and analyzed across the ten variables to determine the overall ranking of CSA practices. The rankings of the practices were consistent across responses from both female and male participants.

3.2.2 Results

Traditional organic composting, agroforestry, and solar-powered irrigation emerged as the highest-ranked CSA practices for Bua Yai. Conversely, keyline plowing received the lowest ranking. Among the ten benefit variables, savings in farm inputs, labor, and water were the most significant benefits across all seven CSA practices. Interestingly, while recognized as beneficial, improved income or profitability ranked the lowest among the aggregated benefits. However, traditional composting and solar-powered irrigation were exceptions, showing profitability as a key benefit.

Table 2:
Ranked CSA Practices and Aggregated Benefits.

CSA Practice	Rank	Top Benefits	Rank
Traditional Organic Composting	1	Input Cost Saving	1
Agroforestry	2	Labor Saving	2
Solar-Powered Irrigation Systems	3	Water Saving	3
Mulching Soil Cover	4	Soil Improvement	4
Stress-Tolerant Crop Varieties	5	Increased Production	5
Biochar	6	Long-Run Sustainability	5
Keyline Approach	7	Adaptation potential	5
		Prior knowledge	6
		Mitigation (GHG Emissions)	7
		Increased income-profitability	8

3.3 Selection of Demonstration Sites

A workshop was conducted with all stakeholders to showcase potential areas for demonstration sites. The selection process utilized multiple criteria, focusing on keyline plowing, solar irrigation systems, and biochar. Farmers interested in participating at the demonstration sites were invited to share their understanding of the technical assistance and provide information about their land.

3.3.1 Farmers' Opinion about Keyline Water Management

Farmers commonly used tractors to plow the soil in highland areas, but this practice was observed to lead to soil erosion and compaction. Some farmers attempted to improve their land by creating terraced ridges to slow water flow. The implementation of the Keyline design was anticipated to reduce soil erosion and enhance the soil's ability to retain water.

3.3.2 Farmers' Opinion about Solar Irrigation

Agricultural activities in Bua Yai depended on rainwater. In this area, at least two solar power installations were used to pump water for domestic purposes and generate electricity for lighting in the Para rubber sales area. However, the lack of an irrigation system made crops vulnerable to damage from inconsistent rainfall. A solar irrigation system was identified as a solution to help farmers adapt to changing climate conditions and reduce challenges during prolonged dry seasons.

3.3.3 Farmers' Opinion about Biochar

Bua Yai farmers used both synthetic fertilizer and manure to nourish the soil. Interest in biochar production was expressed by villagers, though they lacked the necessary knowledge and equipment. While sufficient raw materials for biochar production were available, concerns were raised about the quantity needed for burning and the appropriate amount to apply to farmland.

3.4 Selection of Potential Demonstration Sites

Three potential sites for Keyline plowing and ten sites for solar irrigation were introduced by the TA team. Villagers actively participated in the following activities:

3.4.1 Elaboration on Site Information:

Ten villagers, including two women, provided details on:

(1) Location
(2) Availability of resources
(3) Willingness to participate
(4) Potential benefits

3.4.2 Participation in Demonstration Site Selection

Scores were assigned to each site based on various criteria. A total of 88 participants assessed the demonstration sites for Keyline practice, while 94 assessed the sites for solar irrigation, with more women than men involved in the process.

One of the selected solar irrigation sites is located on the farmland of Ms. Thavorn Chaikaewma (Village 8), Ms. Khwanjai Khaeongriangkhwang (Village 2), and Mr. Nipatpol Prompila (Village 4). For Keyline plowing, two demonstration sites were chosen: one belonging to Mr. Somsak Deepromkul and the other to Ms. Khwanjai Khaeongriangkhwang.

In the case of biochar kilns, biochar was identified as beneficial for improving soil properties, reducing soil acidity, and enhancing soil nutrients. Two biochar kilns were provided for each demonstration plot.

Additional biochar kilns were allocated to Mr. Amornthep Mamart, whose farmland is adjacent to Ms. Khwanjai Khaeongriangkhwang property, which received a solar irrigation system. Mr. Mamart's farm also benefitted from the shared water supply.

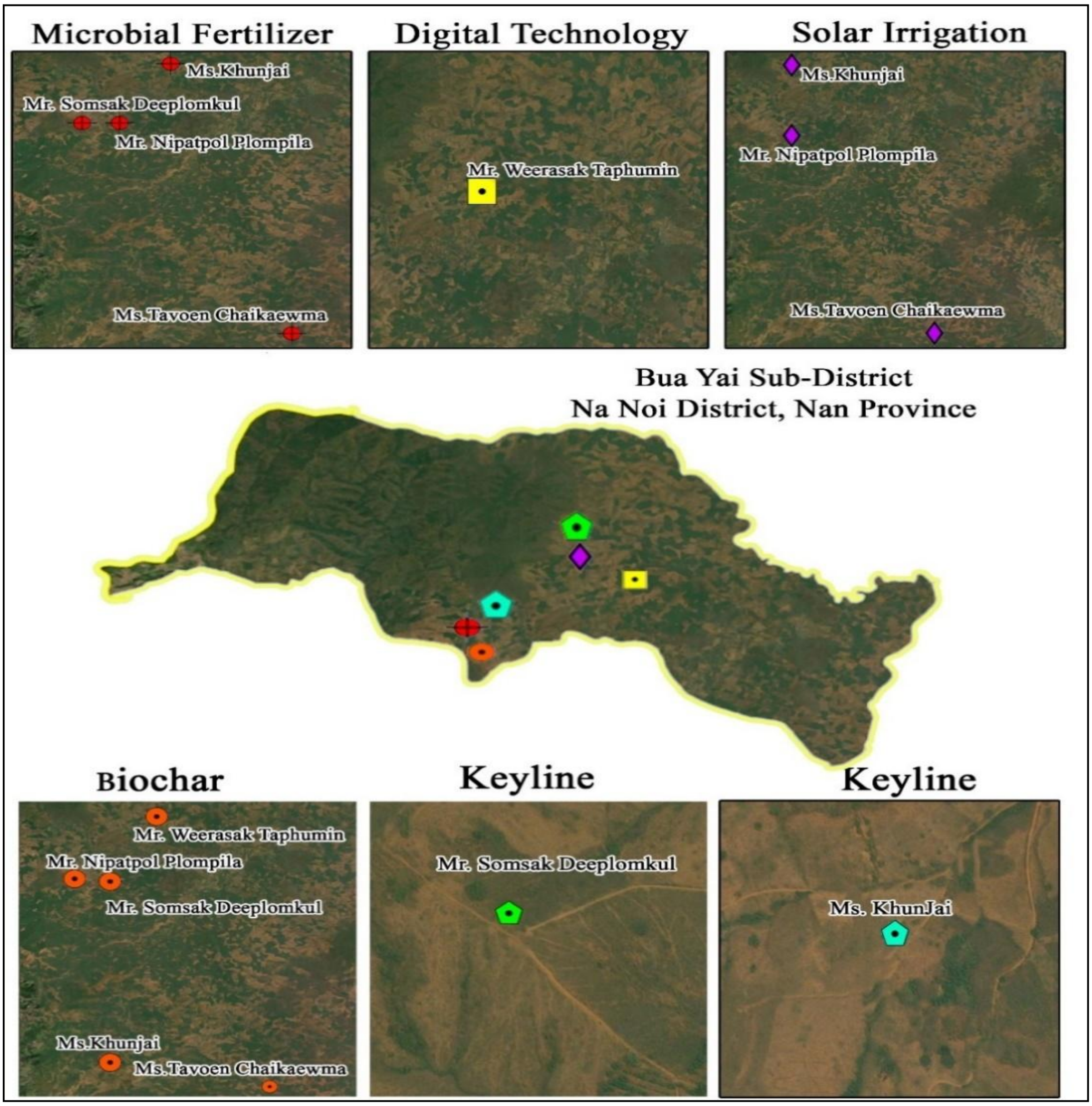
Two biochar kilns were also provided to Mr. Weerasak Tapoomin, the head of an essential oil enterprise, whose farmland showcased digital technology.

3.5 Selection of Locations Representative of the Target Region's Conditions

Three locations were selected for the solar irrigation system, and plowing was conducted in two of those areas. The technical assistant oversaw the installation and management of the plowing process. Biochar kilns were provided to support demonstrations, encouraging farmers to produce biochar and bring it to the demonstration plots.

Efforts were made to ensure the participation of a diverse group of farmers, encompassing various experience levels and farm sizes. Farmers intending to use their areas as demonstration plots were selected in a distributed manner across Bua Yai Subdistrict, ensuring that the designated areas met the conditions established by the TA.

Figure 11:
Pilot demonstration areas.



3.6 Implementation of Climate-Smart Practices

3.6.1 Training Farmers on Selected Practices

The solar energy system was installed under the supervision of technical assistants (TAs) and experts, with participation from farmers. Upon completion of the installation, experts and TAs provided guidance to farmers on the use and maintenance of the system. The straightforward technology involved in the solar energy irrigation system enables farmers to independently manage it.

Solar irrigation system at Ban Nong Ha (Village 8)

Solar irrigation system at Ban Tabman (Village 4)

Solar irrigation system at Ban Mai Mongkol (Village 2)

Keyline plowing required specific equipment modifications. To address this, TAs adapted existing farming equipment to facilitate Keyline plowing. However, it is noteworthy that Keyline plowing needs to be repeated every 4-5 years, which could present challenges for farmers unable to perform subsequent plowing themselves.




The TA Consultant team demonstrated the biochar production process to farmers, guiding them through each step. Farmers were informed that biochar is not a fertilizer but can be enhanced by crushing it into small pieces, fermenting it with manure for approximately two months, and then applying the fermented biochar to their plants to improve its effectiveness.




3.6.2 Sustainable Provision of Necessary Inputs and Equipment

To strengthen agricultural systems, farmers were provided with opportunities to cultivate alternative crops based on criteria such as water conservation, climate change resilience, local suitability, soil improvement, labor efficiency, high returns, value addition, market demand, interest in cultivation, and available support and knowledge. The top ten alternative crops identified were banana, lemongrass, pumpkin, avocado, peanut, cocoa, sesame, citronella, mung bean, and perilla. Cocoa, avocado, lemongrass, and banana seedlings were distributed for planting in demonstration areas to evaluate their potential.




Organic farming practices were supported by providing resources for organic fertilizers. This included tanks for producing organic fertilizer starters and pest and weed control solutions. Farmers were also encouraged to create compost piles and use the provided organic starters. After fermenting the compost for about two months, it could be applied to crops.

3.6.3 Promoting Knowledge Sharing and Peer-to-Peer Learning

An event was organized to invite farmers from the Bua Yai subdistrict, including those not participating in the demonstration areas, to observe the activities. Participants from the highlands of five other provinces, as well as farmers from different districts in Nan Province and various subdistricts in Na Noi District, were also brought in to visit the demonstration areas.

4. Monitoring and Evaluation

4.1 Greenhouse Gas Emissions Using the Solar Irrigation System

A straightforward calculation was conducted to estimate the potential reduction in greenhouse gas emissions from a solar irrigation system. The analysis included determining the number of solar panels installed and the electricity they generated. This electricity production was then compared to the greenhouse gas emissions typically associated with producing 1 watt of electricity.

Figure 12:
Solar irrigation system and Cacao planting at Ms. Kwanjai Khaeongriangkhwang, Village 2.

Figure 13:
Solar irrigation system and Cacao and avocado planting at Mr. Niphatphol Phromphira, Village 4.

The solar irrigation system significantly reduced greenhouse gas emissions compared to using electricity from the grid. Table 3 summarizes the electricity generated by solar panels in different villages and the corresponding greenhouse gas emissions reductions:

Table 3:
Reduction in GHG emissions through solar irrigation.

Items	Village 8	Village 2	Village 4
Number of Solar Panels (Watt)	8 × 410 / 1000	18 × 410 / 1000	14 × 410 / 1000
Electricity Produced	3.28 kW/day	7.38 kW/day	5.74 kW/day
Annual Production (Max 5 hours/day × 265 days)	4346 kW	9778.5 kW	7606.5 kW
GHG Emission Reduction (kg CO2e/year) [(kW × EF)]	2529.81	5692.06	4427.16
Equivalent Trees Planted	316.23	711.51	553.40

(1) Emission Factor of electricity (1 unit): 0.5821 (IPCC, 2006)
(2) One tree absorbs CO_2: 8 kg (Thailand Greenhouse Gas Organization)

Solar-powered irrigation systems enable farmers to irrigate crops during dry spells without concerns about water shortages. Additionally, these pumps provide controlled water distribution, reducing evaporation and runoff waste.

4.2 Soil Moisture Retention

4.2.1 Keyline Plowing

Two demonstration areas underwent keyline plowing, with soil moisture monitored under three conditions:

(1) Without keyline plowing.
(2) With keyline plowing.
(3) With keyline plowing and additional watering.

Results indicated higher soil moisture levels in areas with keyline plowing, particularly in watered zones. Statistically significant differences in moisture content were observed between keyline-plowed and non-keyline-plowed regions (see Figures 19, 20, and 21).

Keyline plowing releases approximately 42 kg of CO_2 equivalent per hectare. Crops suitable for keyline plowing, such as grasses for animal feed, may have limited lifespans since the practice needs to be repeated every 4 to 5 years.

The demonstration highlighted the effectiveness of Climate-Smart Agriculture (CSA) practices in mitigating climate change impacts on highland agriculture. Integration of solar irrigation, biochar, and microbial fertilizers improved crop growth, yield, and soil moisture retention.

(1) Solar irrigation provided a sustainable water supply.
(2) Biochar and microbial fertilizers enhanced soil health and microbial activity.

These CSA practices improved water availability, resulting in healthier plants and potentially higher productivity. Adopting CSA techniques presents a sustainable approach to addressing climate change challenges and promoting food security in Thailand's highlands.

Figure 14:
Keyline plowing and solar irrigation system at Ban Mai Mongkol (Village 2).

Figure 15:
Soil moisture content (%) at Mrs. Khwanjai Khaeongriangkhwang's demonstration plot (Village 2).

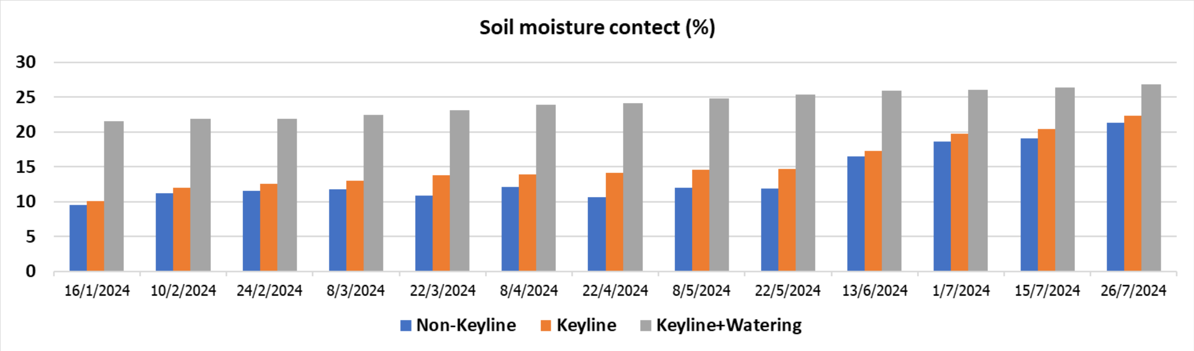
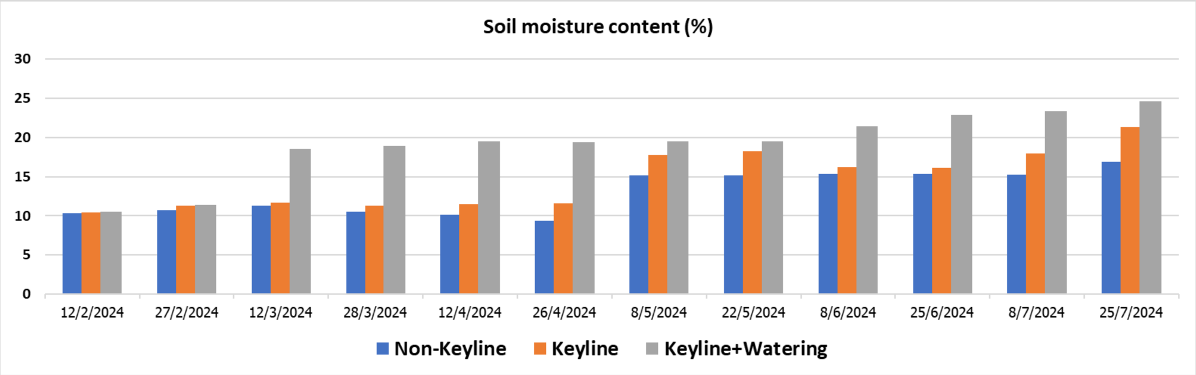


Figure 16:
Soil moisture content (%) at Mr. Somsak Deepromkul's demonstration plot (Village 4).



The two cultivated areas, with Village No. 4 featuring a steeper slope than Village No. 2, were utilized to collect soil moisture data under three scenarios:

(1) Without keyline plowing.
(2) With keyline plowing.
(3) With keyline plowing combined with watering.

The results demonstrated that soil moisture content in areas without keyline plowing was slightly lower compared to areas with keyline plowing. The combination of keyline plowing and watering produced the highest moisture content.

These findings confirm that keyline plowing improves soil moisture retention, while its integration with irrigation further enhances moisture levels and supports plant growth.

Figure 17:
Biochar production and application.

4.3 Crop Growth, Soil Health, and Water Use

This study emphasizes the advantages of Climate-Smart Agriculture (CSA) techniques, focusing on solar irrigation, biochar, and microbial fertilizers. These methods enhance cacao growth while improving soil moisture retention. By increasing water availability, these practices contribute to healthier plants and greater productivity.

Solar irrigation provides a sustainable water supply, while biochar and microbial fertilizers improve soil health by enhancing nutrient availability and microbial activity. The combined application of these CSA practices optimizes resource utilization, ensuring long-term soil vitality critical for climate resilience and food security.

Adopting CSA techniques presents a viable solution for sustainable agriculture in Thailand's highlands, addressing climate change challenges and ensuring a productive agricultural future.

Demonstration on Solar Irrigation, Biochar, and Microbial Fertilizer Using Cacao as a Test Crop in Ban Tabman Village (Village 4)

As part of the CSA initiative, solar irrigation, biochar, and microbial fertilizer were implemented using a randomized design. After planting, data on plant growth (height and diameter) and soil moisture content were collected twice monthly from mid-January 2024 to the end of July 2024.

The results demonstrated that watering had a significant impact on soil moisture content. Furthermore, the combined use of watering, biochar, and microbial fertilizer resulted in significantly higher moisture levels. Cacao trees treated with water, microbial fertilizers, and biochar exhibited significant growth in both height and diameter, resulting in notably larger trees.

Figure 18:
Soil moisture content (%) in different experimental plots.

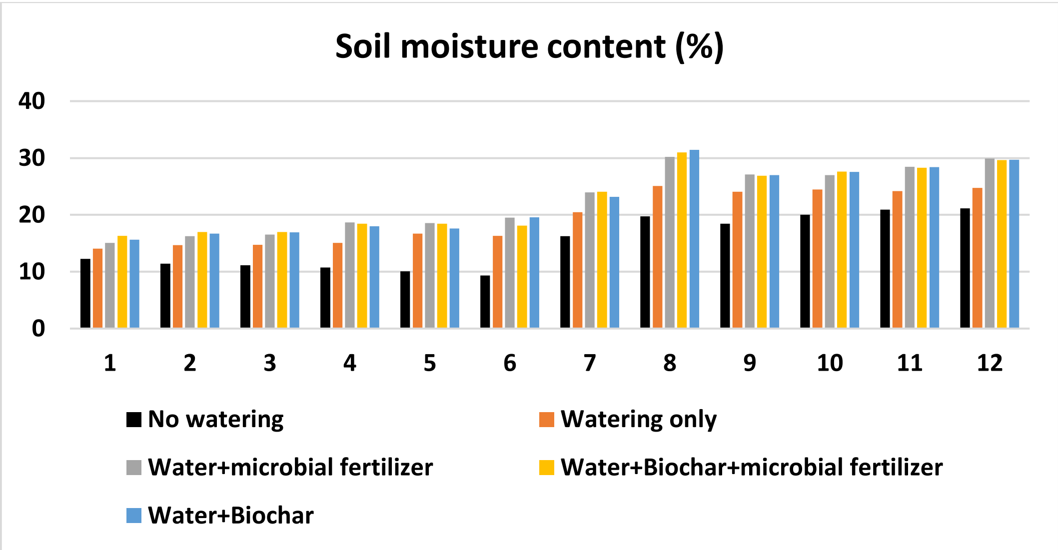


Figure 19:
Cacao height (cm) in different experimental plots.

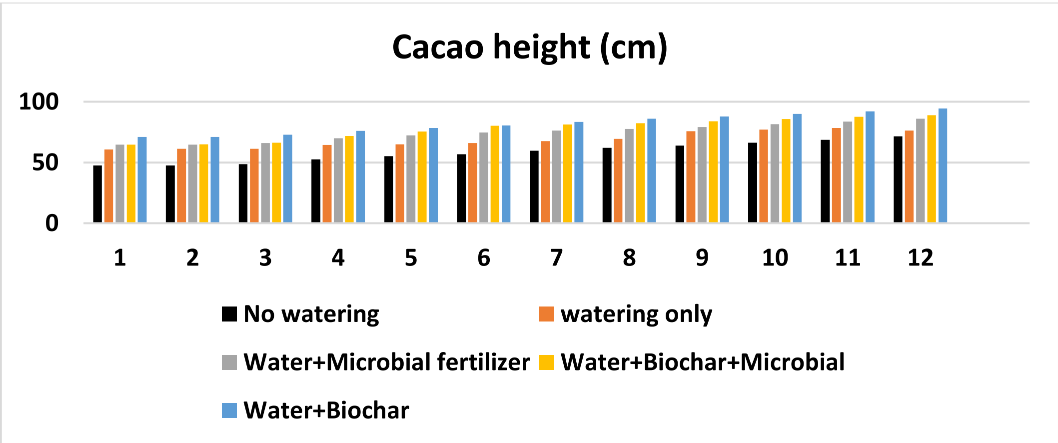
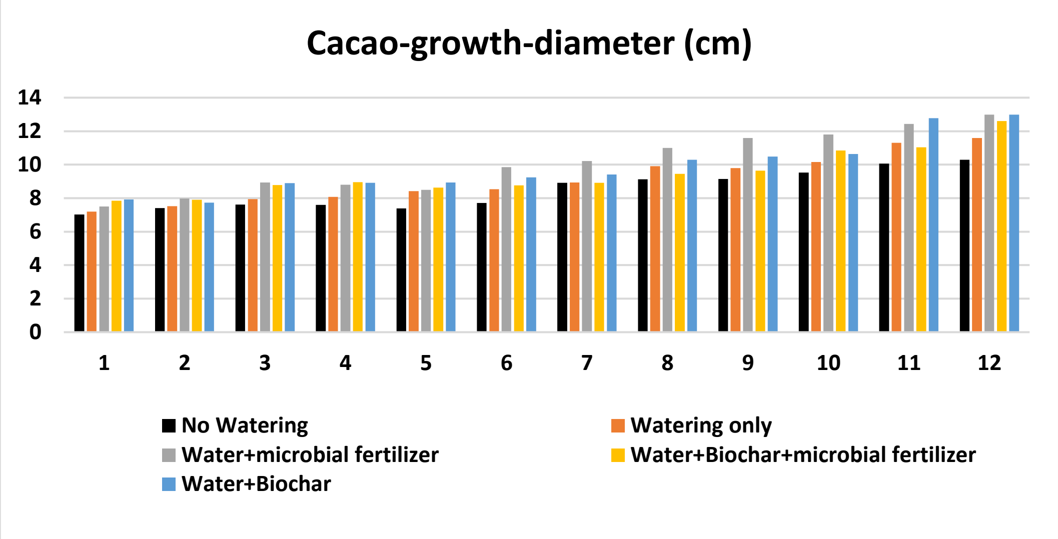


Figure 20:
Cacao growth diameter (cm) in different experimental plots.



4.4 Cost-Benefit Analysis of CSA Practices

Conducting a cost-benefit analysis (CBA) of Climate-Smart Agriculture (CSA) practices provides valuable insights into their economic viability and effectiveness in meeting sustainability objectives. This analysis focuses on solar irrigation and organic cultivation of cacao and avocado, examining costs and benefits associated with adopting CSA methods.

The study evaluates the economic returns and social and environmental benefits of cultivating cacao and avocados in the highlands of Nan Province using CSA practices. Comparisons were made between CSA methods (with the project) and conventional approaches (without the project) to highlight differences in economic outcomes.

Economic analysis of CSA practices for cacao and avocado demonstrated significant financial returns. The Internal Rate of Return (IRR) exceeded discount rates of 3.5%, 6.5%, and 8.0%, and the Benefit-Cost Ratio (BCR) was more than four times higher for cacao and over seven times for avocado under CSA practices.

Comparison of cultivation methods revealed that while avocado returns were similar under both CSA and conventional approaches, cacao yields were approximately 50% higher with CSA methods. This result aligns with the strong market growth potential for cacao, especially for organic beans, which command higher prices than conventional ones. These findings indicate promising opportunities for cacao cultivation as a viable and sustainable agricultural practice.

In addition to financial returns from produce and by-products, CSA methods offer long-term environmental advantages, including carbon sequestration, reduced reliance on fossil fuels, lower chemical contamination, and decreased water usage.

Sensitivity analysis highlighted the significant influence of selling prices for cacao and avocado on the return on investment. Promoting organic farming practices or adherence to Good Agriculture Practices (GAP) can enhance product quality, boost consumer confidence, and stabilize prices, ensuring sustainability and profitability.

Post-harvest processing adds value to cacao by transforming it into high-value products like cacao butter, chocolate liquor, and chocolate bars, significantly increasing profitability compared to selling raw beans. Conversely, avocado cultivation faces challenges related to transportation risks for fresh produce, which can be mitigated by processing damaged or non-standard avocados into value-added products such as avocado oil.

Table 4:
Economic analysis comparison between CSA and conventionally grown cacao.

Items	Costs	Benefits	Net Profit	Profit/Year	IRR	BCR
CSA Cacao						
Discount Rate 3.5%	549,891.63	2,408,762.79	1,899,235.30	94,961.77	88.27%	4.38
Discount Rate 6.5%	419,965.91	1,767,614.93	1,376,206.89	68,810.34	82.41%	4.21
Discount Rate 8.0%	371,362.91	1,529,673.99	1,175,998.73	58,799.94	79.49%	4.12
Ratio between Cash costs and Non-cash costs = 10.86% : 89.14% (1:8.2)						
Payback Period = 4 years						
Conventional Cacao						
Discount Rate 3.5%	533,345.86	1,204,669.62	684,873.99	34,243.70	48.21%	2.26
Discount Rate 6.5%	399,131.12	868,015.81	475,978.16	23,798.91	43.60%	2.17
Discount Rate 8.0%	349,279.13	744,265.38	397,163.35	19,858.17	41.30%	2.13
Ratio between Cash costs and Non-cash costs = 38.76% : 61.24% (1:1.6)						
Payback Period = 5 years						

Table 5:
Economic analysis comparison between CSA and conventionally grown avocado.

Items	Costs	Benefits	Net Profit	Profit/Year	IRR	BCR
CSA Avocado						
Discount Rate 3.5%	215,150.08	1,776,722.70	1,595,901.68	78,078.63	118%	8.26
Discount Rate 6.5%	165,633.30	1,305,430.44	1,165,251.01	56,989.86	114%	7.88
Discount Rate 8.0%	147,113.57	1,130,511.12	480,473.82	49,169.88	114%	7.68
Ratio between Cash costs and non-cash costs = 28.18% : 71.82% (1:2.6)						
Payback Period = 3 year						
Conventional Avocado						
Discount Rate 3.5%	173,037.72	1,484,852.88	1,340,785.49	67,039.27	133%	8.58
Discount Rate 6.5%	133,190.51	1,093,010.52	981,628.72	49,081.44	126%	8.21
Discount Rate 8.0%	118,270.04	947,447.02	843,920.07	42,196.00	122%	8.01
Ratio between Cash costs and non-cash costs = 39.60% : 60.40% (1:1.5)						
Payback Period = 3 years						

5. Current Levels of Adoption of Prioritized CSA Practices

Thailand has implemented several types of Climate-Smart Agriculture (CSA) practices that are carefully tailored to address its diverse agricultural systems and the significant challenges posed by climate variability. Below are the key CSA practices implemented in Thailand, along with their applications and contexts:

5.1 Integrated Farming Systems

Integrated farming systems involve the combination of crops, livestock, and aquaculture to optimize resource use and increase resilience to climate variability.

For instance, integrated rice-fish systems are actively promoted in several regions of Thailand to improve agricultural productivity while enhancing water use efficiency.

5.2 Agroforestry

Agroforestry integrates trees with crops and livestock systems to enhance biodiversity, sequester carbon, and improve soil health.

In Thailand, agroforestry practices are encouraged particularly in upland regions, where they play a crucial role in combating soil erosion and providing essential ecosystem services.

5.3 Climate-Resilient Crop Varieties

Farmers in Thailand have adopted drought-tolerant and flood-resistant rice varieties to mitigate vulnerability to extreme weather events.

These varieties are critical in ensuring stable yields in regions that are frequently affected by either flooding or water scarcity.

5.4 Water-Saving Technologies

Water-saving technologies such as alternate wetting and drying (AWD) techniques in rice farming are implemented to reduce water usage and greenhouse gas emissions.

Additionally, drip irrigation systems have been adopted in horticultural crop production to maximize water use efficiency.

5.5 Soil Management Practices

Conservation agriculture techniques, including minimum tillage, cover cropping, and the use of organic fertilizers, are increasingly being utilized to improve soil health and promote carbon sequestration.

These practices are frequently implemented in conjunction with capacity-building programs and supported by government policies to ensure scalability and sustainability.

5.6 Adoption Levels in Other Regions

The current levels of adoption of prioritized CSA practices vary significantly across regions, agricultural systems, and the specific types of practices. Below are some examples of CSA practices implemented globally, including their adoption levels and relevant applications:

5.7 Conservation Tillage

Approximately 20-25% of cropland in the United States and Western Europe has adopted conservation tillage practices, such as no-till farming.

For example, farmers in the Midwest of the United States, particularly in corn and soybean-dominant regions, use no-till practices to reduce soil erosion and improve soil health.

5.8 Cover Cropping

In the United States, cover cropping is gaining popularity, with an estimated 15% of cropland adopting this practice.

In regions such as the Chesapeake Bay, farmers have embraced cover crops to improve soil fertility and reduce nutrient runoff into waterways, achieving environmental benefits and enhanced crop yields.

5.9 Agroforestry

Globally, agroforestry practices are estimated to cover around 1 billion hectares, although adoption levels differ by region.

In East Africa, smallholder farmers successfully integrate trees with crops and livestock, leading to improved soil fertility, enhanced biodiversity, and diversified income sources.

5.10 Drip Irrigation

About 70% of agricultural land in water-scarce regions like Israel utilizes drip irrigation.

In India, adoption rates for drip irrigation are increasing due to government initiatives, such as in Maharashtra, where apple farmers use this technology to optimize water use and improve fruit quality.

5.11 Integrated Pest Management (IPM)

Integrated Pest Management practices have been widely adopted in specific areas, with approximately 50-70% of vegetable producers in Southeast Asia and certain African regions implementing these methods.

For example, vegetable farmers in the Philippines have reported reduced pesticide costs and higher yields through the adoption of IPM techniques, which also minimize environmental impacts.

5.12 Crop Diversification

Adoption of crop diversification varies, but in Southeast Asia, about 30% of farmers practice some form of diversification.

In Madagascar, diversifying staple crops with legumes and vegetables has improved food security and resilience to climate variability.

5.13 Solar Irrigation

The use of solar irrigation systems is growing in regions with abundant sunlight and limited conventional power access. Globally, thousands of farmers have transitioned to solar-powered irrigation, particularly in developing countries.

In India, the *Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan* (PM-KUSUM) scheme has supported the installation of over 700,000 solar pumps, reducing reliance on diesel while enhancing irrigation efficiency.

5.14 Keyline Plowing

Adoption of keyline plowing remains relatively niche, mainly associated with permaculture and holistic management groups.

In Australia, where the practice originated, some farmers use keyline plowing to improve water retention and soil structure, particularly in regenerative agricultural systems.

5.15 Biochar

Biochar adoption is growing, especially among organic and regenerative farmers, although it is still limited to smaller-scale applications and experimental projects.

For example, farmers in Brazil's Amazon region use biochar to enhance soil fertility and sequester carbon, resulting in increased crop yields and climate mitigation benefits.

5.16 Conclusion

The adoption levels of prioritized CSA practices highlight a growing recognition of their benefits among farmers, policymakers, and agricultural stakeholders worldwide. Adoption rates depend on factors such as access to knowledge, financial incentives, enabling policies, and local environmental conditions. Ensuring sustained support, education, and capacity building will be essential to increase adoption rates and fully realize the economic, social, and environmental benefits of CSA practices across the globe.

6. Assessment of climate-smart agriculture in Bua Yai area and challenges

Overall, in the Bua Yai subdistrict, Nanoi district, Nan province, CSA practices that TA had intervention in the area. As we have explained above regarding the problems that farmers are facing, what CSA type is appropriate to solve those problems, the process of selecting and implementing each CSA practice, and implementation during the project time. However, its successful implementation hinges on addressing the multifaceted challenges farmers and local authorities face before and after CSA adoption. Farmers often grapple with limited knowledge, financial constraints, and resistance to change, while local authorities contend with policy gaps, resource limitations, and coordination challenges. Post-implementation, ongoing technical support, adaptation to environmental variability, and market accessibility remain critical hurdles. This document outlines a comprehensive response to these challenges by proposing targeted solutions such as capacity building, financial support mechanisms, tailored interventions, and market development strategies, ensuring CSA practices are both practical and scalable.

6.1 Challenges currently faced by farmers and local authorities before CSA implementation

6.1.1 Farmers

(1) **Unpredictable Weather Patterns**: Increased variability in rainfall and temperature made traditional farming methods unreliable, affecting crop yields.
(2) **Soil Degradation**: Decades of intensive farming and poor soil management reduced soil fertility and increased erosion.
(3) **Water Scarcity**: Limited access to irrigation resources forced dependence on rain-fed agriculture, exacerbating vulnerability during droughts.
(4) **Pest and Disease Outbreaks**: Changing climate conditions increased the prevalence of pests and diseases, causing significant losses.
(5) **Limited Access to Resources**: Farmers struggled with insufficient knowledge, training, and financial resources to adopt sustainable practices.

6.1.2 Local Authorities

(1) **Policy Gaps**: A lack of well-defined policies to support sustainable agriculture may affect the promotion of CSA.
(2) **Resource Constraints**: Limited funding and human resources to implement CSA initiatives.
(3) **Coordination Challenges**: Difficulty in aligning efforts among various stakeholders, including farmers, NGOs, and governmental bodies.
(4) **Data Deficiency**: Insufficient access to localized climate data that may hinder planning and decision-making.

6.2 Challenges that may be faced after CSA implementation

6.2.1 Farmers

(1) **Adaptation Period**: Initial resistance to change due to unfamiliarity with CSA practices and tools.
(2) **High Upfront Costs**: Investment in infrastructure, such as solar irrigation systems or biochar production, can pose financial challenges.

(3) **Technical Complexity**: Mastering advanced techniques like precision agriculture or integrated pest management is complex.

6.2.2 Local Authorities

(1) **Monitoring and Evaluation**: Ensuring consistent assessment of CSA practices' effectiveness.
(2) **Sustained Engagement**: Maintaining farmer participation and enthusiasm for CSA projects.
(3) **Scaling Challenges**: Expanding CSA adoption beyond pilot areas while maintaining effectiveness.

6.3 Solutions and Guidance to Address Challenges

6.3.1 For Farmers

(1) Capacity Building:
(2) Provide training programs on CSA practices tailored to local conditions.
(3) Develop farmer-to-farmer knowledge-sharing networks and organize training at the current ADB project demonstration sites.
(4) Financial Support:
(5) Introduce microcredit schemes or subsidies for CSA-related investments.
(6) Facilitate access to government and NGO grants for infrastructure development.
(7) Access to Technology:
(8) Provide tools like mobile apps for climate data, groundwater monitoring, and precision agriculture.
(9) Make available drought-resistant seeds and CSA-compatible equipment.
(10) Community-Based Approaches:
(11) Encourage the formation of cooperatives to share resources and best practices.

6.3.2 For Local Authorities

(1) Policy and Governance:
(2) Develop clear, actionable policies to promote CSA at local and regional levels.
(3) Incentivize CSA adoption through certifications for sustainable practices.
(4) Enhanced Coordination:
(5) Establish multi-stakeholder platforms for collaborative decision-making.
(6) Promote partnerships with NGOs, local and national research institutions, and private sector actors.
(7) Resource Allocation:
(8) Prioritize budget allocation for CSA training, infrastructure, and monitoring systems.
(9) Invest in the development of localized climate data systems to inform planning.
(10) Monitoring and Evaluation Frameworks:
(11) Implement robust systems to track CSA adoption and its impacts on productivity, resilience, and emissions reduction.

Considering the above aspects when implementing CSA practices will ensure their positive impacts and sustainability in Thailand and beyond.

7. Opportunities for Scaling Up Climate-Smart Agriculture

Scaling up Climate-Smart Agriculture (CSA) practices offers transformative potential to enhance agricultural productivity, build resilience against climate change, and promote sustainability. The following key opportunities highlight the pathways for advancing CSA adoption, supported by relevant examples:

7.1 Policy Support and Governance

Opportunity: Establishing and strengthening supportive policies that incentivize the adoption of CSA practices can create an enabling environment for widespread implementation. Policies could include subsidies, tax rebates, grants, or regulatory reforms aligned with sustainable agricultural practices.

Example: In Kenya, the National Climate Change Action Plan has facilitated CSA adoption by offering financial support and capacity-building programs. These initiatives have enabled farmers to transition to sustainable farming practices, thereby improving productivity and climate resilience.

7.2 Access to Finance

Opportunity: Affordable financing mechanisms are critical for overcoming economic barriers to adopting CSA technologies. These mechanisms can include microfinance programs, low-interest loans, or innovative crowdfunding initiatives tailored to farmers' needs.

Example: In India, the Self-Employed Women's Association (SEWA) has developed microfinance models that empower women farmers to invest in CSA technologies, such as solar irrigation systems and organic farming inputs. These interventions have significantly enhanced productivity and farm income.

7.3 Capacity Building and Training

Opportunity: Providing targeted education and training programs equips farmers and agricultural practitioners with the knowledge and skills to implement CSA practices effectively. Such programs can also foster awareness about the benefits of CSA, encouraging adoption at scale.

Example: The Food and Agriculture Organization (FAO) conducts extensive training initiatives on agroecology, water management, and sustainable agricultural practices. These programs have enabled thousands of farmers across various regions to adopt CSA techniques, contributing to enhanced resilience and productivity.

7.4 Collaboration and Partnerships

Opportunity: Building multi-stakeholder partnerships involving governments, non-governmental organizations (NGOs), private sector actors, and farmer organizations can mobilize resources, share knowledge, and promote collaborative projects for CSA scaling.

Example: The Global Alliance for Climate-Smart Agriculture (GACSA) brings together diverse stakeholders to promote CSA. Through collaborative projects, GACSA has enhanced food security and resilience to climate change by fostering innovation and disseminating best practices across its member networks.

7.5 Research and Innovation

Opportunity: Investing in research to develop innovative CSA practices and technologies is essential for providing farmers with effective tools to adapt to changing climatic conditions. Research efforts should focus on both local and global challenges, ensuring solutions are scalable and context specific.

Example: In Brazil, research initiatives on biochar production have advanced sustainable agriculture by improving soil fertility and carbon sequestration. By sharing these findings with local farmers, the adoption of biochar as a CSA practice has gained momentum, contributing to environmental and agricultural benefits.

7.6 Market Access and Value Chains

Opportunity: Developing robust market linkages for sustainably produced goods can incentivize farmers to adopt CSA practices. This includes forming cooperatives, establishing fair-trade systems, or creating direct-to-consumer sales channels that reward sustainable production methods.

Example: In Ecuador, farmers who have embraced organic and sustainable farming practices have successfully connected with international markets. This access has enabled them to command premium prices for their products, thereby reinforcing the economic benefits of CSA.

7.7 Conclusion

Scaling up Climate-Smart Agriculture practices requires leveraging opportunities such as supportive policies, financial access, capacity-building initiatives, collaborative partnerships, innovative research, and market linkages. A focus on these strategic areas will drive CSA adoption, enhancing agricultural resilience, economic sustainability, and environmental stewardship. Effective scaling also demands coordinated efforts across sectors, ensuring that farmers and stakeholders are empowered to embrace CSA practices for a sustainable agricultural future.

8. Aligning with Local Development Priorities and Existing Initiatives

Climate-Smart Agriculture (CSA) aligns well with Thai national and local agricultural policies, which emphasize sustainable practices that improve productivity, enhance resilience, and reduce environmental impact. Below is an explanation of how CSA intersects with these policies:

8.1 Alignment with Thai National Agriculture Policy

Thailand's national agricultural policies promote sustainability, innovation, and resilience in the agricultural sector. Key areas of alignment include:

(12) **Sustainability and Food Security**: Thailand's policy prioritizes ensuring food security and sustainable agriculture, echoing CSA's goals of enhancing productivity while conserving natural resources. Initiatives like the Sufficiency Economy Philosophy (SEP) encourage sustainable and self-reliant practices, aligning with CSA principles.

(13) **Climate Resilience**: The Thai government integrates climate change adaptation into agricultural planning, focusing on water management, drought-tolerant crops, and disaster risk reduction—all of which are central to CSA.

(14) **Technological Innovation**: National policies advocate for adopting innovative technologies and precision agriculture, which CSA promotes to improve efficiency and reduce emissions.

(15) **Greenhouse Gas (GHG) Mitigation**: CSA strategies, such as sustainable rice cultivation and reduced chemical use, support Thailand's commitment to reducing emissions under the Paris Agreement.

8.2 Alignment with Thai Local Agriculture Policy

Local agricultural policies in Thailand often aim to address the specific needs of communities while respecting cultural and environmental contexts. CSA aligns with these goals by:

(1) **Localized Practices**: CSA emphasizes context-specific solutions, such as intercropping, agroforestry, and organic farming, which are compatible with local Thai farming practices.

(2) **Community Empowerment**: Local policies often focus on empowering farmers through education and cooperative systems, like CSA's goal of building capacity and knowledge.

(3) **Water Resource Management**: CSA promotes efficient water use and irrigation techniques, aligning with local policies on sustainable water management, particularly in water-scarce areas.

(4) **Biodiversity Conservation**: Thailand's local policies frequently include measures to preserve biodiversity, aligning with CSA's goal of maintaining healthy ecosystems.

8.3 Specific Programs and Policies Supporting CSA in Thailand

Rice Development Strategy (2020–2024): Promotes climate-resilient rice varieties and sustainable practices, a direct CSA application.

Agricultural Master Plan (2023–2027): Focuses on sustainable development goals and integrates CSA-compatible approaches such as carbon farming and precision agriculture.

Smart Farmer Initiative: Encourages Thai farmers to adopt modern, environmentally friendly techniques, mirroring CSA's objectives.

By integrating CSA principles into national and local policies, Thailand can effectively address the challenges of climate change while enhancing agricultural sustainability and improving farmers' livelihoods.

9. Dissemination and Scaling Up: Advocating for Climate-Smart Agriculture in Highland Regions

Advocating for policy changes and incentives that support climate-smart agriculture (CSA) in highland regions is crucial to ensuring that farming practices in these areas become more sustainable, resilient to climate change, and economically viable. To effectively advocate for such changes, a structured approach is necessary, as presented below:

9.1 Understand the Local Context and Challenges

Climate Risks in Highland Regions: Identify the specific climate challenges farmers face in highland areas, such as changes in precipitation patterns, increasing temperature variability, and the risks of soil erosion and landslides. Understand how these challenges affect agriculture, livelihoods, and food security.

Existing Agricultural Practices: Review current farming practices in the highland region and assess how they align with or hinder climate-smart practices. Many highland farmers may still rely on traditional methods that may not be resilient to changing climates.

Barriers to CSA Adoption: Identify the obstacles preventing farmers from adopting CSA techniques, such as lack of knowledge, limited access to finance, inadequate infrastructure, or insufficient government support.

9.2 Build Evidence of the Benefits of CSA

Research and Data Collection: Collect data and research on how CSA practices (e.g., agroforestry, conservation tillage, soil health improvement, water management, crop diversification) have improved resilience and productivity in highland regions.

Case Studies: Showcase successful CSA case studies from similar regions or within the highland areas where CSA has led to positive outcomes like increased crop yields, reduced environmental degradation, and enhanced livelihoods.

Economic Analysis: Conduct an economic assessment demonstrating the cost-benefit analysis of adopting CSA practices in highland agriculture. Highlight the potential for CSA to provide long-term economic gains through increased resilience to climate impacts, reduced input costs, and enhanced productivity.

9.3 Engage Stakeholders and Build Alliances

Farmers and Local Communities: Involve farmers and local communities in discussions about the importance of CSA. Ensure their voices are heard and their needs are incorporated into policy recommendations.

Government Agencies: Engage with local and national government agencies responsible for agriculture, environment, and climate change. Highlight how CSA can help achieve national climate goals, food security, and sustainable development targets.

NGOs and Civil Society: Partner with non-governmental organizations and civil society groups working in agriculture and climate. These groups often have strong networks and advocacy experience.

Private Sector: Involve the private sector, particularly agricultural input suppliers, insurers, and finance institutions, to explore market-driven incentives such as insurance products or sustainable investment opportunities for farmers.

9.4 Propose Specific Policy Changes and Incentives

Climate-Smart Agriculture Training and Education: Advocate for creating programs that train farmers in CSA techniques. Propose subsidies or incentives for farmers to attend such programs.

Financial Incentives and Subsidies: Call for government subsidies, tax incentives, or low-interest loans for farmers who adopt CSA practices. These incentives can help mitigate the initial costs of transitioning to climate-smart methods.

Access to Climate-Smart Technologies: Advocate for policies that make CSA technologies (e.g., drought-resistant seeds, water-saving irrigation systems, and organic fertilizers) more accessible and affordable for farmers.

Climate Resilience Insurance: Promote the development of climate risk insurance products tailored to the needs of highland farmers. This could be done through government-backed insurance schemes or partnerships with private insurance companies.

Research and Development (R&D) Funding: Request increased funding for agricultural R&D to develop CSA techniques suitable for highland regions, including crop varieties resilient to changing climatic conditions and agroecological innovations.

Sustainable Land Management Programs: Support policies that promote soil conservation and sustainable land management, such as terracing, agroecological practices, and reforestation, which help prevent soil erosion and improve water retention in highland areas.

Carbon Sequestration Programs: Promote the inclusion of highland farmers in carbon offset programs, allowing them to benefit financially from their climate-smart practices that contribute to carbon sequestration.

9.5 Advocacy Campaigns

Policy Briefs and Recommendations: Develop clear and concise policy briefs that outline highland farmers' challenges and propose actionable policy solutions. Present substantial evidence of the potential benefits of CSA.

Public Awareness Campaigns: Launch campaigns that educate the public and policymakers on the importance of CSA for food security, environmental sustainability, and climate resilience. Use social media, local radio, and community events to spread the message.

Engage Policymakers: Hold meetings and discussions with policymakers at local, regional, and national levels. Present your case with evidence, case studies, and examples of how CSA can contribute to the region’s climate adaptation and economic development goals.

Advocacy Events: Organize workshops, seminars, and conferences to showcase CSA’s impact on highland agriculture and to advocate for policy changes. Invite key decision-makers to attend and engage in discussions.

9.6 Policy Integration and Institutional Support

Mainstream CSA Across Government Ministries: Integrate CSA into policies across different sectors, including agriculture, water, environment, and rural development. Encourage inter-ministerial collaboration to ensure a holistic approach to climate resilience. For example:

Ministry of Agriculture and Cooperatives (MOAC): Focus on climate-resilient farming systems, agricultural research, and farmer training programs.

Ministry of Natural Resources and Environment (MONRE): Incorporate CSA into national and regional environmental protection policies, focusing on soil conservation and biodiversity.

Ministry of Interior: Support local governments and municipalities in implementing CSA policies at the grassroots level.

Capacity Building for Government Agencies: Strengthen the capacity of local and regional authorities to design and implement CSA programs through training, workshops, and resources. This will ensure that the policy is effectively implemented on the ground.

9.7 Incentives and Support Mechanisms

Subsidies and Financial Incentives: Offer financial incentives to farmers to adopt CSA practices. This could include subsidies for water-saving technologies such as drip irrigation, drought-resistant crop varieties, plants that require minimal water, and organic farming practices. Expand access to low-interest loans for farmers transitioning to CSA techniques.

Insurance and Risk Management: Develop climate risk insurance programs to protect farmers from climate-related shocks. Integrate climate risk insurance schemes into agricultural policies to protect farmers from weather extremes like floods and droughts.

Access to Technology and Innovation: Promote the adoption of climate-smart technologies through partnerships with the private sector, NGOs, and international organizations. These may include precision farming tools, weather forecasting services, and drought-resistant crop seeds.

Carbon Markets: Establish programs that allow farmers to earn carbon credits for adopting CSA practices like agroforestry and reduced tillage. These credits can be traded in carbon markets, providing financial incentives for sustainable agriculture.

9.8 Farmer Education, Outreach, and Training

Farmer Field Schools and Extension Services: Invest in agricultural extension services to train farmers on CSA techniques. Establish Farmer Field Schools (FFS) in each region to provide practical, hands-on learning about CSA practices, such as soil conservation, integrated pest management, and water management.

Public Awareness Campaigns: Raise awareness about the benefits of CSA through media campaigns, community events, and partnerships with agricultural organizations. Highlight successful CSA case studies and share knowledge on how these practices can lead to increased resilience, higher yields, and improved livelihoods.

Farmers should also be assisted by providing knowledge on water management and training to help them effectively access and utilize irrigation technologies and systems.

9.9 Monitoring, Evaluation, and Feedback Mechanisms

Monitoring and Evaluation Framework: Develop a comprehensive monitoring and evaluation framework to track the effectiveness of CSA integration in agricultural plans. This framework should focus on assessing the environmental, social, and economic outcomes of CSA practices.

Data Collection and Research: Support ongoing research on the impact of CSA in Thai agricultural systems and regularly update national and regional agricultural development plans based on findings from pilot projects, field trials, and data collection efforts.

Farmer Feedback: Collect feedback from farmers and stakeholders on implementing CSA policies. Use this feedback to improve programs, refine strategies, and ensure policies align with farmers' needs.

9.10 International Cooperation and Support

Collaboration with International Bodies: Work with international organizations, such as the FAO, UNDP, and the World Bank, to secure technical and financial assistance for CSA initiatives. Leverage global climate finance mechanisms like the Green Climate Fund to support transitioning to climate-smart practices.

Regional Cooperation: Collaborate with neighboring Southeast Asian countries to share knowledge and experiences related to CSA. For example, work with countries like Vietnam and Cambodia on joint research, technology exchange, and shared agricultural climate resilience strategies.

9.11 Monitor and Evaluate Progress

Follow-up on Policy Commitments: After engaging with policymakers, track the progress of advocacy efforts. Hold follow-up meetings to ensure that CSA policies are moving forward.

Evaluate Policy Impact: Continuously evaluate the effectiveness of new policies and incentives as they are implemented. Collect feedback from farmers on how the changes have impacted their ability to implement CSA practices.

Advocate for Adjustments: If necessary, propose policy adjustments based on the feedback and evidence gathered during the implementation phase.

9.12 Conclusion

By following this structured approach, we can advocate effectively for policy changes and incentives that encourage the adoption of climate-smart agriculture in highland regions. This will help build more resilient agricultural systems that can thrive in climate change, ensuring food security and sustainable livelihoods for farmers. Integrating climate-smart agriculture into national and regional agricultural development plans in Thailand is essential for building resilience to climate change, ensuring long-term food security, and promoting sustainable development. By aligning CSA with Thailand's national climate goals, providing financial and technical support, and fostering collaboration between government, farmers, and the private sector, the country can transform its agricultural sector into a more climate-resilient and sustainable one.