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

Vulnerability of Highland Agriculture: Current and Future Climate Change Scenarios

Insights from Nan Province, Thailand

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

Knowledge Product

Vulnerability of Highland Agriculture: Current and Future Climate Change Scenarios

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Abbreviations

ADB	Asian Development Bank
AIT	Asian Institute of Technology
CDF	Cumulative Distribution Function
CMCC	Centro Euro-Mediterraneo sui Cambiamenti Climatici
CMIP	Coupled Model Intercomparison Project
COVID	Coronavirus Disease
CSA	Climate Smart Agriculture
ECMWF	European Centre for Medium-Range Weather Forecasts
GCM	General Circulation Model
GDP	Gross Domestic Product
GFDL	Geophysical Fluid Dynamics Laboratory
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
HDI	Human Development Index
IDW	Inverse Distance Weightage
IPCC	Intergovernmental Panel On Climate Change
JFPR	Japan Fund for Prosperous and Reserve in Asia and the Pacific
LDD	Land Development Department
MAE	Mean Absolute Error
MOAC	Ministry of Agriculture and Cooperatives
NCC	Norwegian Climate Centre
NSE	Nash-Sutcliffe Efficiency
NSO	National Statistical Office
OAE	Office of Agricultural Economics
PBIAS	Percent Bias
RID	Royal Irrigation Department
RMSE	Root Mean Square Error
RSQ	R-Square
RSR	RMSE to Standard Deviation Ratio
SMHI	Swedish Meteorological and Hydrological Institute
SPEI	Standardized Precipitation-Evapotranspiration Index
SPK	Sor-Por-Kor
THA	Thailand
TMD	Thai Meteorological Department
USD	United States Dollar

1. Introduction

1.1 Background

Anthropogenic climate change has been a global threat as humankind faces new challenges every year due to changing climatic conditions and increasing natural disasters. With most of the sectors being affected, to name a few: agriculture, transportation, industry, land-use, and forestry, the urgency for mitigation and adaptation plan is undeniable. Thailand's Vision (2037): National security, prosperity, and sustainability has well comprehended the urgency of mainstreaming climate change in National Strategy (2018–2037) which set out Thai Master Plan on Agriculture with preferences to climate smart value-added agriculture and safe biological farming with local identity. This project "Climate Change Adaptation in Agriculture for Enhanced Recovery and Sustainability of Highlands" shares common goals to Thai Master Plan to reduce climate change vulnerability and enhance the adaptive capacity of highland communities and ecosystems to cope with current and projected climate change impacts; improve household livelihoods, food/nutritional security; and boost rural employment and support Thailand's economic recovery amid the COVID-19 pandemic. Funded by the Asian Development Bank (ADB) and Japan Fund for Prosperous and Resilient Asia and the Pacific (JFPR), The Ministry of Agriculture and Cooperatives (MOAC) acts as an executing agency, and the Office of Agricultural Economics (OAE) as the coordination and implementing agency of the project.

1.2 About the Analytical Booklet

The Technical Assistance (TA) is expected to improve agricultural competitiveness enabling the environment for the adoption of Climate-Smart Agriculture (CSA) in the highlands of Thailand. It is aimed to accomplish under four outputs: (i) capacity to assess climate change vulnerability of highland agriculture evaluated; (ii) gender and COVID-19 responsive CSA practices prioritized and analyzed; (iii) agricultural product quality, value addition, and market linkages assessed, and (iv) capacity of local governments and communities to address climate change strengthened. Each of the TA objectives are tied up with the knowledge products which act as a medium of communication and dissemination of information from project to the concerned stakeholders. This booklet "Climate change vulnerability of highland agriculture insights from nan province, Thailand" fall under output 1 of the TA and aims to disseminate the climate change vulnerability of highland agriculture in Bua Yai subdistrict as a reference such that the government officials at the local level can and improve their understanding and utilize the results while developing community-based adaptation plans.

1.3 Target Users

This booklet Vulnerability of Highland Agriculture: Current and Future Climate Change Scenarios is primarily meant for the local government officials to assess the level of climate vulnerability in the areas of their responsibilities so that they can have policy and operational implications in the ground. It can also be used by central level government officials, private sector, NGOs and research institutions as a reference material. Since it is an analytical booklet, a typical user is supposed to understand vulnerability, climate change, crop modelling and highland agriculture, however it doesn't expect them to be the expert in all the fields. Considering the multi-disciplinary nature of the work being presented in the booklet, a separate guidance manual is prepared describing detailed methodology and fundamental terms as a complementary document referred to as Climate Change Vulnerability Assessment in Highlands (KP3). We expect users to follow the guidance manual for detailed understanding on vulnerability assessment while this booklet focuses more on results and their interpretation.

1.4 Climate change impact in Thai agriculture

Since highland differs from other regions on agriculture practice, terrain, climatic variation within small locality, socio-economic activities and so on, there is much less understanding about highlands/highland agriculture. Limited data is one of the major hindrances to deduce concrete information from research and analysis. The spatiotemporal variability of crops and their yield from field to field along with its multiple driving factors is another challenge to in have comprehensive understanding on an extensive scale. Hence, we can find only a few studies, especially on highland agriculture. All research conducted is mostly focused on a particular crop, which can't provide an overall picture of the agriculture sector. However, there are few studies which used empirical approach to evaluate overall impact of climate change on agriculture (Attavanich, 2014; Jatuporn & Takeuchi, 2022). In particular, Attavanich, 2014 estimated loss of 24–94 billion USD in Thailand's agriculture during 2040–2049 due to climate change. It also found that most of the highland region of Thailand is likely to have either minimum positive or negative impact due to climate change. On a more recent study, Jatuporn & Takeuchi, (2022) found that extreme weather is likely to have negative impact on agricultural economy of Thailand whereas increase in rainfall is likely to have positive impact. Moreover, it found that increase in mean average and minimum temperature is likely to reduce variability in agricultural growth.

1.5 Vulnerability of highland agriculture: Learnings from the past

In absence of local or national research, studies from similar geography and climatic conditions can be vital in developing our understanding regarding vulnerability of highlands/highland agriculture (Table 1). Although different studies used different frameworks, the United Nations Intergovernmental Panel on Climate Change (IPCC) vulnerability framework is found to be the most common in recent days (Mekonen & Berlie, 2021; Simane et al., 2016). The concept of vulnerability has been well described by McDowell & Hess (2012) as a dynamic quantity rather than static and depends on the perception of the exposed people. It stresses the understanding of the dynamic nature of stressors such as land scarcity and delayed seasonal rainfall which can simultaneously reduce access to assets for adaptation creating a compounding effect. Hence, it suggests addressing the constraints for adaptation thus increasing flexibility to reduce exposure and improve the adaptive capacity.

As we know, Vulnerability Index (VI) is function of three different components 1) Exposure 2) Sensitivity and 3) Adaptive Capacity, combination of different indicators from different components can play different role in VI. Mekonen & Berlie, (2021) found that the highest levels of exposure and sensitivity combined with low level of adaptive capacity have increased households' livelihood vulnerability. More importantly, the biophysical and socioeconomic sensitivity to livelihood vulnerability were exacerbated by slope/topography, soil erodibility, and population pressure. Therefore, it stresses designing livelihood zone-based identifiable adaptation strategies to reduce the exposure and sensitivity of crop-livestock mixed agricultural systems to climate calamity. Similarly, Simane et al. (2016) found that high elevation sloping lands and low elevation steep lands exhibited relatively low adaptive capacity and high vulnerability while midland agroecological systems had higher adaptive capacity and lower vulnerability. Hence, it suggests area specific solutions according to the given circumstance of the region. On a separate study conducted in highlands of Vietnam found that double cultivation of rice increases exposure of soil surface to raindrop impacts increasing the probability of soil erosion although it has high soil conservation practices (Vezina et al., 2006). Moreover, rainfed cropping systems in sloping lands are found to be prone to soil loss due to intrinsic soil erosion vulnerability while shifting of cultivation system is likely to increase the soil management.

Since the main goal of vulnerability assessment is mitigation and adaptation, findings from such studies can be taken as a step forward in climate change adaptation. In this context, Heikkinen, (2021) found that larger socio-political structures in which protection of the highland farmers is not prioritized play vital role in climate vulnerability. It emphasizes that the uneven scalar power dynamics and adaptation policy formulation are critical to address as it hits the most-stressed marginalized group during climate disaster. It suggests on more detailed attention must be paid to place-based climate experiences within context-specific, socio-political processes, and to the ways these are shaped by unequal power relations across multiple scales to better understand the multidimensionality of vulnerabilities.

On a separate study from Peru, Lennox, (2015) found that transition from planting traditional staple crops to improved varieties of grasses for livestock and dairy production as an effective measure to reduce climate vulnerability. It also emphasizes the need for balanced development strategies to promote market participation while allowing smallholder farmers to maintain food self-sufficiency and agrobiodiversity in the face of climate change and a changing global economy. Similarly, Gebrehiwot & Van Der Veen, (2013) found that level of education, age, and wealth of the head of the household; access to credit and agricultural services; information on climate, and temperature all influence farmers' choices of adaptation. Moreover, lack of information on adaptation measures and lack of finance are found to be the main factors inhibiting adaptation to climate change.

As extreme weather events led to significant annual productivity losses, amounting to USD 84 billion, the need for agricultural transformation is utmost (Mendelsohn, 2014). In addition, agriculture's environmental footprint and greenhouse gas emissions are of particular concern, with current estimates attributing approximately 14% of total greenhouse gas emissions to the sector. This figure could rise to as high as 30% if deforestation resulting from agricultural expansion is considered (IPCC, 2007).

In the quest for sustainable and climate-resilient agriculture, various strategies and practices have emerged. Field schools have played a pivotal role in promoting organic farming systems and establishing seed banks within communities (Chandra et al., 2017). Meanwhile, techniques such as soil conservation, reforestation, and agroforestry aim to bolster carbon stocks while enhancing crop production. Postharvest management in paddy field supply chains has shown potential in increasing yields and preserving product quality, particularly in rural areas (Hamzah et al., 2019). Enhanced livestock feeding strategies have been linked to methane emissions reduction and increased annual income for farm households (Shikuku et al., 2017). For example, the projected increase in annual income from USD 728 to USD 968, which represents a 33% increase for farm households with zero purchase cost, from improved feeding and breeds. Additionally, significant yield gaps have been observed in the range of 28% to 167% for livestock products and 16% to 209% for crop products among smallholder farmers (Henderson et al., 2016).

In context, a field survey conducted on Mae Chaem district, Chiang Mai province, Northern Thailand, reveals several ongoing challenges faced by highland smallholder agriculture under the influence of climate change which includes shifting cultivation, deforestation, short crop rotation cycles, intensive farming, soil erosion from corn cropping and so on (Khamkhunmuang et al., 2022). On addressing these multifaceted issues, ten specific strategies and practices tailored to the community's livelihood context were identified viz. climate-smart, energy-smart, carbon-smart, knowledge-smart, nutrition-smart, water-smart, harvesting-smart, species diversity-smart, livestock-smart, and policy & private sector-smart approaches. Tools employed to identify such strategies includes a diverse set of participatory tools, including key informant interviews, focus group discussions, transect walks, resource mapping, historical timelines, activity calendars, and livelihood economy assessments.

Table 1:
Summary of studies on highland/highland agriculture vulnerability across globe.

Title	Citation	Study area
Rural households' livelihood vulnerability to climate variability and extremes: a livelihood zone-based approach in the North-eastern Highlands of Ethiopia	(Mekonen & Berlie, 2021)	Ethiopia
Climate change, power, and vulnerabilities in the Peruvian Highlands	(Heikkinen, 2021)	Peru
Agroecosystem specific climate vulnerability analysis: application of the livelihood vulnerability index to a tropical highland region	(Simane et al., 2016)	Ethiopia
Double Exposure to Climate Change and Globalization in a Peruvian Highland Community	(Lennox, 2015)	Peru
Farm Level Adaptation to Climate Change: The Case of Farmer's in the Ethiopian Highlands	(Gebrehiwot & Van Der Veen, 2013)	Ethiopia
Accessing adaptation: Multiple stressors on livelihoods in the Bolivian highlands under a changing climate	(McDowell & Hess, 2012)	Bolivia
Agricultural land-use patterns and soil erosion vulnerability of watershed units in Vietnam's northern highlands	(Vezina et al., 2006)	Vietnam
Cases of Climate-Smart Agriculture in Southeast Asian highlands: Implications for ecosystem conservation and sustainability	(Khamkhunmuang et al., 2022)	ASEAN region

2. Project Area and Key Characteristics of Highland Agriculture

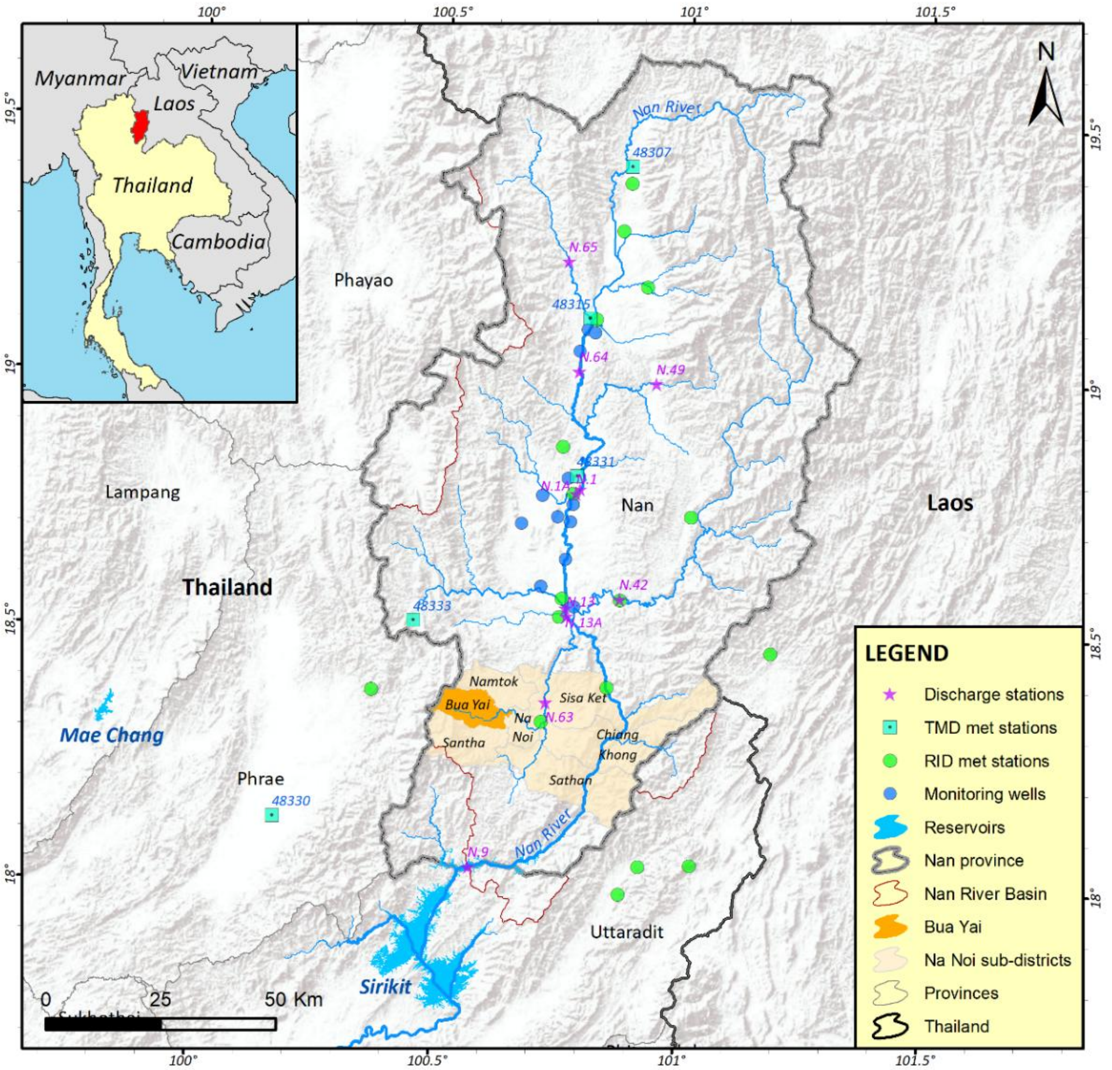
2.1 Project area

The project area consists of nine highland provinces in the Northern Thailand namely: Chiang Mai, Chiang Rai, Lamphun, Mae Hong Son, Nan, Phayao, Phetchabun, Phitsanulok, Phrae and Uttaradit. Extending over an area of 91,778.8 km^2 Thai highlands are mountain ranges extending through Laos, Burma and China linking to the Himalayas. Characterized by steep hill ranges and intermontane basins, there are alluvial valleys providing agricultural and residential space. The elevation ranges between 38–2565 meters above sea level including the highest peak of Thailand, Doi Inthanon in Chiang Mai province. The region is also the origin of three main tributaries of Chao Phraya River: Nan, Yom, and Ping. These rivers drain most of the water from the Northern Thailand to the Southern plains contributing substantially to irrigation, water supply and hydroelectricity. The biggest dams of Thailand, Bhumibol and Sirikit lie on these rivers just on the lap of the mountains which control 22% of the Chao Phraya's annual runoff.

2.2 Characteristics of Thai highland

Although the Thai highland is not devoid of water resources, irrigation in the region is more complex due to its high terrain. Most of the cultivable land is either solely dependent on rainfall or on small farm scale reservoirs. The heterogeneity in vertical and horizontal planes in terms of microclimate, geographical, and other factors determine the nature of agriculture practiced in the region. The characteristics feature of highland agriculture such as small land holding sizes, rainfed farming, shallow soils depths, low fertility and soil erosion, reliance on animal husbandry, poor market reach and so on are prevalent in Thai highlands too. To overcome the existing problems of infertility and low yield, heavy use of fertilizer and pesticide, deforestation for expansion of cultivable land and migration to other regions have become common practice. However, changes in agriculture practice such as monoculture to polyculture, exploration of alternative water resources for irrigation, less water intensive crops, terrace farming, change in cropping calendar and pattern are often less in practice. Exploration of such alternatives and assurance in terms of climate resiliency to market reach and value is what the TA aims to deliver through climate change projection, crop yield projection and vulnerability assessment of crops in context of socio-economic condition of highland community. Once vulnerable regions are identified different CSA approaches will be proposed and demonstrated in the field. The value chain analysis will be conducted, and market reach and value will be assured bringing farmers, government, and private investors to a common platform. Considering the project objectives, implementation and dissemination of CSA practices, the pilot demonstration sites have been selected at Bua Yai subdistrict, Na Noi district in Nan Province as shown in Figure 1.

Figure 1:
Location map of Nan province showing Nan river basin, hydro-meteorological stations and administrative divisions of Na Noi district.



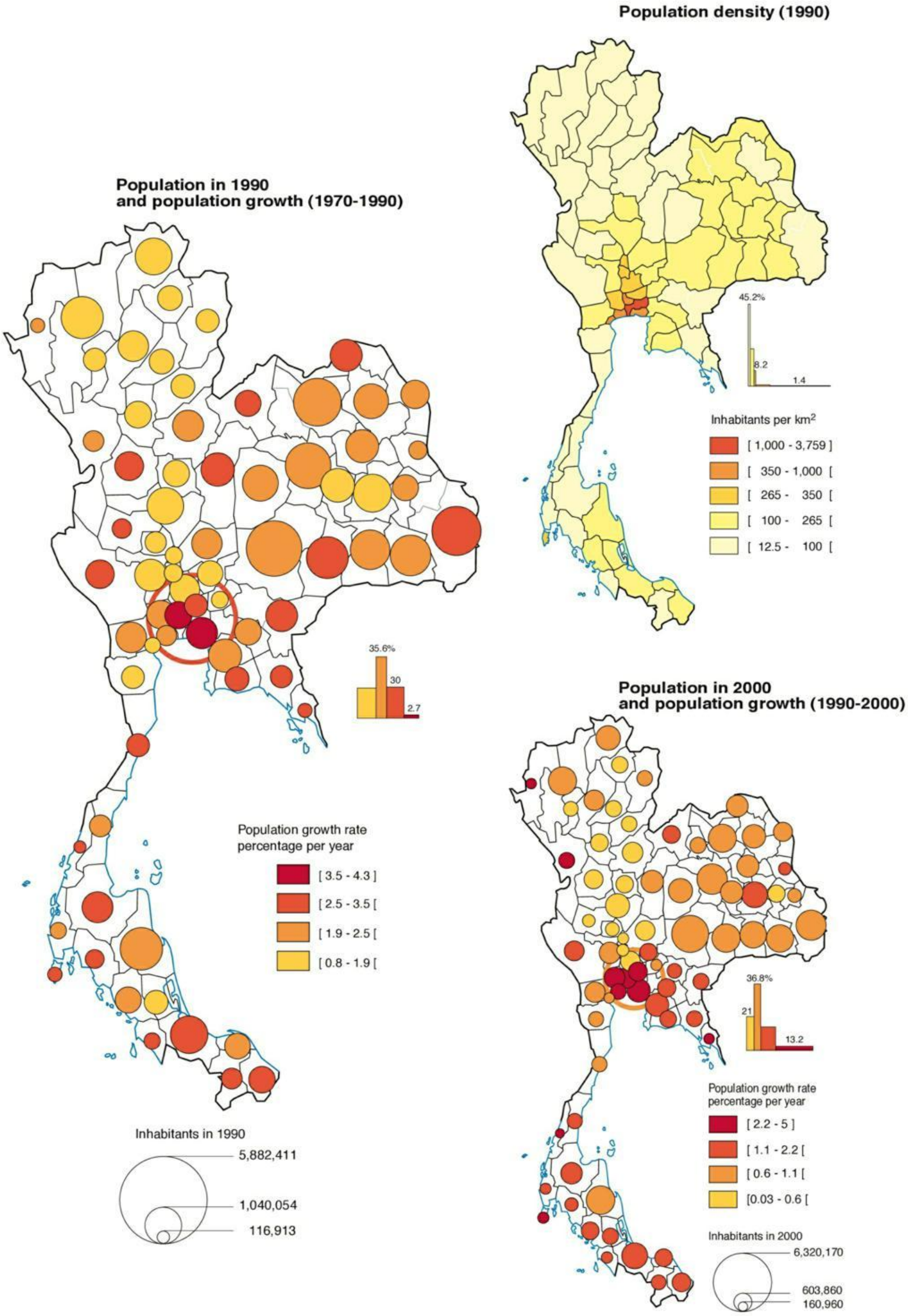
2.3 People of Thai Highlands

The inhabitants of Thai highlands are mostly the hill tribes mostly from Chinese or Tibeto-Burman descent, such as Akha, Yao, Lahu, Khmu, Hmong and Lisu. The population density in the region is the lowest (12.5–100/km^2) compared to other regions (Figure 2). The population growth rate is also the lowest (0.8–1.9% p.a.) in the region. To put into perspective, mean population density of the Nan province was 39 persons/km^2, compared to the national population density (130 persons/km^2) due to mountainous topography, considered a barrier to economic development. The 2019-2020 population of Nan Province was 478,227 persons[1] (0.995 gender ratio), comprised of approximately 170,000 households across 924 villages/communities, 99 subdistricts and 15 districts, and an average three household members. 55% of households were engaged in agriculture and that is the main source of income. In 2015, 28.8% of Nan's population lived under the poverty line (USD 1,057 per person per year in 2015), considerably greater than the national

[1] Official statistics registration systems, 2019

proportion of 8.6%[2]. An increased density of households living in poverty was found in steeper terrains because of low agricultural incomes and a lack of job opportunities.

Figure 2:
Population distribution and growth in Thailand (source: NSO, 1970, 1990, 2000).



[2] Office of National Economic and Social Development Board, 2015

2.4 Topography, Land-use and soil in Nan

The land-use distribution shows that the population is highly concentrated along the nan river (Figure 3). The forest area is mostly on the higher elevation while cultivable land acts as a buffer zone. We found that most of the Nan province (62%) is covered by forest while it was less in Na Noi (65%) and lowest (46%) in Bua Yai (Table 2). The distribution of cropland was exactly opposite with maximum cropland area in Bua Yai (32%) compared to Na Noi (24%) and Nan province (20%). Interestingly, Orchard has significant coverage in Bua Yai (18%), Na Noi (8%) and Nan (9%).

Table 2:
Areal distribution of different land-use types at provincial, district and sub-district scale (LDD, 2018).

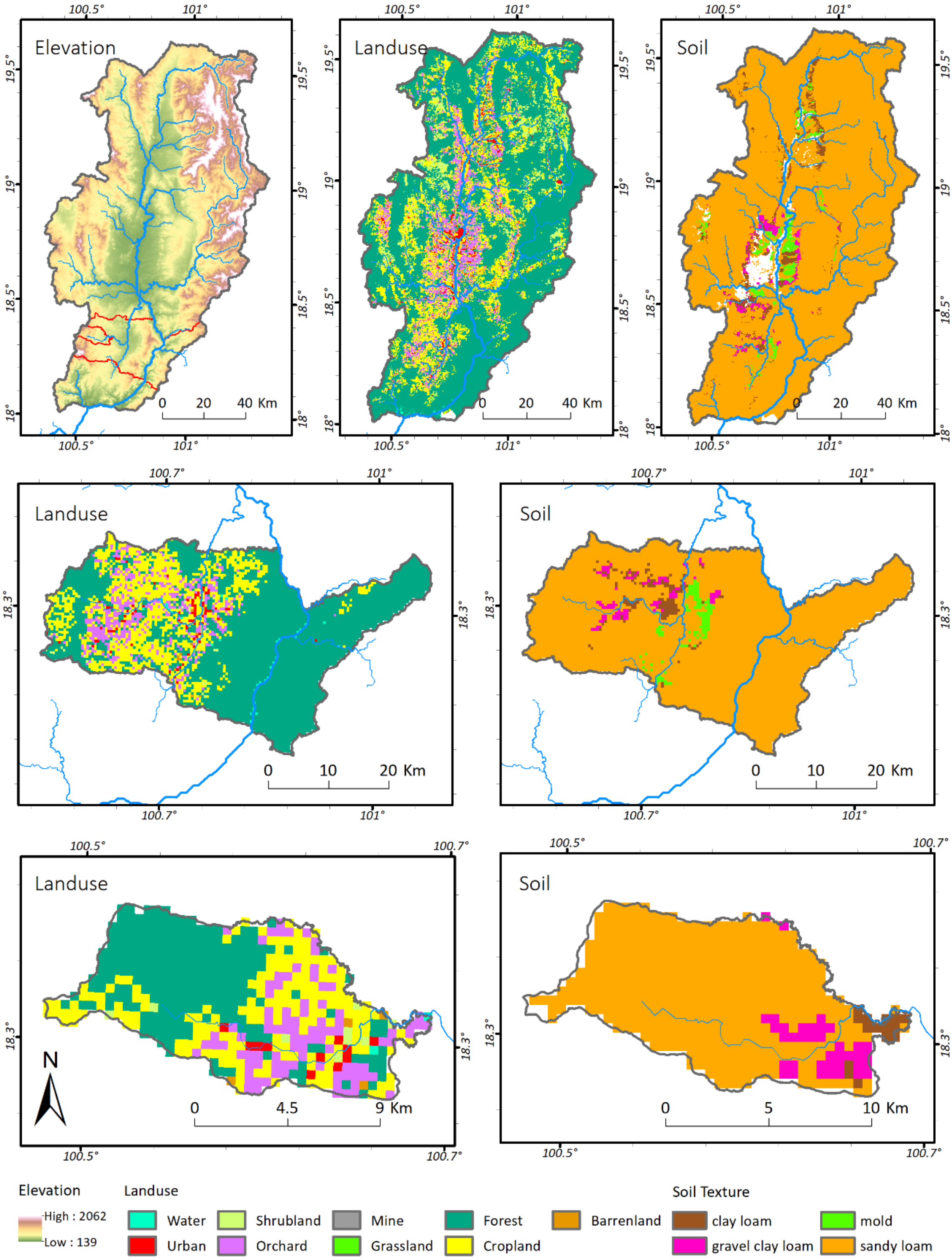
Land-use	Area (%)		
	Nan	Na Noi	Bua Yai
Cropland	20	24	32
Barren land	1	0	1
Orchard	9	8	18
Shrubland	6	1	2
Urban	2	1	2
Water	1	1	0
Forest	62	65	46
Others	0.1	0.0	0.0

Figure 3 shows not much spatial variation in soil type in the whole Nan province with only four different types of soil: sandy loam, clay loam, mold, and gravel clay loam in the order of abundancy. The dominant soil type: sandy loam covers 90%, 94% and 89% of Nan, Na Noi and Bua Yai respectively. Interestingly, all these soil types lie within the same soil type loam. Moreover, the variation in soil type exist only near to the stream network.

Table 3:
Areal distribution of different soil types at provincial, district and sub-district scale (LDD, 2018).

Soil type	Area (%)		
	Nan	Na Noi	Bua Yai
Clay loam	3	2	3
Gravel clay loam	1	2	8
Mold	2	2	0
Sandy loam	90	94	89
Others	3	0	0

Figure 3:
Elevation, land-use and soil distribution in Nan (top), Na Noi (middle) and Bua Yai (bottom) (LDD, 2018).



2.5 Agriculture in Bua Yai

Thai highlands is characterized by monocropping mostly rubber or maize. In Bua Yai, Rubber production was the most common crop for mono-cropping households (reported by 23%-33% of households followed by maize (8-18% of households) and a combination of maize and rubber, the most common two crop system (10-33% of households). The 3,741 rai of rubber represents 50% of the total 7,481 rai of cropping area: the 3,259 rai of maize represents 44% of the total area planted to crops (Figure 4).

Fruit trees include lime, mango, durian, banana + tamarind, vegetables & herbs include pumpkin, herbs, vegetables, sesame, and plantation includes cacao, cashew nut, teak, and bamboo. There were significant differences in the cropping pattern between the different villages during baseline survey in 2022. Under hypothesis testing with null hypothesis H0: The distribution of cropping system is the same across the eight villages (Kruskall-Wallis H= 15.446; degree of freedom =7; Asymptotic significance = 0.031; Monte Carlo 1000 iterations random seed generator). The cropping system reported for B. Nakai is significantly different Ban Nakai than B. Tong Muang (α=0.03). Respondents in B. Nakai reported 15% of no crops, compared to 0% in B. Tong Muang, 25% of 2 crops compared to 48% and 13% of 3 crops compared to 23%.

Figure 4:
Proportion of major crops planted in Bua Yai sub-district.

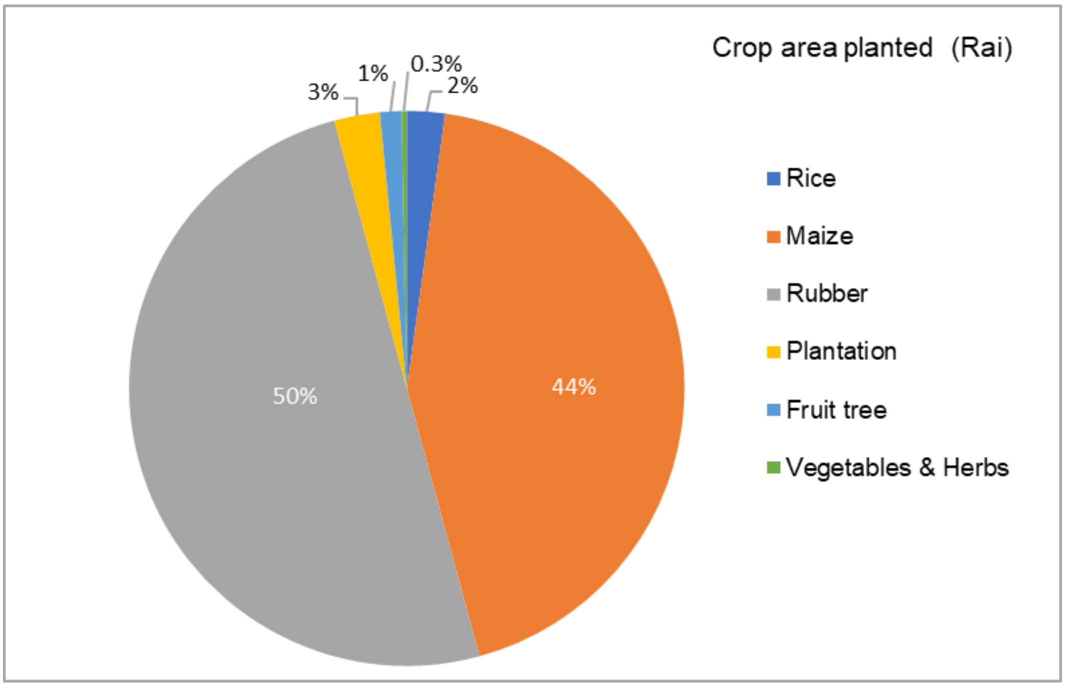


Table 4:
Cropping systems reported in Bua Yai during baseline survey (2022).

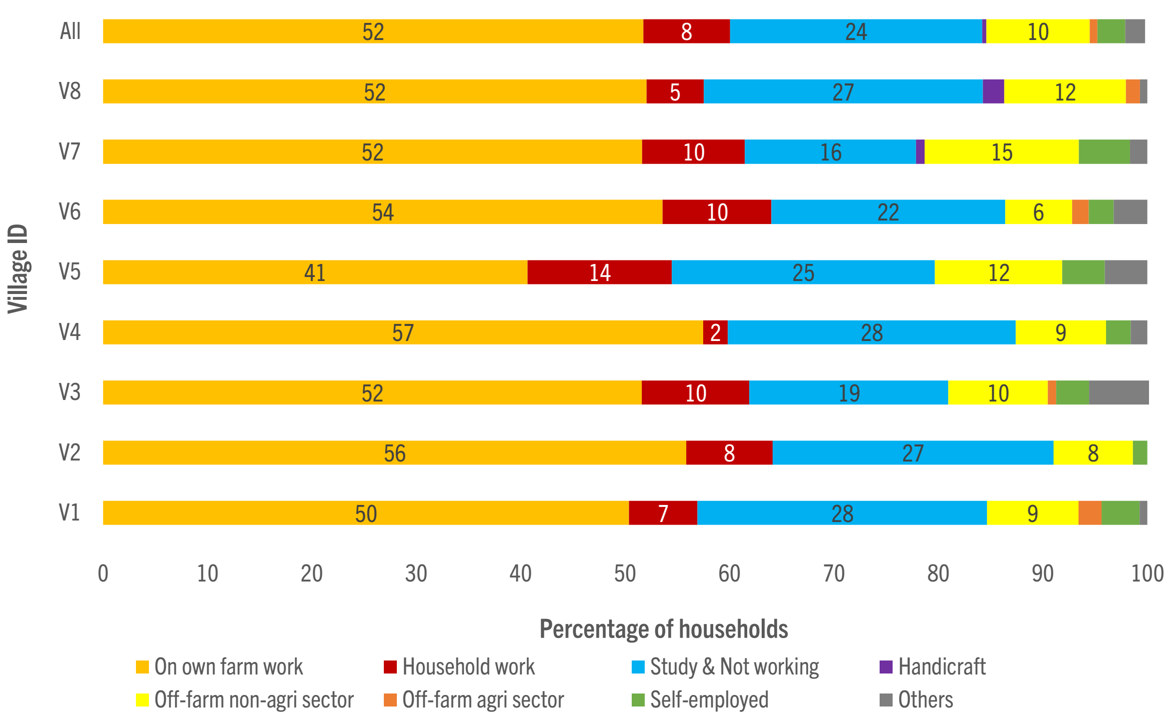
Village ID	Villages	No crops	One crop	Two crops	Three crops	Four crops	Five crops
V1	B. Oi	5%	28%	48%	18%	0%	3%
V2	B. Mai Mongkol	0%	50%	23%	13%	10%	5%
V3	B. Na Haen	3%	38%	48%	13%	0%	0%
V4	B. Tabman	13%	35%	38%	13%	3%	0%
V5	B. Nakai	15%	48%	25%	13%	0%	0%

Village ID	Villages	No crops	One crop	Two crops	Three crops	Four crops	Five crops
V6	B. Tong Muang	0%	28%	48%	23%	3%	0%
V7	B. San Phayom	5%	45%	33%	10%	8%	0%
V8	B. Nong Ha	0%	35%	40%	20%	3%	3%

2.6 Livelihood in Bua Yai

Although there is difference in cropping pattern across the villages, monoculture farm practices, especially maize production, is likely to increase vulnerability as compared to diversified cropping pattern. Large variation in the landholding size indicates a wide economic disparity among the villages. It can pose challenges in terms of technology adoption as different land holding sizes may allow different kinds of technologies to be employed. There is relatively moderate degree of livelihood diversification with high dependency on agriculture and related activities (Figure 5). This indicates a high degree of vulnerability to agriculture related economic shocks to households. 33% households reported stable income (in the past 10 years) and 80% reported sufficient income, while 28% reported unstable income with highest unstable income reported in Oi, Mai Mongkol, and Nong Ha. The perception of stability of income is found to be normally distributed with most of the people being neutral towards their stability. Although the median income of above 100,000 Baht per annum seems out of vulnerable zone, 77–91% dependency in farming as an income source suggest higher sensitivity. Also, adoption of animal husbandry appears to be poor (27%), which can have important resilience implications against climatic and economic shocks as households already have less non-farm income diversification.

Figure 5:
Livelihood diversification in Bua Yai.



High spatial variability in local characteristics of highlands means the need to have high granular/high resolution and quality data on all bio-physical and socio-economic conditions which is largely lacking in highlands. This pushes researchers to make assumptions that drive the analysis and interpretation of the analysis a challenging one to the local conditions. Vulnerability indicators are often location specific and hence the available literature on highland vulnerabilities and related indicators is scarce. In addition, since vulnerability studies are also focused on hazard-specific conditions, the nature and degree of difference between hazards of highlands and lowlands often means the limited suitability for application in highland conditions. Even within the highlands, spatial extrapolation of vulnerabilities is faced with a challenge due to high heterogeneity in highlands. For example, insecure and constrained land rights in the reserved forest in Ban Na Haen (more than 80% of their farmland is in the reserved forest area in the other district, not under Sor–Por–Kor 4-01 [SPK 4-01][3] document, and Kor–Tor–Cho[4]) can increase the susceptibility under exposure thus changing the vulnerability of the village.

On the other hand, increment in dependency on animal husbandry can provide an important opportunity to strengthen resource circulation and closed-loop agricultural systems in highlands that can improve agricultural resilience. Highlands also provide greater opportunity for crop diversification due to vertical cooling and greater heterogeneity. The traditional systems in highlands can help protect the local ecosystems and ecosystem services that can be beneficial to regions beyond highlands.

[3] Sor Por Kor 4-01 (SPK 4-01) is a document entitled for people to use the land for agriculture and pass on to the next generation, which began with the Agricultural Land Reform Act 2518.
[4] Kor–Tor–Cho is initiated by The National Land Policy Committee Act B.E. 2562. People can use the area that has been declared an area under the Kor–Tor–Cho project but the conditions for utilization must be in accordance with the announcement attached to the Kor–Tor–Cho.

Table 5:
Crop, soil, field management and socio-economic data used in VA.

S.N.	Data	Duration	Spatiotemporal resolution	Source
Crop Data				
1	Crop type (land-use)	28/12/2018	1:4,000/25,000/50,000	LDD
2	Planting method (Transplant/sowing)	-	-	Baseline survey & literature
3	Cropping period (Planting and Harvest Date)	-	Farm scale	
4	Maximum canopy cover (CC_x)	-	-	FAO database & literature
5	Crop yield	2012–2019 1984–2019	District/Annual Province/Annual	RID, OAE, DOAE
6	Cropping intensity	Cropping period	Farm scale/Per annum	Baseline survey & literature
7	% of HH with crop rotation	2022	Village	
8	Crop diversity (crops/100 rai)	2022	Village	
Soil Data				
1	Soil textural class (sand/silt/ clay/loam etc.)	2018	1:25,000	LDD
2	No. of soil horizons	-	Farm scale	Baseline survey & literature
3	Thickness of soil horizons	-	Farm scale	
4	Soil properties: • Soil moisture content (θ) at saturation, Field capacity and Permanent wilting point • Saturated hydraulic conductivity • Depth of layer restricting/limiting root deepening • Soil organic matter • Soil pH	Cropping period	Farm scale	A hydraulic properties calculator (Saxton and Rawls, 2006) is available to estimate θ_s and K_{sat} from soil texture. From θ_{sat}, θ_{fc}, θ_{pwp} and K_{sat} FAO Harmonised World Soil Database (Fisher et al., 2008) (AquaCrop derives other physical parameters governing soil evaporation, internal drainage, deep percolation, surface runoff and capillary rise)
Field Management Practices				
1	Soil fertility (Indication of maximum relative dry above ground biomass)	Cropping period	Farm scale	Baseline survey & literature
2	Practices affecting soil evaporation and/or surface runoff: • Mulches	Cropping period	Farm scale	

S.N.	Data	Duration	Spatiotemporal resolution	Source
	• Tied ridges • Soil bunds • Cover and type of soil mulches • Height of soil bunds • Adjustment of surface runoff when affected by crop type and planting			
3	Rainfed/Irrigation	Cropping period	Farm scale	DOAE, RTG, Baseline survey
Socio-economic Data				
1	People perception to erosion risk	2022	Village	Baseline Survey, CIESIN (2018), literature
2	HH living on farm income only	2022	Village	
3	Person/HH	2022	Village	
4	Land holding size (rai/HH)	2022	Village	
5	Employment rate (% of respondents employed)	2022	Village	
6	Availability of credit (% of respondents believing credit is easy)	2022	Village	
7	Proportion of off-farm median income to total income (%)	2022	Village	
8	Education level (% of respondents with education higher than primary level)	2022	Village	
9	Livestock density (Animal Unit: AU/HH)	2022	Village	
10	Transportation cost from home to selling place (Baht/rai)	2022	Village	

Note: DOAE: Department of Agricultural Extension; RTG: Royal Thai Government; LDD: Land development Department; OAE: Office of Agricultural Economics, FAO: Food and Agriculture Organization. Data collection might vary according to consideration of indicators for VI calculation.

3. Climate in Project Area

3.1 Climate data

Climate projection is conducted throughout the Nan province. All the ground station data were collected from concerned Thai authorities while the gridded dataset from ECMWF Reanalysis Version 5 (ERA5) was used for downscaling (Table 6). Future climate data was acquired from the latest released Coupled Model Intercomparison Project Phase 6 (CMIP6) for six General Circulation Models (GCMs) and two different scenarios i.e., Shared Socioeconomic Pathways (SSP245 and SSP585). The selection of GCMs is made as recommended by Khadka et al. (2022) which has evaluated all the CMIP6 GCMs over Thailand. Selection of multiple GCMs is critical during climate projection due to their ability to reproduce the climate in area of interest for given period.

These scenarios are defined by the Intergovernmental Panel on Climate Change (IPCC) based on global socio-economic development trends. Among the five contrasting scenarios we have chosen the most likely scenario: SSP245 and the most pessimistic scenario: SSP585.

Incorporation of six GCMs, alongside optimistic and pessimistic scenarios, empowers us to comprehensively understand the uncertainties among different GCMs and scenarios.

Table 6:
Summary of data and their sources.

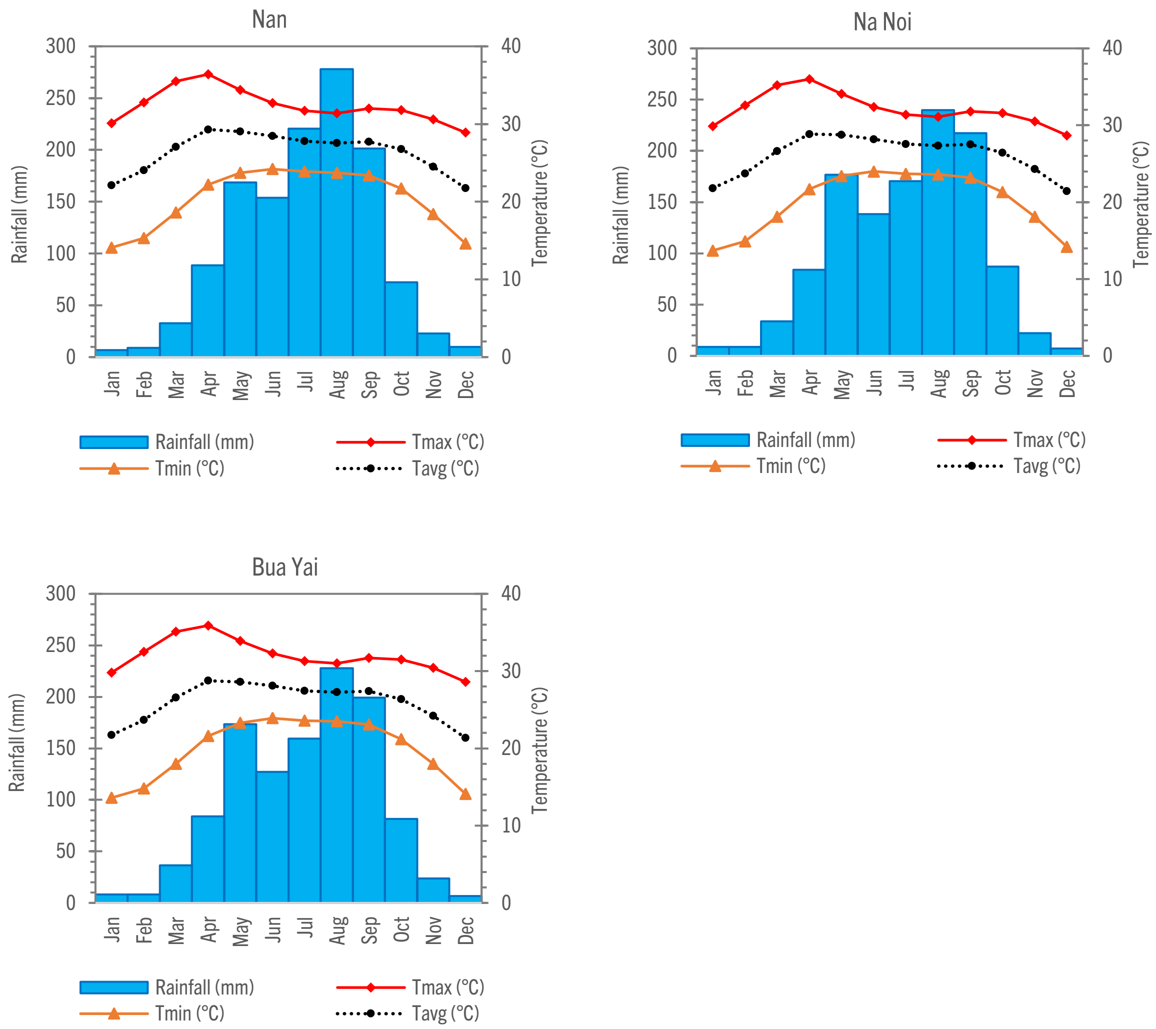
SN	Data	Time	Resolution (Temporal/Spatial)	Source
Observed meteorological data				
a	Minimum Temperature	1985–2014	Point/Daily	TMD
b	Maximum Temperature	1985–2014	Point/Daily	TMD
c	Rainfall	1985–2014	Point/Daily	TMD, RID
Gridded dataset: (ERA5 and GCMs)				
a	ERA5	1985–2014	Daily/0.25°×0.25°	https://cds.climate.copernicus.eu/#!/search?text=ERA5&type=dataset
b	CMCC-ESM2	1985–2100	Daily/1°×1°	CCCMA
c	EC-Earth3	1985–2100	Daily/1°×1°	EC-Earth Consortium, Rossby Center, SMHI
d	EC-Earth3-CC	1985–2100	Daily/1°×1°	
e	GFDL-ESM4	1985–2100	Daily/1°×1°	NOAA
f	NorESM2-MM	1985–2100	Daily/1°×1°	NCC
g	TaiESM1	1985–2100	Daily/1°×1°	RCEC

Note: TMD=Thai Meteorological Department, Thailand; RID=Royal Irrigation Department, Thailand; NCC: Norwegian Climate Centre, Norway, NOAA: National Oceanic and Atmospheric Administration, Geophysical Fluid Dynamics Laboratory, United States; RCEC: Research Center for Environmental Changes, Academia Sinica (Taiwan); SMHI: Swedish Meteorological and Hydrological Institute, Sweden and CCCMA: Canadian Centre for Climate Modeling and Analysis.

3.2 Baseline climate

Climate in Thai highland is typical of tropical mountains characterized by decrease in temperature with increase in altitude. There is a clear distinction between dry and wet seasons. Figure 6 shows that the summer monsoon is dominant from April to September (rainy season). The average dry season rainfall in Nan is 153.4 mm while the wet season rainfall is 1110.8 mm (1985–2014). Meanwhile, the average dry and wet season temperature is found to be 24.4°C and 28.3°C respectively. We found that Na Noi and Bua Yai receive less annual rainfall than the overall province while they remain around 0.4°C cooler, suggesting the cooling effect due to rise in elevation. The maximum fluctuation in daily temperature (diurnal range) is found to be in the month of February (17.7°C) while August has the minimum diurnal range of 7.5 °C.

Figure 6:
Climate in Nan province, Na Noi district and Bua Yai subdistrict during 1985–2014.



4. Future Climate and Anticipated Impacts in Project Area

4.1 Downscaling & Bias correction

Although the future climate data is acquired for different GCMs they can't be utilized directly as they have coarser resolution (100km x 100km) and possess bias. Hence, ERA5 dataset was used to downscale the GCM data to 9km×9km resolution using Empirical Quantile mapping technique (Eqns. (1) to (4)). Subsequently, we enhanced the resolution to 2.5km using a bilinear interpolation technique. Additionally, we utilized ground station data to perform bias correction on the downscaled output. We opted to utilize Empirical Quantile Mapping in our study due to its capacity to rectify both mean bias and variance. Moreover, recent literature strongly recommends this method for its superior performance when compared to other approaches (Luo et al., 2018; Mendez et al., 2020). Results from downscaling were tested for Root Mean Square Error (RMSE), RMSE to Standard Deviation Ratio (RSR), R-Square (RSQ) and Mean Absolute Error (MAE) for each variable.

Table 7:
Equations used for Empirical Quantile Mapping technique.

$$P_{his}(d)^* = F^{-1}_{obs,m}\left[F_{his,m}\left(P_{his,m}\right)\right] \quad (1)$$

$$P_{fut}(d)^* = F^{-1}_{sim,m}\left[F_{sim,m}\left(P_{sim,m}\right)\right] \quad (2)$$

$$T_{his}(d)^* = F^{-1}_{obs,m}\left[F_{his,m}\left(T_{his,m}\right)\right] \quad (3)$$

$$T_{fut}(d)^* = F^{-1}_{sim,m}\left[F_{sim,m}\left(T_{sim,m}\right)\right] \quad (4)$$

where, P = Precipitation, T = Temperature, d = daily, m = monthly* = bias corrected, his = Raw GCM data, obs = observed data, fut = Raw GCM future data, F= Cumulative Distribution Function (CDF), F^(-1)= inverse of CDF.

There was a decrement in Root Mean Square Error, Mean Absolute Error and RSR suggesting improvement in results while increase in R-square suggesting improvement in capturing pattern (Table 8 & Table 9). Table 8 and 9 portray the result for downscaling from 100km to 2.5km resolution while no such indicators were evaluated for bias correction at station level. The bias corrected results from GCMs were analyzed for three different future periods: near (NF: 2020–2046), mid (MF: 2047–2073) and far future (FF: 2074–2100). Seasonal climate change analysis was also conducted considering April through September as wet season and October through March as dry season.

The spatial plots were created using Inverse Distance Weightage (IDW) method. The projected future climate data were used in conjunction with soil data, crop data and management practices to simulate future crop yield through crop modelling.

4.2 Future climate

Nan province is anticipated to be hotter in future with an increase in average annual temperature between 1.8 and 3.6°C by the end of century. Figure 7 and Figure 8 show an increasing trend in minimum and maximum temperature throughout the 21st century. Minimum temperature in Nan province is expected to increase more (i.e., 1.9–4.1°C) than that of maximum temperature (i.e., 1.7–3°C), suggesting the decrement in diurnal temperature range. There was little to no spatial variation regarding the increment in temperature within the province (Figure 17 and Figure 18), however, slight variation of around 0.5°C could be found at some areas. This must be due to sparsely available gage stations which couldn't capture the micro-climate.

Future temperatures are likely to change differently in between seasons. The dry season minimum temperature is likely to rise higher by around 0.4°C compared to the wet season suggesting less seasonal variation in minimum temperature. However, the change in maximum temperature is more or less the same across the seasons. These results are coherent to IPCC, (2013) which estimates the average increase in the global temperature between 1.1–4.8°C. Gunathilake et al. (2020) estimated 1.9–3.4°C of increase in minimum temperature and 1.8–3°C increase in maximum temperature which is quite close to the results from our study. Any discrepancies in the result must have come from the use of different CMIP (version 5) RCMs result. (Annexure I: Maps)

Table 8:
Performance evaluation of downscaling for a) minimum and b) maximum temperature at monthly scale.

Minimum Temperature								
GCMs	Before Downscaling				After Downscaling			
	RMSE (°C)	RSR	RSQ	MAE (°C)	RMSE (°C)	RSR	RSQ	MAE (°C)
CMCC-ESM2	2.5	0.87	0.22	2.1	1.1	0.39	0.85	0.8
EC-Earth3	2.0	0.72	0.47	1.6	1.1	0.4	0.84	0.8
EC-Earth3-CC	2.0	0.7	0.48	1.6	1.0	0.36	0.87	0.7
GFDL-ESM4	4.1	1.45	-1.15	3.1	1.1	0.39	0.85	0.8
NorESM2-MM	3.5	1.25	-0.59	2.6	1.2	0.42	0.82	0.9
TaiESM1	3.2	1.14	-0.34	2.4	1.1	0.4	0.84	0.8
Maximum Temperature								
GCMs	Before Downscaling				After Downscaling			
	RMSE (°C)	RSR	RSQ	MAE (°C)	RMSE (°C)	RSR	RSQ	MAE (°C)
CMCC-ESM2	3.0	1.32	-0.82	2.4	1.6	0.72	0.48	1.2
EC-Earth3	2.6	1.16	-0.42	2.0	1.6	0.69	0.52	1.2
EC-Earth3-CC	2.3	1.02	-0.09	1.8	1.4	0.62	0.62	1.1
GFDL-ESM4	3.5	1.52	-1.33	2.7	1.6	0.69	0.53	1.1
NorESM2-MM	3.4	1.51	-1.32	2.8	1.5	0.65	0.57	1.1
TaiESM1	2.9	1.28	-0.64	2.3	1.5	0.67	0.54	1.2

Table 9:
Performance evaluation of downscaling precipitation at monthly scale.

GCMs	Precipitation							
	Before Downscaling				After Downscaling			
	RMSE (mm)	RSR	RSQ	MAE (mm)	RMSE (mm)	RSR	RSQ	MAE (mm)
CMCC-ESM2	89.2	0.6	0.64	60	78.6	0.53	0.72	54.3
EC-Earth3	94.2	0.64	0.59	63	86.1	0.58	0.66	58.0
EC-Earth3-CC	95.3	0.64	0.58	66	84.4	0.57	0.66	58.2
GFDL-ESM4	109.2	0.74	0.44	74	82.5	0.56	0.69	55.8
NorESM2-MM	101.0	0.68	0.53	68	87.7	0.59	0.65	61.1
TaiESM1	98.9	0.66	0.57	68	85.4	0.58	0.66	59.7

Figure 7:
Temporal change in minimum temperature during 1985–2100. Future values are from the mean of six GCMs under SSP245 and SSP585 emission scenarios.

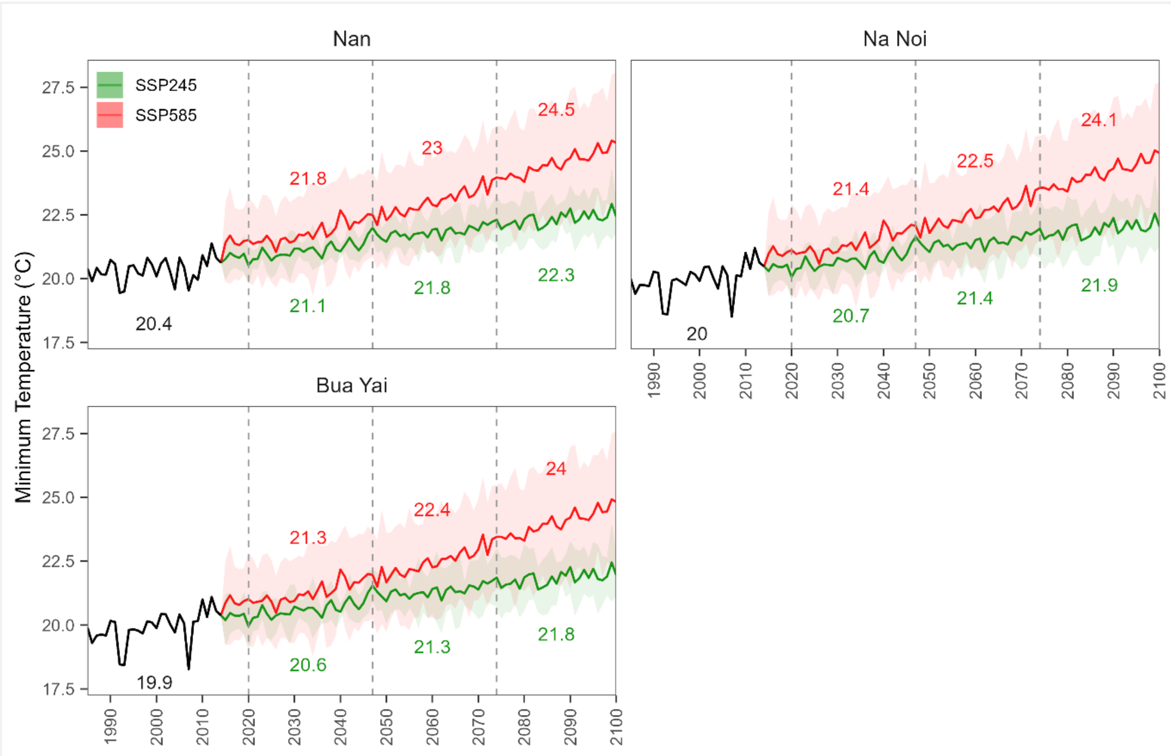
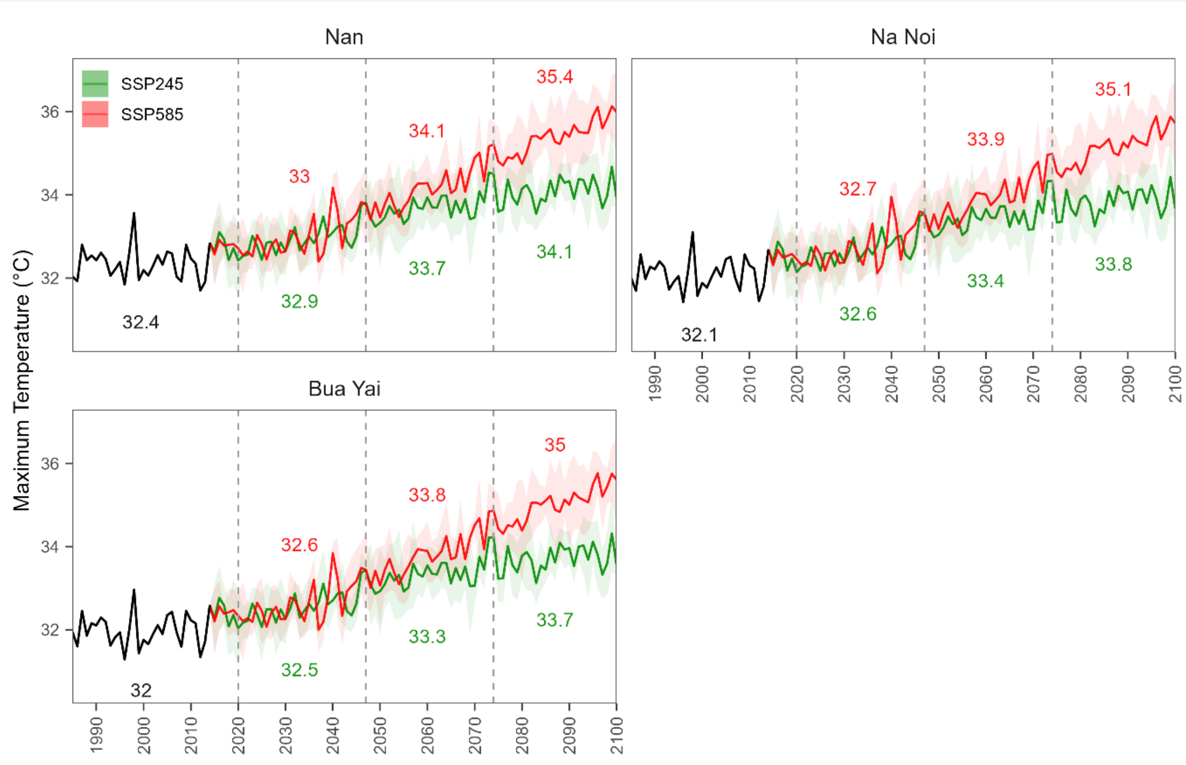


Figure 8:
Temporal change in maximum temperature during 1985–2100. Future values are from the mean of six GCMs under SSP245 and SSP585 emission scenarios.

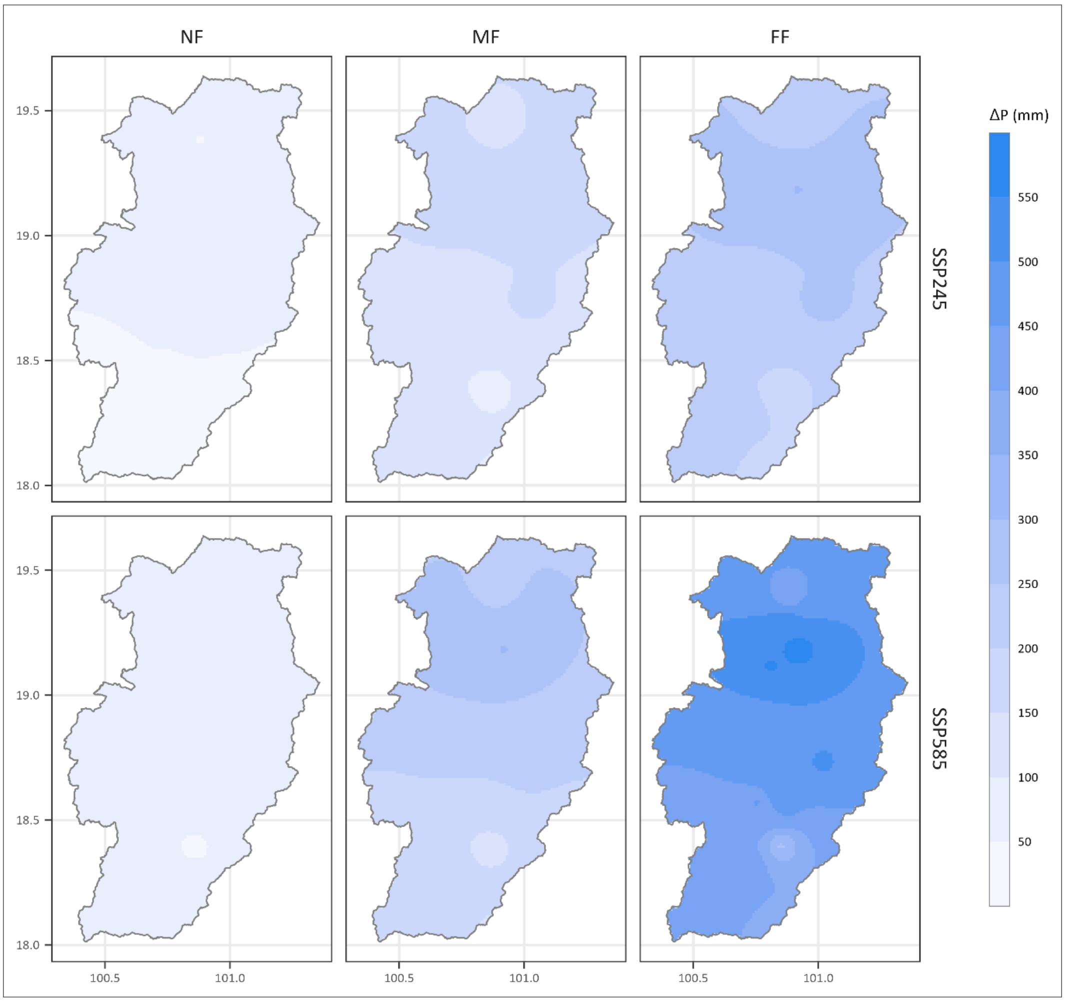


Nan province is expected to be wetter in future compared to the baseline period with an increase in average annual rainfall between 239 and 466mm by the end of century. Figure 9 shows significant spatiotemporal variation in absolute change in future rainfall. As compared to the overall Nan province, Bua Yai and Na Noi are expected to receive less rainfall in future (Table 10). Both dry and wet seasons are likely to receive more rainfall in future, however the percentage increase in dry season rainfall (maximum 40–60% during far future) is higher than wet season (maximum 16–34% during far future). Upon literature review we found that most of them are consistent about increase in wet season rainfall however, there are discrepancies in projection of dry season rainfall (Petpongpan et al., 2021; Gunathilake et al., 2020).

Table 10:
Absolute change in future rainfall compared to the baseline period.

Stations	Season	BL (mm)	SSP245 (mm)			SSP585 (mm)		
			NF	MF	FF	NF	MF	FF
Bua Yai	Annual	1136	39	119	216	73	183	442
Na Noi	Annual	1194	32	99	192	60	156	389
Nan	Annual	1264	56	142	239	72	222	466
Bua Yai	Dry	165	11	36	76	36	65	106
Na Noi	Dry	168	8	32	69	31	55	95
Nan	Dry	153	7	31	61	29	56	92
Bua Yai	Wet	971	29	83	140	36	119	336
Na Noi	Wet	1027	25	67	123	30	101	294
Nan	Wet	1111	49	111	178	43	165	374

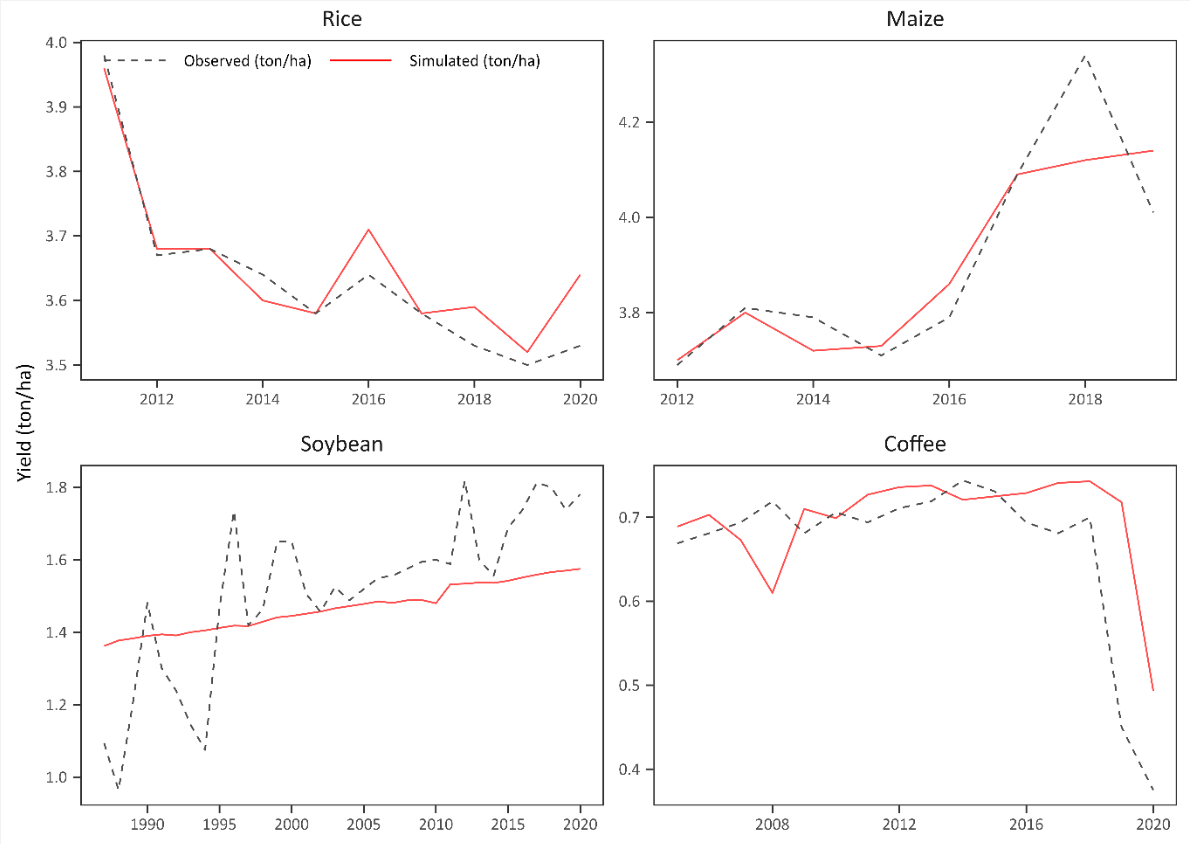
Figure 9:
Spatiotemporal distribution of absolute change in precipitation in Nan province during near (NF), mid (MF) and far (FF) future compared to the baseline period (1985–2014). Results are from the mean of six GCMs under SSP245 and SSP585 emission scenarios.



4.3 Future Crop Yield

Crop yield can be estimated based on climate, soil properties, field management practices and crop properties (type, planting method, cropping period and maximum canopy cover). For this we have selected Aqua-Crop model and calibrated the model against observed crop yield data (Figure 10). Rice, Maize, Soybean and Coffee were selected for the analysis based upon data availability and experts' suggestion.

Figure 10:
Simulated and observed crop yield at Bua Yai during Aqua-Crop model calibration.



Model performance during calibration was evaluated based on five different statistical indicators as shown in Table 11. RMSE, RSR and PBIAS measure the amount of error within the model while NSE measures the efficiency and R-Square measures ability to capture the pattern. The overall performance of the models was good for all the crops. RMSE was found to be least for Rice, Coffee, Maize, and Soybean respectively.

Table 11:
Summary of model performance.

Indicators	Rice	Maize	Soybean	Coffee	Ideal value
RMSE (ton/ha)	0.05	0.10	0.18	0.08	0
RSR	0.39	0.46	0.81	0.84	0
R^2	0.88	0.79	0.66	0.40	1
NSE	0.85	0.78	0.35	0.30	1
PBIAS (%)	-0.64	0.23	2.84	-4.75	0

The calibrated model was fed with future climate to simulate the future yield. Simulation was made for five different villages with local soil type to capture the spatial variation. Rice yield is projected to decrease in near future (up to -6%) while it increases in mid (up to 8%) and far (up to 14%) future (Table 12). In contrast, maize and soybean yield is anticipated to increase up to 15% and 35% respectively until the end of century (Table 13 and Table 14). We found that coffee yield is likely to decrease up to 32% till the end of 21st century (Table 15).

Table 12:
Percentage change in rice yield in future compared to the baseline period.

Scenarios	Villages	BL (ton/ha)	NF (%)	MF (%)	FF (%)
SSP2-4.5	Mai Mongkol	3.65	-1	5	11
	Na Haen	3.65	-2	5	11
	Nakai	3.65	-1	6	12
	Nong Ha	3.65	-4	2	7
	Tabman	3.65	1	8	14
SSP5-8.5	Mai Mongkol	3.65	-6	3	6
	Na Haen	3.65	-6	3	6
	Nakai	3.65	-5	5	9
	Nong Ha	3.65	-4	2	7
	Tabman	3.65	-1	5	11

Table 13:
Percentage change in maize yield in future compared to the baseline period.

Scenarios	Villages	BL (ton/ha)	NF (%)	MF (%)	FF (%)
SSP2-4.5	Mai Mongkol	3.89	2	10	14
	Na Haen	3.89	2	9	14
	Nakai	3.89	2	10	14
	Nong Ha	3.89	2	9	14
	Tabman	3.89	2	9	14
SSP5-8.5	Mai Mongkol	3.89	2	9	14
	Na Haen	3.89	3	10	15
	Nakai	3.89	2	9	14
	Nong Ha	3.89	1	8	13
	Tabman	3.89	2	9	14

Table 14:
Percentage change in soybean yield in future compared to the baseline period.

Scenarios	Villages	BL (ton/ha)	NF (%)	MF (%)	FF (%)
SSP2-4.5	Mai Mongkol	1.45	19	27	32
	Na Haen	1.45	19	27	33
	Nakai	1.45	19	27	33
	Nong Ha	1.45	19	27	33
	Tabman	1.45	19	27	33
SSP5-8.5	Mai Mongkol	1.45	20	29	34
	Na Haen	1.45	19	28	33
	Nakai	1.45	19	28	33
	Nong Ha	1.45	19	28	33
	Tabman	1.45	19	28	33

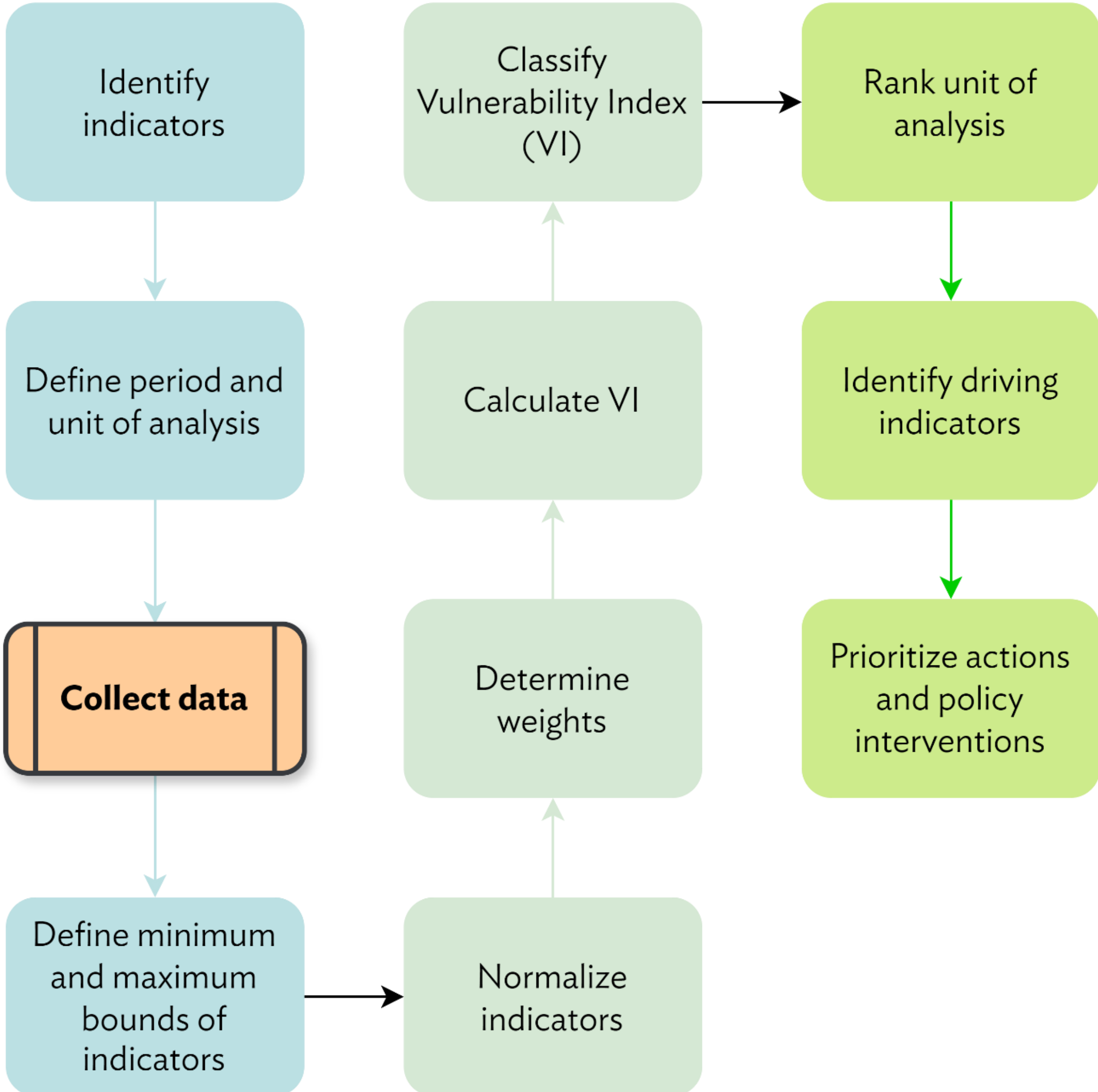
Table 15:
Percentage change in coffee yield in future compared to the baseline period.

Scenarios	Villages	BL (ton/ha)	NF (%)	MF (%)	FF (%)
SSP2-4.5	Mai Mongkol	0.71	-20	-14	-29
	Na Haen	0.71	-19	-14	-29
	Nakai	0.71	-19	-14	-28
	Nong Ha	0.71	-19	-14	-28
	Tabman	0.71	-20	-15	-29
SSP5-8.5	Mai Mongkol	0.71	-20	-15	-32
	Na Haen	0.71	-21	-16	-32
	Nakai	0.71	-21	-16	-32
	Nong Ha	0.71	-21	-15	-30
	Tabman	0.71	-21	-16	-32

5. Vulnerability Assessment Framework

Vulnerability assessment can be commenced only after defining the system of interest in the project area which in our case was highland agricultural system in Bua Yai sub-district, Nan province, Thailand. The step-by-step process as stated in Figure 11 was then followed to evaluate highland agriculture vulnerability on the face of climate change. To begin with, the indicators from each element of vulnerability: Exposure (Table 17), Sensitivity (Table 18) and Adaptive Capacity (Table 19) were collected, reviewed and identified based on stakeholder consultation and experts' opinion. We considered eight villages in Bua Yai sub-district as unit of analysis for baseline (1985–2014), near future (2020–2046), mid future (2047–2073) and far future (2074–2100) periods.

Figure 11:
Vulnerability assessment framework.



Unit of analysis: Villages and Periods: Baseline (1985–2014), Near Future (2020–2046), Mid Future (2047–2073) and Far Future (2074–2100).

Data were collected from both primary (baseline survey of 40 households at each village) and secondary sources (climate change projection, crop modelling and geospatial analysis). The sources of secondary data range from local and national government agencies to global open-source data and literature reviews. Minimum and maximum bounds of each indicator were defined based on their corresponding values across villages over baseline and future periods which were used to normalize the indicators. Weights for each indicator were defined using both equal and different weight (variance equation (5)) methods to compare and contrast the results. Equal weight method was chosen since different weight method removes spatial variability of the indicators resulting in similar vulnerabilities of all the villages at a given period. Finally, vulnerability index for each village was derived by summing up the product of weight and normalized indicators as shown in equation (6). Similarly, all three components of vulnerability were derived using equations (7), (8) and (9).

$$w_j = \frac{1}{\left(SD_i \times \sum_{i=1}^{n} \frac{1}{SD_i}\right)} \qquad (5)$$

Where w_j is the weight of the j^{th} indicator and X_{ij} is the normalized value of X_{ij} and SD is the standard deviation.

$$\mathrm{VI} = \sum_{i=1}^{n} (w_j \times X_{ij}) \qquad (6)$$

$$\mathrm{E} = \sum_{i=1}^{n} (w_j \times E_{ij}) \qquad (7)$$

$$\mathrm{S} = \sum_{i=1}^{n} (w_j \times S_{ij}) \qquad (8)$$

$$\mathrm{AC} = \sum_{i=1}^{n} (w_j \times AC_{ij}) \qquad (9)$$

Where VI is the vulnerability index, w_j is the weight of the j^{th} indicator, X_{ij} , E_{ij}, S_{ij} and AC_{ij} are the normalized values of X_{ij} indicator, exposure, sensitivity and adaptive capacity indicators.

The vulnerability index was classified into five different classes according to percentile as shown in Table 16. Also, the villages were ranked based on their vulnerabilities. Finally, the percentage contribution of each indicator (equation (10)) to the vulnerability index of each village were evaluated and priority actions and policy interventions were recommended.

$$\%\ \text{contribution of}\ X_{ij} = \frac{w_j \times X_{ij}}{VI_i} * 100 \qquad (10)$$

Where w_j is the weight of the j^{th} indicator and X_{ij} is the normalized value of X_{ij} and VI_i is the vulnerability index of i^{th} village.

Table 16:
Percentile-based vulnerability classes.

Percentiles	Vulnerability class
80 – 100	Very Highly Vulnerable
60 – 80	Highly Vulnerable
40 – 60	Moderate Vulnerable
20 – 40	Low Vulnerable
0 – 20	Very Low Vulnerable

Example: 60 percentile refers to a VI value such that 60% of the VI values are less than or equal to that particular value. For detailed steps involved in Vulnerability Index (VI) calculation please refer to KP3.

5.1 Exposure

Table 17:
Indicators derived from the reviewed indices of exposure and their functional relationship to agricultural vulnerability.

Index	Indicators (unit)	Calculation	Relation	Reference
E1	Drought severity for wet/primary season (unitless)*	-Sum SPEI <= -1.5	Positive	Wang et al. (2020); Duong et al. (2017)
E2	Drought severity for dry/secondary season (unitless)*	-Sum SPEI <= -1.5	Positive	Wang et al. (2020); Duong et al. (2017)
E3	Drought duration for wet/primary season (Month)*	Count SPEI <= -1.5	Positive	Wang et al. (2020); Duong et al. (2017)
E4	Drought duration for dry/secondary season (Month)*	Count SPEI <= -1.5	Positive	Wang et al. (2020); Duong et al. (2017)
E5	Flood severity for wet/primary season (unitless)*	Sum SPEI <= 1.5	Positive	Wang et al. (2020); Duong et al. (2017)
E6	Flood severity for dry/secondary season (unitless)*	Sum SPEI <= 1.5	Positive	Wang et al. (2020); Duong et al. (2017)
E7	Flood duration for wet/primary season (Month)*	Count SPEI <= 1.5	Positive	Wang et al. (2020); Duong et al. (2017)
E8	Flood duration for dry/secondary season (Month)*	Count SPEI <= 1.5	Positive	Wang et al. (2020); Duong et al. (2017)
E9	Change in annual temperature (°C/year)*	Slope of annual temperature	Positive	Neset et al. (2019); Gbetibouo et al. (2010)
E10	Change in annual rainfall (mm/year)*	Slope of annual rainfall	Negative	Neset et al. (2019); Gbetibouo et al. (2010)

* : Min and max bounds are evaluated based on indicator values across unit of analysis (villages) over baseline and future periods.

5.2 Sensitivity

Table 18:
Indicators derived from the reviewed indices of sensitivity and their functional relationship to agricultural vulnerability.

Index	Indicators (unit)	Calculation	Relation	Reference
S1	Yield gap (%)	Yield Gap = [Potential Yield (Y_p) – Water-limited Yield (Y_w)] / Potential Yield (Y_p)	Positive	Wang et al. (2020)
S2	Erosion risk (% of respondents believing in erosion risk)	No. of respondents believing in erosion risk/Total respondents*100	Positive	Brien et al. (2003); Carter et al. (2010); Parker et al. (2019)
S3	Soil organic matter in topsoil (% of cultivable land with moderate fertile soil)	Area of cultivable land with moderate fertile soil/Total area of cultivable land*100	Negative	Brien et al. (2003); Carter et al. (2010); Parker et al. (2019)
S4	Soil acidity (% of cultivable land with medium to neutral soil)	Area of cultivable land with medium to neutral soil/Total area of cultivable land*100	Negative	Brien et al. (2003); Carter et al. (2010); Parker et al. (2019)
S5	Proportion of arable land to agricultural land (%)	Area of cultivated land/Total area of agricultural land*100	Positive	Wiréhn et al. (2015); Neset et al. (2019)
S6	Crop water use efficiency (Kg/m^3)^^	Crop yield/Water applied	Negative	
S7	Crop water demand (mm/year)^^	Evapotranspiration - Effective rainfall	Positive	Duong et al. (2017)
S8	HH living on farm income only (%)	Number of households/Total households*100	Positive	Duong et al. (2017)
S9	Deforestation rate (% of forest area destroyed/30 years)	-Slope of annual forest area percentage*30 years	Positive	Hagenlocher et al. (2018)
S10	Human population density (Person/HH)^	Number of person/HH	Positive	Gbetibouo et al. (2010)
S11	Crop rotation (% of HH with crop rotation)	No. of HH with crop rotation/Total number of HH*100	Negative	Swami & Parthasarathy (2021)
S12	Crop diversity (crops/100 rai)*	Number of crops grown*Total area of cultivation/100	Negative	Gbetibouo et al. (2010); Neset et al. (2019); Bhatia (1965)

^ : Min and max bounds are evaluated from baseline survey
^^ : Min and max bounds are evaluated based on literatures

* : Min and max bounds are evaluated based on indicator values across unit of analysis (villages) during baseline and future periods

5.3 Adaptive Capacity

Table 19:
Indicators derived from the reviewed indices of adaptive capacity and their functional relationship to agricultural vulnerability.

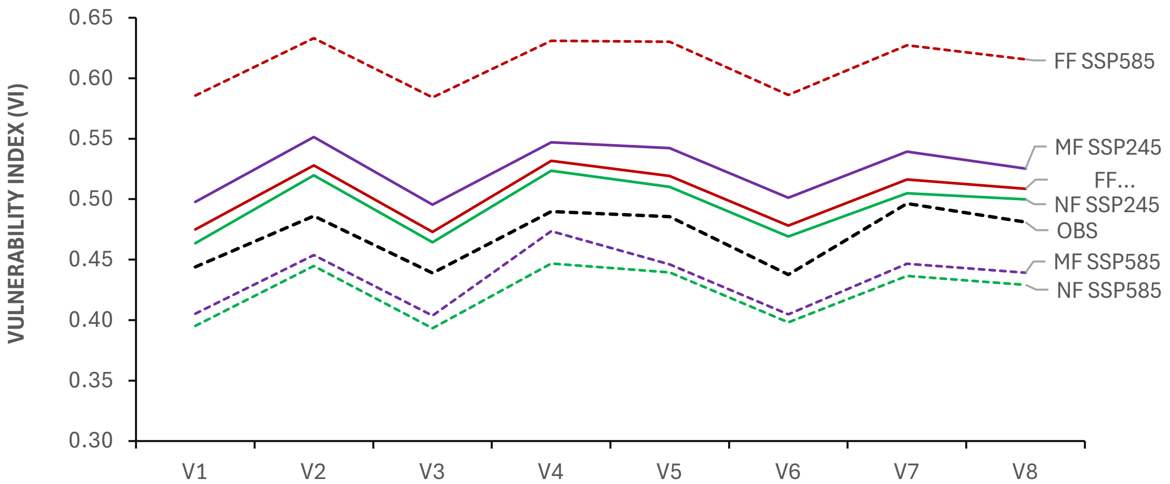
Index	Indicators (unit)	Calculation	Relation	Reference
AC1	Land holding size (rai/HH)^	Total landholding area/No. of HH	Negative	Gbetibouo et al. (2010); Wiréhn et al. (2015)
AC2	Employment rate (% of respondents employed)	No. of respondents employed/Total no. of respondents*100	Negative	Gbetibouo et al. (2010)
AC3	Availability of credit (% of respondents believing credit is easy)	No. of respondents believing in that credit is easy/Total no. of respondents*100	Negative	Gbetibouo et al. (2010)
AC4	Proportion of off-farm median income to total income (%)	Off-farm median income of HH/Average HH income*100	Negative	Gbetibouo et al. (2010)
AC5	Education level (% of respondents with education higher than primary level)	No. of respondents with education higher than primary level/Total no. of respondents*100	Negative	KC et al. (2015)
AC6	Livestock density (Animal Unit: AU/HH)^	Total no. of livestock in terms of Animal Unit (AU)/No. of HH raring livestock	Negative	
AC7	Transportation cost from home to selling place (Baht/rai)*	Transportation cost from home to selling place/ Total area of cultivation	Positive	

^ : Min and max bounds are evaluated from baseline survey
* : Min and max bounds are evaluated based on indicator values across unit of analysis (villages) during baseline and future periods

6. Vulnerability Profile of Highland Agriculture in Project Area

Highland agriculture at Bua Yai is most likely to be more vulnerable in future compared to the baseline period (1985–2014) as shown in Figure 12. Village 7 (B. San Phayom) is found to be the most vulnerable village during the baseline period, followed by V4 (B. Tabman) , V2 (B. Mai Mongkol), V5 (B. Nakai), V8 (B. Nong Ha), V1 (B. Oi), V3 (B. Na Haen), and V6 (B. Tong Muang). However, the variation across villages is significantly low compared to variation across time (periods). Moreover, uncertainty exist within the result for different climate change scenarios (SSP245 and SSP585). SSP245 scenario anticipates increase in vulnerability whereas, opposite is expected for SSP585 scenario during near and mid future. Nevertheless, both scenarios' projects increase in vulnerability at far future period.

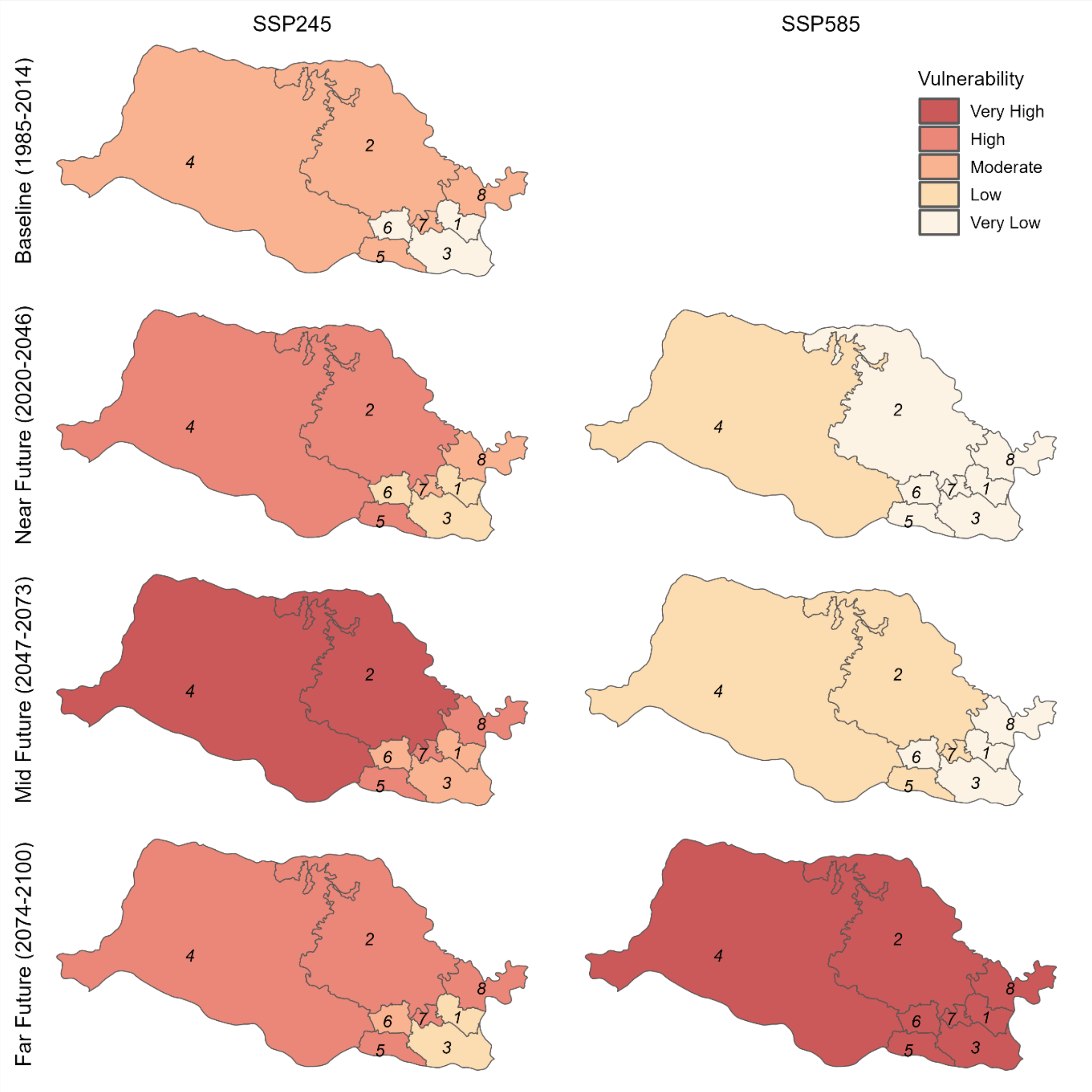
Figure 12:
Variation in vulnerabilities across villages (units) and time periods [baseline (1985–2014), near future (2020–2046), mid future (2047–2073) and far future (2074–2100)] for different climate change scenarios (SSP245 and SSP585).



Uncertainty in the vulnerability index arose due to uncertainty in climate change scenarios is critical to judge. As we know SSP245 scenario is the most likely scenario and SSP585 as an extreme scenario it would be wise to follow results from SSP245 scenario. However, it's essential to identify the root cause of such uncertainty. We found that change in precipitation, a top driving indicator (for detail: refer to Drivers of vulnerability) of vulnerability is projected to have opposite trend at different scenarios resulting in such uncertainty. Moreover, while temperature possess increasing trend in both scenarios, rainfall is likely to have significant impact on droughts, floods and water demand in future. Since vulnerability assessment is all about being prepared for uncertain future and the worst-case scenario, we recommend formulating adaptation strategies and policy interventions to address projected vulnerabilities during the near future period under the Shared Socioeconomic Pathway (SSP245) scenario. Moving forward, our discussions will primarily revolve around this specific scenario to ensure a more focused and targeted approach.

Vulnerability Index (VI) itself cannot disseminate much information to the target users of the booklet i.e., local government officials, policy makers, private sector, NGOs and researchers, hence vulnerability classes have been attributed for each village based on the percentile values of VI as shown in the map (Figure 13). The map shows that village 1, 3 and 6 climb from very low to low vulnerable state until near future while village 7 and 8 holds on to moderate vulnerable state and village 2, 4 and 5 jumps from moderate to highly vulnerable state (for SSP245 scenario). The situation is anticipated to be worse during the mid and far future; however, these conditions are far-fetched and are characterized by high uncertainties.

Figure 13:
Vulnerability classes of different villages during baseline and future periods under SSP245 and SSP585 scenarios.

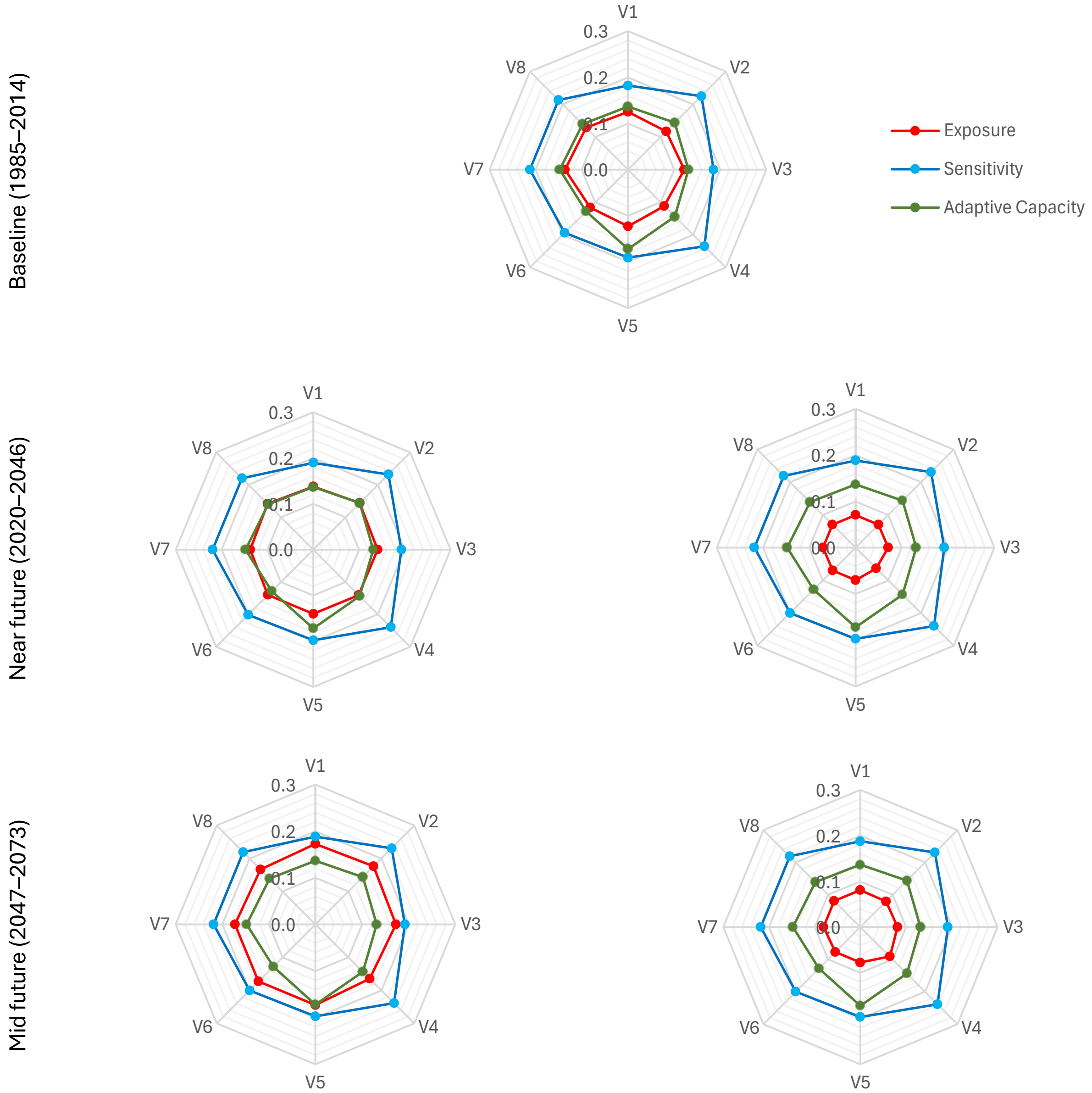


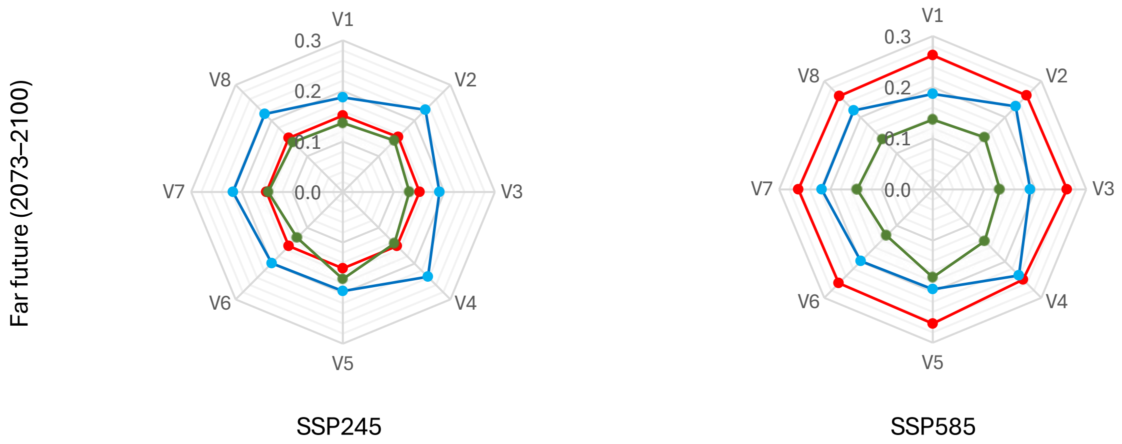
V1: B. Oi, V2: B. Mai Mongkol, V3: B. Na Haen, V4: B. Tabman, V5: B. Nakai, V6: B. Tong Muang, V7: B. San Phayom, V8: B. Nong Ha

6.1 Vulnerability components composition

Understanding vulnerability requires deeper understanding of its composition; which component is contributing to the overall vulnerability and by how much at each unit and for a given period. Villages in Bua Yai are found to be more sensitive and have low adaptive capacity towards exposed climate change during the baseline period as shown in Figure 14. Moreover, exposure is anticipated to amplify in future while sensitivity progresses steadily, and adaptive capacity remains constant. Again, the uncertainty in exposure is reflected clearly across two different scenarios.

Figure 14:
Contribution of exposure, sensitivity and adaptive capacity to the vulnerability index.





V7 (B. San Phayom) is found to be the most exposed village followed by V8 (B. Nong Ha) and V1 (B. Oi) while V4 (B. Tabman) and V2 (B. Mai Mongkol) are the most sensitive followed by V8 (B. Nong Ha) and V7 (B. San Phayom). Adaptive capacity is lacking the most in V5 (B. Nakai) followed by V7 (B. San Phayom).

6.2 Drivers of vulnerability

Among the twenty-nine indicators featuring vulnerability index, we have identified the top five driving indicators at each village. All the indicators' spider plot including contribution of driving indicators at each village during near mid and far future periods are provided in Annexure II: Driving Indicators. A summary of driving indicators at all villages with their frequency of occurrence from rank 1 to 5 is shown in Table 20. It shows that Change in annual rainfall (mm/year) is the top driving indicator (around 7% contribution) at 6 different villages while Land holding size (rai/HH) and Livestock density (Animal Unit: AU/HH) are at top at each village. Similarly, Proportion of off-farm median income to total income (%), Crop water use efficiency (kg/m^3) and Change in annual rainfall (mm/yr.) were the top second driving indicators at 2 villages each while Proportion of arable land to agricultural land (%) and Soil acidity (% of cultivable land with medium to neutral soil) are at top second at each village.

Table 20:
Frequency of occurrence of driving indicators from rank 1 to 5 during near future period under SSP245 scenario.

Index	Description	Rank1	Rank2	Rank3	Rank4	Rank5	Total
E10	Change in annual rainfall (mm/yr.)*	6	2	0	0	0	8
AC4	Proportion of off-farm median income to total income (%)	0	2	2	2	2	8
S6	Crop water use efficiency (Kg/m3)^^	0	2	1	1	2	6
S5	Proportion of arable land to agricultural land (%)	0	1	1	1	0	3
S8	HH living on farm income only (%)	0	0	0	3	0	3

Index	Description	Rank1	Rank2	Rank3	Rank4	Rank5	Total
S3	Soil organic matter in topsoil (% of cultivable land with moderate fertile soil)	0	0	1	0	1	2
S4	Soil acidity (% of cultivable land with medium to neutral soil)	0	1	0	1	0	2
S12	Crop diversity (crops/100 rai)*	0	0	1	0	1	2
AC1	Land holding size (rai/HH)^	1	0	1	0	0	2
AC7	Transportation cost from home to selling place (Baht/rai)*	0	0	1	0	1	2
AC6	Livestock density (Animal Unit: AU/HH)^	1	0	0	0	1	2

7. Policy and Operational Implications

This chapter aims to bridge our understanding from vulnerability assessment to develop climate friendly local agricultural development plans seeking synergy with the National Strategy (2018–2037) of Thailand.

7.1 Integrating Climate Change Vulnerability Considerations in Local Agricultural Development Plans, Policies and Projects

We found that the highland agricultural system is vulnerable to climate hazards during the baseline period and the situation is likely to become worse in future posing significant challenges to agricultural productivity and food security. Given the high sensitivity and low adaptive capacity of villages in Bua Yai, it is imperative to incorporate adaptation strategies to address the vulnerabilities faced by local communities. This requires creating local agricultural development plans, policies and projects considering driving indicators and putting adaptive measures in place to lessen the negative effects on agriculture. Synergy of such plans, policies and projects with the National Strategy (2018-2037) would be effective in enhancing coordinated actions.

Thailand's National Strategy (2018-2037) has formulated three main concepts to enhance the competitiveness in the agricultural sector: 1) Learning from the past for further development 2) Adjusting the present and 3) Creating new future values. It has highlighted following strategic guidelines to explore the value-added agriculture and develop future industry within the agricultural sector:

(1) Farming with local identity
(2) Safe Farming
(3) Biological farming
(4) Agro-processing industry
(5) Smart farming
(6) Bio-industry

Besides, the Thailand's National Strategy has set specific guidelines to promote Eco-Friendly Development and Growth:

(1) Promoting sustainable climate-friendly based society growth
(2) Mitigating greenhouse gas emissions
(3) Adapting to prevent and reduce losses and damages caused by natural disasters and impacts of climate change
(4) Focusing on investment in public and private sectors' climate-friendly infrastructure development
(5) Developing preparedness and response systems for emerging and re-emerging infectious diseases caused by climate change
(6) Developing urban, rural, agricultural, and industrial areas with a key focus on a sustainable growth
(7) Establishing ecological landscape plans to promote urban, rural, agricultural, industrial, and conservation area development on an integrated basis in harmony with area capacity and suitability
(8) Developing urban, rural as well as agricultural and industrial areas in line with the ecological landscape plans
(9) Eliminating pollution and damaging agricultural chemicals in line with international standard
(10) Creating eco-friendly water, energy, and agricultural security

(11) Enhancing productivity of an entire water system to promote water-use efficiency and generate value added for water consumption adequate with international standard
(12) Developing agricultural and food security in terms of quantity, quality, pricing, and access at both national and community

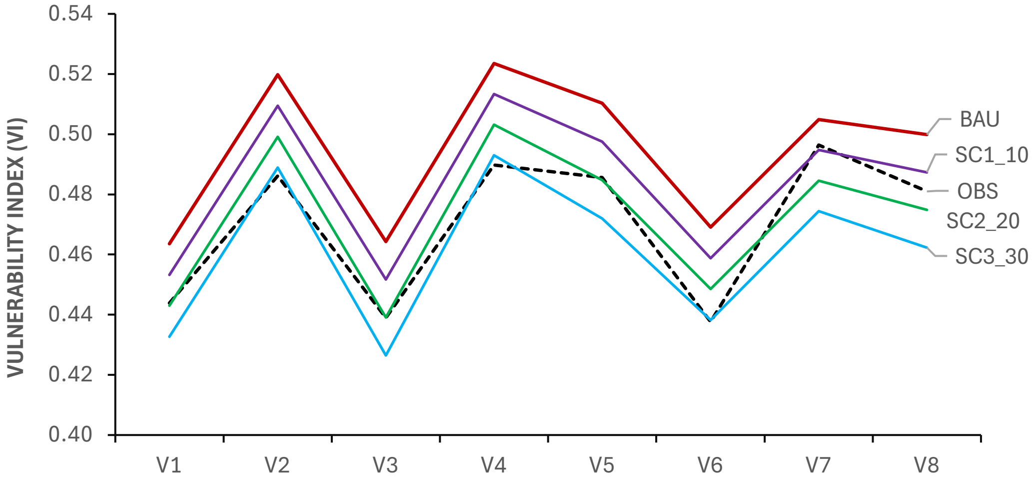
It is evident that Thailand's Vision (2037) "Thailand becomes a developed country with security, prosperity and sustainability in accordance with the Sufficiency Economy Philosophy" would be beyond reach without addressing climate change impacts on agricultural system and naturally, highland agriculture, which has high potential to Agro-forestry, agri-tourism, agri-business and high value crops would have a key role in achieving the goal.

Table 21:
Adaptation scenario analysis.

Scenarios	Description
SC1_BAU	No intervention **No policies to intervene**
SC2_10	Change in priority indicators (add/subtract based on functional relationship to VI) by 10% of the maximum value **Shortfall in Policy Implementation**
SC3_20	Change in priority indicators (add/subtract based on functional relationship to VI) by 10% of the maximum value **Marginal Shortfall in Policy Implementation**
SC4_30	Change in priority indicators (add/subtract based on functional relationship to VI) by 10% of the maximum value **Successful Policy Implementation**

Accounting the outcomes derived from the project and aligning with Thailand's national strategy, we have analyzed four distinct adaptation scenarios as shown in Table 21. By incorporating these scenarios on top three driving indicators, we observed a notable decline in vulnerability, either dropping below or returning to the baseline period. This outcome was particularly pronounced in the most optimistic scenario (SC4_30) followed by (SC3_20) as shown in Figure 15. Based on the analysis we can recommend action on priority indicators (for details refer to Priorities for Action) in sequence where action on more indicators might be necessary on critical villages.

Figure 15:
Declination of vulnerability under different adaptation scenarios.


VULNERABILITY INDEX (VI)
0.54
0.52
0.50
0.48
0.46
0.44
0.42
0.40
V1
V2
V3
V4
V5
V6
V7
V8
BAU
SC1_10
OBS
SC2_20
SC3_30

7.2 Community-based adaptation vs. highland ecosystem-based adaptation

Community-based adaptation has received increasing attention over the years among the adaptation fraternity. This is because of the several advantages it provides to the adaptation itself. Some of these include the following:

(1) Communities are the first responders to any emergencies.
(2) Communities have developed certain knowledge, skills and informal institutions that imbibe the principles and needed capacities that adaptation interventions can utilize.
(3) There is a sense of ownership developed when adaptation is implemented with the involvement of communities. This ownership results in promotion of adaptation at scale as well as sustainability of initiatives that is otherwise not possible.
(4) Communities also possess vulnerabilities that can only be understood by closely working with them.
(5) Since communities are the ultimate benefactors of the adaptation interventions, in most projects and programs, their involvement will also help mobilize community support, understand community needs and in turn result in achieving objectives such as equality, equity and fairness in adaptation. In fact, community participation has been seen as pivotal to achieving these objectives that are central to adaptation effectiveness.
(6) Keeping in view the relevance of communities in adaptation, several community-based adaptation (CBA) strategies have been developed that include locally-led adaptation (LLA), indigenous and local knowledge (ILK) which differ in their nuances but have strong underlying community engagement principles in adaptation.

7.2.1 Communities and ecosystems-based adaptation

Asia in general and highlands in particular are still very much agrarian societies that have strong bondages with the ecosystems. Restoring, strengthening and rejuvenating ecosystems goes a long way in contributing to the adaptation causes of these communities who depend on ecosystem services. There are several ecosystem services in agriculture that are highly threatened by climate change and addressing these issues are in direct relevance to the societies not only that live in rural areas but also in urban areas as urbanization is rapidly threatening the ecosystems and ecosystem services. In this context, looking at the communities as caretakers of ecosystems is a right approach rather than limiting their role as users of ecosystems services.

Community stewardship of ecosystems is a highly documented area of ecosystem governance initiatives globally and this role of communities should be recognized and nurtured in adaptation interventions. Such an approach is even more important for highlands ecosystems that are threatened by climate change while social bondage with the ecosystems is dwindling over the years due to outmigration and changing societal values.

While communities have been engaged with the local ecosystems, although that engagement is on the decline for the reasons stated above, there is high demand for ecosystem restoration in many countries irrespective of their developmental state. Initiatives such as green infrastructure and green cities have been introduced. However, these initiatives, though in principle have potential to engage communities, their design and implementation currently falls short of the potential it offers. There is a need for these initiatives to bring human values into their design elements.

One of the major limitations with the current green initiatives has been the lack of institutional capacity to engage communities and green initiatives in one package. This is largely due to the way institutions such as power and infrastructure have become highly technical and engineering oriented with less emphasis on social and ecological elements. There is a need to rekindle these institutions with these necessary values by capacity building, creating new departments that engage communities with infrastructure building and more importantly try to look at the outcomes not just from the financial and technical standpoint but also from ecological and social outcomes as well. Cross collaboration with departments such as forestry and agriculture could help some of these line ministries to reshape themselves.

Such a change is necessary both in the urban and rural settings. In rural settings, agricultural departments are promoting ecologically sound agricultural practices that need to be scaled up that could be in tension with the already sector gearing to engage with the strong private sector players. Such tensions can be overcome by providing appropriate incentives to private sector to support ecosystem-based interventions and more importantly to engage the private sector ingenuity to benefit the rural populations.

7.3 Designing locally appropriate adaptation strategies for highland agriculture

In this section, we leverage our comprehensive understanding of the physical characteristics, socio-economic dynamics, agricultural systems, and practices within the study area to formulate locally tailored adaptation strategies. Our approach considers various aspects of the study area, as outlined in Table 22 to ensure the relevance and effectiveness of the proposed adaptation measures at the local level. By integrating these key considerations, we aim to develop strategies that address the specific challenges and opportunities prevalent in the study area.

Table 22:
Characteristics of project area considered to design local adaptation strategies.

Characteristics	Description
Physical	(1) Climate (2) Topography (3) Land-use (4) Soil type (5) Natural resources (6) Environment quality
Socio-economic	(1) **Demography:** Population size, composition, age distribution, gender ratios, and ethnic diversity (2) **Economy:** Employment rate, Job opportunities, Income levels, Occupations, Insurance, Availability of credit & Livelihoods of the residents (3) **Education:** Literacy rate, Education levels & vocational trainings (4) **Poverty & Inequality:** Income disparities, wealth distribution and social inequalities (5) **Cultural norms:** Community practices, traditions and community engagement
Agricultural System & Practices	(1) Farm size and scale (2) Land Tenure (3) Crops & livestock (4) Agroecosystem Diversity (5) Farm management practices (6) Agricultural inputs (7) Market orientation (8) Technological adoption (9) Environmental conservation and sustainability (10) Stakeholders of agricultural system

Figure 16 presents an outline of our systematic approach in formulating adaptation strategies for highland agriculture. Throughout this process, we have actively sought synergies among various elements, including driving indicators, characteristic features of the project area, stakeholder input (refer to Annexure III for further details on stakeholder consultation), existing plans and strategies, and identified priority actions and policy interventions as highlighted in Table 23.

It is evident that the Nan Provincial Agriculture and Cooperative Office (PACO), representing the Office of Permanent Secretariat of the Ministry of Agriculture and Cooperatives (MOAC), in collaboration with the Office of Agricultural Economics (OAE), will play a pivotal role in the successful implementation of these practices at the local level. Their involvement is crucial for effective execution and the realization of desired outcomes.

Figure 16:
Steps for designing local adaptation strategies.

Table 23:
Adaptation strategies and relevant policies for driving indicators.

Driving Indicators	Actions/Practices	Policy Interventions
E10: Change in annual rainfall (mm/yr.)* (7%)	**Development of alternative irrigation facilities:** (1) On-farm reservoirs (2) Rainwater harvesting **Shift to efficient irrigation systems:** (1) Solar Irrigation (2) Keyline water management (3) Drip irrigation, Subsurface Irrigation (4) Vertical Farming and Hydroponics	**Demonstration projects:** Establish demonstration projects where farmers can observe and learn about the benefits and effectiveness of efficient irrigation systems, alternative irrigation facilities and use of water efficient crops. **Technical assistance program:** Establish programs that offer technical assistance to farmers, helping them assess their irrigation needs, select suitable crops, select suitable technologies, and provide guidance on system design, installation, and maintenance. **Information and extension services:** Improve access to information and extension services for farmers, providing them with up-to-date knowledge and resources.
S6: Crop water use efficiency (kg/m^3)^^ (5.9%)	(1) Shifting to water efficient crops (2) Cover cropping, Mulching	**Demonstration projects:** Establish demonstration projects where farmers can observe and learn about the benefits and effectiveness of efficient irrigation systems, alternative irrigation facilities and use of water efficient crops. **Technical assistance program:**

<table>
<tr><th>Driving Indicators</th><th>Actions/Practices</th><th>Policy Interventions</th></tr>
<tr><td></td><td></td><td>Establish programs that offer technical assistance to farmers, helping them assess their irrigation needs, select suitable crops, select suitable technologies, and provide guidance on system design, installation, and maintenance.
Information and extension services:
Improve access to information and extension services for farmers, providing them with up-to-date knowledge and resources.</td></tr>
<tr><td>AC4: Proportion of off-farm median income to total income (%) (5.9%)</td><td>Increasing farm income:
(1) Value-added processing of agricultural products
(2) Direct Marketing and Community Supported Agriculture (Farm-to-Restaurant)
(3) Climate Smart Agriculture (Use of drought tolerant crops, shifting to high value crops)
(4) Access to Improved Inputs (seeds, fertilizers, agricultural tools and equipment)
Creating alternative occupation:
Agro-tourism (farm tours, farm stays, educational workshops, or hosting events like farm-to-table dinners or festivals)</td><td>Market diversification, value addition, linkages, and value chain development:
(1) Promote diversification and support farmers in adding value to their agricultural products through processing, packaging, branding, and marketing initiatives.
(2) Facilitate market linkages between farmers and non-farm sectors, such as agribusinesses, processors, retailers, and service providers.
Access to agriculture inputs:
Input subsidies, quality control and certification of agricultural inputs, farmer cooperatives and group purchasing
Access to credit and financial services:
Improve access to credit and financial services for farmers seeking to establish or expand non-farm businesses.
Rural employment programs:
Create job opportunities for farmers in sectors such as rural services, public works projects and infrastructure development.</td></tr>
<tr><td>AC1: Land holding size (rai/HH)^ (5%)</td><td>(1) Farm Size Optimization
(2) Land reclamation</td><td>Land consolidation and redistribution program:
(1) Provide incentives, such as tax breaks or financial assistance, to encourage landholders to voluntarily participate in land consolidation programs which will consolidate small parcels of land to more productive units
(2) Land reform programs, land purchase schemes, or government-initiated land acquisitions to reallocate land from larger landholders to small-scale farmers or landless individuals.
(3) Legal reforms for longer-term land leases, transparent land lease agreements and mechanisms to protect tenant's rights.
(4) Land reclamation regulation: Implement a "stick and carrot" approach by introducing higher taxation for vacant or underutilized land and lower taxation for agricultural land.</td></tr>
</table>

Driving Indicators	Actions/Practices	Policy Interventions
		Rural employment programs: Create job opportunities for farmers in sectors such as rural services, public works projects and infrastructure development which decreases farmers number and in turn increases land holding sizes
S3: Soil organic matter in topsoil (% of cultivable land with moderate fertile soil) (4.5%)	**Enhance soil management practices:** (1) Addition of organic matter such as biochar, compost (2) Crop rotation helps break disease cycles, improve soil structure, and enhance nutrient availability (3) Conservation tillage to minimize soil erosion and disturbances	**Soil health monitoring and assessment programs:** Establish soil health monitoring and assessment programs to track soil quality and provide feedback to farmers. **Incentives for organic and regenerative agriculture:** Certification support, market access assistance and premium prices for organic or regenerative products
S5: Proportion of arable land to agricultural land (%) (5%)	**Increasing efficiency of cultivated land:** (1) **Sustainable intensification:** Using high-yielding crop varieties and improved farming practices. (2) **Technology and innovation:** Precision agriculture technologies, greenhouse farming, hydroponics, aquaponics, vertical farming, and other efficient etc. (3) Agroforestry can help generate income while reducing arable land	**Agricultural land protection legislation:** Enact legislation to protect agricultural land from conversion to non-agricultural uses such as agricultural land easements, conservation restrictions, or development rights purchases to permanently preserve agricultural land, comprehensive land use planning and zoning policies that prioritize the preservation of agricultural land **Incentives for agricultural innovation:** Provide incentives, grants, or research funding for innovative agricultural practices that maximize productivity while minimizing land requirements.
S8: HH living on farm income only (%) (5%)	**Non-agricultural income opportunities:** Small-scale businesses, agro-processing enterprises, rural tourism, handicraft production, or providing services such as transportation, healthcare, education, or technology)	**Rural employment programs:** (1) Create job opportunities for farmers in sectors such as rural services, public works projects and infrastructure development. (2) Creating an enabling environment for small-scale businesses, offering incentives for value-added activities, and addressing barriers to accessing markets and financial services **Community development and collaboration:** Formation of cooperatives, producer groups, or community-based organizations to enable collective marketing, resource-sharing, and the development of common initiatives for income diversification
AC6: Livestock density (Animal Unit:	(1) **Genetic improvement:** Select and breed livestock animals with improved	**Land-use management:** Provision of agricultural land for fodder and grazing

Driving Indicators	Actions/Practices	Policy Interventions
AU/HH)^ (4.1%)	genetics for higher productivity and efficiency (2) Integrated Farming System	**Health and disease management:** Implement robust health management practices such as regular vaccinations, parasite control, biosecurity measures, and proper herd/flock health monitoring. **Promote integrated farming system:** Promote the benefits of integrated farming system where biproducts of livestock such as manure is utilized for farming and farming bi-products are used as fodder for livestock.
S4: Soil acidity (% of cultivable land with medium to neutral soil) (4%)	**Enhance soil management practices** (1) Addition of organic matter such as biochar, compost prevent pH fluctuations (2) Liming for Acidic Soils (3) Mulching such as wood chips or pine needles, can gradually acidify the soil over time (4) Use of crops suitable to the soil pH type	**Soil health monitoring and assessment programs:** Establish soil health monitoring and assessment programs to track soil quality and provide feedback to farmers. **Technical assistance program:** Establish programs that offer technical assistance to farmers, helping them select suitable crops as per soil pH and provide appropriate solution on increasing or decreasing soil pH.
S12: Crop diversity (crops/100 rai)* (3.4%)	(1) Intercropping (2) Crop rotation (3) Planting cover crops	**Seed policy and access:** Promote open access to diverse seeds, including traditional and locally adapted varieties streamlining seed certification processes, removing barriers to seed exchange, and supporting community-based seed-saving initiatives. **Land use policies:** Integrate crop diversity considerations into land use planning and zoning policies.
AC7: Transportation cost from home to selling place (Baht/rai)* (3.4%)	(1) Bulk/collaborative transportation (2) Direct Marketing and Community Supported Agriculture (Farm-to-Restaurant)	**Market linkages and value chain development** (1) Facilitate market linkages between farmers and non-farm sectors, such as agribusinesses, processors, retailers, and service providers. (2) Encourage governments to invest in rural infrastructure, provide incentives for agricultural industries for local consumption.
53.2% (Total contribution to VI)		

Values inside parenthesis represent each indicator's % contribution to VI averaged across villages

7.4 Priorities for action

Table 24 to Table 31 present a comprehensive overview of the priority actions and policy interventions identified for each village within the study area. These tables outline specific measures that are deemed crucial for addressing the unique challenges and opportunities prevalent in each village. The proposed actions and interventions have been carefully formulated based on extensive analysis, stakeholder consultations, and consideration of the local context. By implementing these tailored strategies at the village level, we aim to promote sustainable development, enhance resilience, and improve the well-being of the communities within the study area.

Table 24:
Priority actions and policy interventions for Oi village.

V1: B. Oi		
Indicators	**Actions/practices**	**Policy Interventions**
Change in annual rainfall (mm/y)* (7.4%)	**Development of alternative irrigation facilities:** (1) On-farm reservoirs (2) Rainwater harvesting **Shift to efficient irrigation systems:** (1) Solar Irrigation, Keyline water management, Drip irrigation, Subsurface Irrigation (2) Vertical Farming and Hydroponics	**Demonstration projects:** Establish demonstration projects where farmers can observe and learn about the benefits and effectiveness of efficient irrigation systems, alternative irrigation facilities and use of water efficient crops. **Technical assistance program:** Establish programs that offer technical assistance to farmers, helping them assess their irrigation needs, select suitable crops, select suitable technologies, and provide guidance on system design, installation, and maintenance. **Information and extension services:** Improve access to information and extension services for farmers, providing them with up-to-date knowledge and resources.
Proportion of off-farm median income to total income (%) (6.5%)	(1) Increasing farm income (2) Value-added processing of agricultural products (3) Direct Marketing and Community Supported Agriculture (Farm-to-Restaurant) (4) Climate Smart Agriculture (Use of drought tolerant crops, shifting to high value crops) (5) Access to Improved Inputs (seeds, fertilizers, agricultural tools and equipment) (6) Creating alternative occupation (7) Agritourism (farm tours, farm stays, educational workshops, or hosting events like farm-to-table dinners or festivals)	**Market diversification, value addition, linkages, and value chain development:** (1) Promote diversification and support farmers in adding value to their agricultural products through processing, packaging, branding, and marketing initiatives. (2) Facilitate market linkages between farmers and non-farm sectors, such as agribusinesses, processors, retailers, and service providers. **Access to agriculture inputs:** Input subsidies, quality control and certification of agricultural inputs, farmer cooperatives and group purchasing. **Access to credit and financial services:** Improve access to credit and financial services for farmers seeking to establish or expand non-farm businesses. **Rural employment programs:** Create job opportunities for farmers in sectors such as rural services, public works projects and infrastructure development.

V1: B. Oi		
Indicators	**Actions/practices**	**Policy Interventions**
Crop water use efficiency (kg/m3)^^ (6.3%)	(1) Shifting to water efficient crops (2) Cover cropping, Mulching	**Demonstration projects:** Establish demonstration projects where farmers can observe and learn about the benefits and effectiveness of efficient irrigation systems, alternative irrigation facilities and use of water efficient crops. **Technical assistance program:** Establish programs that offer technical assistance to farmers, helping them assess their irrigation needs, select suitable crops, select suitable technologies, and provide guidance on system design, installation, and maintenance. **Information and extension services:** Improve access to information and extension services for farmers, providing them with up-to-date knowledge and resources.
Proportion of arable land to agricultural land (%) (6.2%)	(1) Increasing efficiency of cultivated land (2) **Sustainable Intensification:** Using high-yielding crop varieties and improved farming practices. (3) **Technology and Innovation:** Precision agriculture technologies, greenhouse farming, hydroponics, aquaponics, vertical farming, and other efficient etc. (4) Agroforestry can help generate income while reducing arable land	**Agricultural land protection legislation:** Enact legislation to protect agricultural land from conversion to non-agricultural uses such as agricultural land easements, conservation restrictions, or development rights purchases to permanently preserve agricultural land, comprehensive land use planning and zoning policies that prioritize the preservation of agricultural land **Incentives for agricultural innovation:** Provide incentives, grants, or research funding for innovative agricultural practices that maximize productivity while minimizing land requirements.
HH living on farm income only (%) (5.8%)	**Non-Agricultural Income Opportunities:** Small-scale businesses, agro-processing enterprises, rural tourism, handicraft production, or providing services such as transportation, healthcare, education, or technology)	**Rural employment programs:** (1) Create job opportunities for farmers in sectors such as rural services, public works projects and infrastructure development. (2) Creating an enabling environment for small-scale businesses, offering incentives for value-added activities, and addressing barriers to accessing markets and financial services. **Community development and collaboration:** Formation of cooperatives, producer groups, or community-based organizations to enable collective marketing, resource-sharing, and the development of common initiatives for income diversification.
32%		

Note: Percentage within parenthesis represent contribution of the indicator to Vulnerability Index (VI)

Table 25:
Priority actions and policy interventions for Mai Mongkol village.

V2: B. Mai Mongkol		
Indicators	**Actions/practices**	**Policy Interventions**
Change in annual rainfall (mm/y)* **(6.6%)**	**Development of alternative irrigation facilities:** (1) On-farm reservoirs (2) Rainwater harvesting **Shift to efficient irrigation systems:** (1) Solar Irrigation, Keyline water management, Drip irrigation, Subsurface Irrigation (2) Vertical Farming and Hydroponics	**Demonstration projects:** Establish demonstration projects where farmers can observe and learn about the benefits and effectiveness of efficient irrigation systems, alternative irrigation facilities and use of water efficient crops. **Technical assistance program:** Establish programs that offer technical assistance to farmers, helping them assess their irrigation needs, select suitable crops, select suitable technologies, and provide guidance on system design, installation, and maintenance. **Information and extension services:** Improve access to information and extension services for farmers, providing them with up-to-date knowledge and resources.
Proportion of off-farm median income to total income (%) **(6.0%)**	(1) Increasing farm income (2) Value-added processing of agricultural products (3) Direct Marketing and Community Supported Agriculture (Farm-to-Restaurant) (4) Climate Smart Agriculture (Use of drought tolerant crops, shifting to high value crops) (5) Access to Improved Inputs (seeds, fertilizers, agricultural tools and equipment) (6) Creating alternative occupation (7) Agritourism (farm tours, farm stays, educational workshops, or hosting events like farm-to-table dinners or festivals)	**Market diversification, value addition, linkages, and value chain development:** (1) Promote diversification and support farmers in adding value to their agricultural products through processing, packaging, branding, and marketing initiatives. (2) Facilitate market linkages between farmers and non-farm sectors, such as agribusinesses, processors, retailers, and service providers. **Access to agriculture inputs:** Input subsidies, quality control and certification of agricultural inputs, farmer cooperatives and group purchasing. **Access to credit and financial services:** Improve access to credit and financial services for farmers seeking to establish or expand non-farm businesses. **Rural employment programs:** Create job opportunities for farmers in sectors such as rural services, public works projects and infrastructure development.
Crop water use efficiency (kg/m^3)^^ **(5.6%)**	(1) Shifting to water efficient crops (2) Cover cropping, Mulching	**Demonstration projects:** Establish demonstration projects where farmers can observe and learn about the benefits and effectiveness of efficient irrigation systems, alternative irrigation facilities and use of water efficient crops. **Technical assistance program:**

V2: B. Mai Mongkol		
Indicators	**Actions/practices**	**Policy Interventions**
		Establish programs that offer technical assistance to farmers, helping them assess their irrigation needs, select suitable crops, select suitable technologies, and provide guidance on system design, installation, and maintenance. **Information and extension services:** Improve access to information and extension services for farmers, providing them with up-to-date knowledge and resources.
Soil organic matter in topsoil (% of cultivable land with moderate fertile soil) **(5.5%)**	(1) Enhance soil management practices (2) Addition of organic matter such as biochar, compost (3) Crop rotation helps break disease cycles, improve soil structure, and enhance nutrient availability (4) Conservation tillage to minimize soil erosion and disturbances	**Soil health monitoring and assessment programs:** Establish soil health monitoring and assessment programs to track soil quality and provide feedback to farmers. **Incentives for organic and regenerative agriculture:** Certification support, market access assistance and premium prices for organic or regenerative products.
Soil acidity (% of cultivable land with medium to neutral soil) **(5.4%)**	(1) Enhance soil management practices (2) Addition of organic matter such as biochar, compost prevent pH fluctuations (3) Liming for Acidic Soils (4) Mulching such as wood chips or pine needles, can gradually acidify the soil over time (5) Use of crops suitable to the soil pH type	**Soil health monitoring and assessment programs:** Establish soil health monitoring and assessment programs to track soil quality and provide feedback to farmers. **Technical assistance program:** Establish programs that offer technical assistance to farmers, helping them select suitable crops as per soil pH and provide appropriate solution on increasing or decreasing soil pH.
29%		

Note: Percentage within parenthesis represent contribution of the indicator to Vulnerability Index (VI)

Table 26:
Priority actions and policy interventions for Na Haen village.

V3: B. Na Haen		
Indicators	**Actions/practices**	**Policy Interventions**
Change in annual rainfall (mm/y)* **(7.4%)**	**Development of alternative irrigation facilities:** (1) On-farm reservoirs (2) Rainwater harvesting **Shift to efficient irrigation systems:** (1) Solar Irrigation, Keyline water management, Drip irrigation, Subsurface Irrigation (2) Vertical Farming and Hydroponics	**Demonstration projects:** Establish demonstration projects where farmers can observe and learn about the benefits and effectiveness of efficient irrigation systems, alternative irrigation facilities and use of water efficient crops. **Technical assistance program:** Establish programs that offer technical assistance to farmers, helping them assess their irrigation needs, select suitable crops, select suitable technologies, and provide guidance on system design, installation, and maintenance. **Information and extension services:** Improve access to information and extension services for farmers, providing them with up-to-date knowledge and resources.
Crop water use efficiency (kg/m^3)^^ **(6.3%)**	(1) Shifting to water efficient crops (2) Cover cropping, Mulching	**Demonstration projects:** Establish demonstration projects where farmers can observe and learn about the benefits and effectiveness of efficient irrigation systems, alternative irrigation facilities and use of water efficient crops. **Technical assistance program:** Establish programs that offer technical assistance to farmers, helping them assess their irrigation needs, select suitable crops, select suitable technologies, and provide guidance on system design, installation, and maintenance. **Information and extension services:** Improve access to information and extension services for farmers, providing them with up-to-date knowledge and resources.
Crop diversity (crops/100 rai)* **(5.8%)**	(1) Intercropping (2) Crop rotation (3) Planting cover crops	**Seed policy and access:** Promote open access to diverse seeds, including traditional and locally adapted varieties streamlining seed certification processes, removing barriers to seed exchange, and supporting community-based seed-saving initiatives. **Land use policies:** Integrate crop diversity considerations into land use planning and zoning policies.
Land holding size (rai/HH)^ **(5.8%)**	(1) Farm Size Optimization (2) Land reclamation	**Land consolidation and redistribution program:** (1) Provide incentives, such as tax breaks or financial assistance, to encourage landholders to voluntarily participate in land consolidation programs which will consolidate small parcels of land to more productive units. (2) Land reform programs, land purchase schemes, or government-initiated land acquisitions to

V3: B. Na Haen		
Indicators	**Actions/practices**	**Policy Interventions**
		reallocate land from larger landholders to small-scale farmers or landless individuals. (3) Legal reforms for longer-term land leases, transparent land lease agreements and mechanisms to protect tenant's rights. (4) Land reclamation regulation: Implement a "stick and carrot" approach by introducing higher taxation for vacant or underutilized land and lower taxation for agricultural land. **Rural employment programs:** Create job opportunities for farmers in sectors such as rural services, public works projects and infrastructure development which decreases farmers number and in turn increases land holding sizes.
Proportion of off-farm median income to total income (%) **(5.7%)**	(1) Increasing farm income (2) Value-added processing of agricultural products (3) Direct Marketing and Community Supported Agriculture (Farm-to-Restaurant) (4) Climate Smart Agriculture (Use of drought tolerant crops, shifting to high value crops) (5) Access to Improved Inputs (seeds, fertilizers, agricultural tools and equipment) (6) Creating alternative occupation (7) Agritourism (farm tours, farm stays, educational workshops, or hosting events like farm-to-table dinners or festivals)	**Market diversification, value addition, linkages and value chain development:** (1) Promote diversification and support farmers in adding value to their agricultural products through processing, packaging, branding, and marketing initiatives. (2) Facilitate market linkages between farmers and non-farm sectors, such as agribusinesses, processors, retailers, and service providers. **Access to agriculture inputs:** Input subsidies, quality control and certification of agricultural inputs, farmer cooperatives and group purchasing. **Access to credit and financial services:** Improve access to credit and financial services for farmers seeking to establish or expand non-farm businesses. **Rural employment programs:** Create job opportunities for farmers in sectors such as rural services, public works projects and infrastructure development.
31%		

Note: Percentage within parenthesis represent contribution of the indicator to Vulnerability Index (VI)

Table 27:
Priority actions and policy interventions for Tabman village.

V4: B. Tabman		
Indicators	**Actions/practices**	**Policy Interventions**
Change in annual rainfall (mm/y)* (6.6%)	**Development of alternative irrigation facilities:** (1) On-farm reservoirs (2) Rainwater harvesting **Shift to efficient irrigation systems:** (1) Solar Irrigation, Keyline water management, Drip irrigation, Subsurface Irrigation (2) Vertical Farming and Hydroponics	**Demonstration projects:** Establish demonstration projects where farmers can observe and learn about the benefits and effectiveness of efficient irrigation systems, alternative irrigation facilities and use of water efficient crops. **Technical assistance program:** Establish programs that offer technical assistance to farmers, helping them assess their irrigation needs, select suitable crops, select suitable technologies, and provide guidance on system design, installation, and maintenance. **Information and extension services:** Improve access to information and extension services for farmers, providing them with up-to-date knowledge and resources.
Soil organic matter in topsoil (% of cultivable land with moderate fertile soil) (6.6%)	(1) Enhance soil management practices (2) Addition of organic matter such as biochar, compost (3) Crop rotation helps break disease cycles, improve soil structure, and enhance nutrient availability (4) Conservation tillage to minimize soil erosion and disturbances	**Soil health monitoring and assessment programs:** Establish soil health monitoring and assessment programs to track soil quality and provide feedback to farmers. **Incentives for organic and regenerative agriculture:** Certification support, market access assistance and premium prices for organic or regenerative products.
Soil acidity (% of cultivable land with medium to neutral soil) (6.5%)	(1) Enhance soil management practices (2) Addition of organic matter such as biochar, compost prevent pH fluctuations (3) Liming for Acidic Soils (4) Mulching such as wood chips or pine needles, can gradually acidify the soil over time (5) Use of crops suitable to the soil pH type	**Soil health monitoring and assessment programs:** Establish soil health monitoring and assessment programs to track soil quality and provide feedback to farmers. **Technical assistance program:** Establish programs that offer technical assistance to farmers, helping them select suitable crops as per soil pH and provide appropriate solution on increasing or decreasing soil pH.

V4: B. Tabman		
Indicators	**Actions/practices**	**Policy Interventions**
Crop water use efficiency (kg/m^3)^^ (5.6%)	(1) Shifting to water efficient crops (2) Cover cropping, Mulching	**Demonstration projects:** Establish demonstration projects where farmers can observe and learn about the benefits and effectiveness of efficient irrigation systems, alternative irrigation facilities and use of water efficient crops. **Technical assistance program:** Establish programs that offer technical assistance to farmers, helping them assess their irrigation needs, select suitable crops, select suitable technologies, and provide guidance on system design, installation, and maintenance. **Information and extension services:** Improve access to information and extension services for farmers, providing them with up-to-date knowledge and resources.
Proportion of off-farm median income to total income (%) (5.3%)	(1) Increasing farm income (2) Value-added processing of agricultural products (3) Direct Marketing and Community Supported Agriculture (Farm-to-Restaurant) (4) Climate Smart Agriculture (Use of drought tolerant crops, shifting to high value crops) (5) Access to Improved Inputs (seeds, fertilizers, agricultural tools and equipment) (6) Creating alternative occupation (7) Agritourism (farm tours, farm stays, educational workshops, or hosting events like farm-to-table dinners or festivals)	**Market diversification, value addition, linkages, and value chain development:** (1) Promote diversification and support farmers in adding value to their agricultural products through processing, packaging, branding, and marketing initiatives. (2) Facilitate market linkages between farmers and non-farm sectors, such as agribusinesses, processors, retailers, and service providers. **Access to agriculture inputs:** Input subsidies, quality control and certification of agricultural inputs, farmer cooperatives and group purchasing. **Access to credit and financial services:** Improve access to credit and financial services for farmers seeking to establish or expand non-farm businesses. **Rural employment programs:** Create job opportunities for farmers in sectors such as rural services, public works projects and infrastructure development.
31%		

Note: Percentage within parenthesis represent contribution of the indicator to Vulnerability Index (VI)

Table 28:
Priority actions and policy interventions for Nakai village.

V5: B. Nakai		
Indicators	**Actions/practices**	**Policy Interventions**
Transportation cost from home to selling place (Baht/rai)* **(6.8%)**	(1) Bulk/collaborative transportation (2) Direct Marketing and Community Supported Agriculture (Farm-to-Restaurant)	**Market linkages and value chain development:** (1) Facilitate market linkages between farmers and non-farm sectors, such as agribusinesses, processors, retailers, and service providers. (2) Encourage governments to invest in rural infrastructure, provide incentives for agricultural industries for local consumption.
Change in annual rainfall (mm/y)* **(6.7%)**	**Development of alternative irrigation facilities:** (1) On-farm reservoirs (2) Rainwater harvesting **Shift to efficient irrigation systems:** (1) Solar Irrigation, Keyline water management, Drip irrigation, Subsurface Irrigation (2) Vertical Farming and Hydroponics	**Demonstration projects:** Establish demonstration projects where farmers can observe and learn about the benefits and effectiveness of efficient irrigation systems, alternative irrigation facilities and use of water efficient crops. **Technical assistance program:** Establish programs that offer technical assistance to farmers, helping them assess their irrigation needs, select suitable crops, select suitable technologies, and provide guidance on system design, installation, and maintenance. **Information and extension services:** Improve access to information and extension services for farmers, providing them with up-to-date knowledge and resources.
Livestock density (Animal Unit: AU/HH)^ **(6.6%)**	(1) Genetic Improvement: Select and breed livestock animals with improved genetics for higher productivity and efficiency (2) Integrated Farming System	**Land-use management:** Provision of agricultural land for fodder and grazing. **Health and disease management:** Implement robust health management practices such as regular vaccinations, parasite control, biosecurity measures, and proper herd/flock health monitoring. **Promote integrated farming system:** Promote the benefits of integrated farming system where byproducts of livestock such as manure is utilized for farming and farming bi-products are used as fodder for livestock.
Land holding size (rai/HH)^ **(5.8%)**	(1) Farm Size Optimization (2) Land reclamation	**Land consolidation and redistribution program:** (1) Provide incentives, such as tax breaks or financial assistance, to encourage landholders to voluntarily participate in land consolidation programs which will consolidate small parcels of land to more productive units. (2) Land reform programs, land purchase schemes, or government-initiated land acquisitions to reallocate land from larger landholders to small-scale farmers or landless individuals.

V5: B. Nakai		
Indicators	**Actions/practices**	**Policy Interventions**
		(3) Legal reforms for longer-term land leases, transparent land lease agreements and mechanisms to protect tenant's rights. (4) **Land reclamation regulation**: Implement a "stick and carrot" approach by introducing higher taxation for vacant or underutilized land and lower taxation for agricultural land. **Rural employment programs:** Create job opportunities for farmers in sectors such as rural services, public works projects and infrastructure development which decreases farmers number and in turn increases land holding sizes.
Crop water use efficiency (kg/m^3)^^ (5.7%)	(1) Shifting to water efficient crops (2) Cover cropping, Mulching	**Demonstration projects:** Establish demonstration projects where farmers can observe and learn about the benefits and effectiveness of efficient irrigation systems, alternative irrigation facilities and use of water efficient crops. **Technical assistance program:** Establish programs that offer technical assistance to farmers, helping them assess their irrigation needs, select suitable crops, select suitable technologies, and provide guidance on system design, installation, and maintenance. **Information and extension services:** Improve access to information and extension services for farmers, providing them with up-to-date knowledge and resources.
32%		

Note: Percentage within parenthesis represent contribution of the indicator to Vulnerability Index (VI)

Table 29:
Priority actions and policy interventions for Tong Muang village.

V6: B. Tong Muang		
Indicators	**Actions/practices**	**Policy Interventions**
Change in annual rainfall (mm/y)* **(7.3%)**	**Development of alternative irrigation facilities:** (1) On-farm reservoirs (2) Rainwater harvesting **Shift to efficient irrigation systems:** (1) Solar Irrigation, Keyline water management, Drip irrigation, Subsurface Irrigation (2) Vertical Farming and Hydroponics	**Demonstration projects:** Establish demonstration projects where farmers can observe and learn about the benefits and effectiveness of efficient irrigation systems, alternative irrigation facilities and use of water efficient crops. **Technical assistance program:** Establish programs that offer technical assistance to farmers, helping them assess their irrigation needs, select suitable crops, select suitable technologies, and provide guidance on system design, installation, and maintenance. **Information and extension services:** Improve access to information and extension services for farmers, providing them with up-to-date knowledge and resources.
Crop water use efficiency (kg/m^3)^^ **(6.2%)**	(1) Shifting to water efficient crops (2) Cover cropping, Mulching	**Demonstration projects:** Establish demonstration projects where farmers can observe and learn about the benefits and effectiveness of efficient irrigation systems, alternative irrigation facilities and use of water efficient crops. **Technical assistance program:** Establish programs that offer technical assistance to farmers, helping them assess their irrigation needs, select suitable crops, select suitable technologies, and provide guidance on system design, installation, and maintenance. **Information and extension services:** Improve access to information and extension services for farmers, providing them with up-to-date knowledge and resources.
Proportion of off-farm median income to total income (%) **(6.0%)**	(1) Increasing farm income (2) Value-added processing of agricultural products (3) Direct Marketing and Community Supported Agriculture (Farm-to-Restaurant) (4) Climate Smart Agriculture (Use of drought tolerant crops, shifting to high value crops) (5) Access to Improved Inputs (seeds, fertilizers, agricultural tools and equipment)	**Market diversification, value addition, linkages, and value chain development:** (1) Promote diversification and support farmers in adding value to their agricultural products through processing, packaging, branding, and marketing initiatives. (2) Facilitate market linkages between farmers and non-farm sectors, such as agribusinesses, processors, retailers, and service providers. **Access to agriculture inputs:** Input subsidies, quality control and certification of agricultural inputs, farmer cooperatives and group purchasing. **Access to credit and financial services:** Improve access to credit and financial services for farmers seeking to establish or expand non-farm businesses.

<table>
<tr><th colspan="3">V6: B. Tong Muang</th></tr>
<tr><th>Indicators</th><th>Actions/practices</th><th>Policy Interventions</th></tr>
<tr><td></td><td>(6) Creating alternative occupation
(7) Agritourism (farm tours, farm stays, educational workshops, or hosting events like farm-to-table dinners or festivals)</td><td>Rural employment programs:
Create job opportunities for farmers in sectors such as rural services, public works projects and infrastructure development.</td></tr>
<tr><td>Land holding size (rai/HH)^ (5.9%)</td><td>(1) Farm Size Optimization
(2) Land reclamation</td><td>Land consolidation and redistribution program:
(1) Provide incentives, such as tax breaks or financial assistance, to encourage landholders to voluntarily participate in land consolidation programs which will consolidate small parcels of land to more productive units.
(2) Land reform programs, land purchase schemes, or government-initiated land acquisitions to reallocate land from larger landholders to small-scale farmers or landless individuals.
(3) Legal reforms for longer-term land leases, transparent land lease agreements and mechanisms to protect tenant's rights.
(4) Land reclamation regulation: Implement a "stick and carrot" approach by introducing higher taxation for vacant or underutilized land and lower taxation for agricultural land.
Rural employment programs:
Create job opportunities for farmers in sectors such as rural services, public works projects and infrastructure development which decreases farmers number and in turn increases land holding sizes.</td></tr>
<tr><td>Livestock density (Animal Unit: AU/HH)^ (5.3%)</td><td>(1) Genetic Improvement: Select and breed livestock animals with improved genetics for higher productivity and efficiency
(2) Integrated Farming System</td><td>Land-use management:
Provision of agricultural land for fodder and grazing.
Health and disease management:
Implement robust health management practices such as regular vaccinations, parasite control, biosecurity measures, and proper herd/flock health monitoring.
Promote integrated farming system:
Promote the benefits of integrated farming system where biproducts of livestock such as manure is utilized for farming and farming bi-products are used as fodder for livestock.</td></tr>
<tr><td colspan="3">31%</td></tr>
</table>

Note: Percentage within parenthesis represent contribution of the indicator to Vulnerability Index (VI)

Table 30:
Priority actions and policy interventions for San Payom village.

V7: B. San Payom		
Indicators	**Actions/practices**	**Policy Interventions**
Change in annual rainfall (mm/y)* **(6.8%)**	**Development of alternative irrigation facilities:** (1) On-farm reservoirs (2) Rainwater harvesting **Shift to efficient irrigation systems:** (1) Solar Irrigation, Keyline water management, Drip irrigation, Subsurface Irrigation (2) Vertical Farming and Hydroponics	**Demonstration projects:** Establish demonstration projects where farmers can observe and learn about the benefits and effectiveness of efficient irrigation systems, alternative irrigation facilities and use of water efficient crops. **Technical assistance program:** Establish programs that offer technical assistance to farmers, helping them assess their irrigation needs, select suitable crops, select suitable technologies, and provide guidance on system design, installation, and maintenance. **Information and extension services:** Improve access to information and extension services for farmers, providing them with up-to-date knowledge and resources.
Proportion of arable land to agricultural land (%) **(6.7%)**	(1) Increasing efficiency of cultivated land (2) Sustainable Intensification: Using high-yielding crop varieties and improved farming practices. (3) Technology and Innovation: Precision agriculture technologies, greenhouse farming, hydroponics, aquaponics, vertical farming, and other efficient etc. (4) Agroforestry can help generate income while reducing arable land	**Agricultural land protection legislation:** Enact legislation to protect agricultural land from conversion to non-agricultural uses such as agricultural land easements, conservation restrictions, or development rights purchases to permanently preserve agricultural land, comprehensive land use planning and zoning policies that prioritize the preservation of agricultural land. **Incentives for agricultural innovation:** Provide incentives, grants, or research funding for innovative agricultural practices that maximize productivity while minimizing land requirements.
HH living on farm income only (%) **(5.8%)**	**Non-Agricultural Income Opportunities:** Small-scale businesses, agro-processing enterprises, rural tourism, handicraft production, or providing services such as transportation, healthcare, education, or technology)	**Rural employment programs:** Create job opportunities for farmers in sectors such as rural services, public works projects and infrastructure development. Creating an enabling environment for small-scale businesses, offering incentives for value-added activities, and addressing barriers to accessing markets and financial services. **Community development and collaboration:** Formation of cooperatives, producer groups, or community-based organizations to enable collective marketing, resource-sharing, and the development of common initiatives for income diversification.

V7: B. San Payom		
Indicators	**Actions/practices**	**Policy Interventions**
Crop water use efficiency (kg/m³)^^ (5.8%)	(1) Shifting to water efficient crops (2) Cover cropping, Mulching	**Demonstration projects:** Establish demonstration projects where farmers can observe and learn about the benefits and effectiveness of efficient irrigation systems, alternative irrigation facilities and use of water efficient crops. **Technical assistance program:** Establish programs that offer technical assistance to farmers, helping them assess their irrigation needs, select suitable crops, select suitable technologies, and provide guidance on system design, installation, and maintenance. **Information and extension services:** Improve access to information and extension services for farmers, providing them with up-to-date knowledge and resources.
Transportation cost from home to selling place (Baht/rai)* (5.6%)	(1) Bulk/collaborative transportation (2) Direct Marketing and Community Supported Agriculture (Farm-to-Restaurant)	**Market linkages and value chain development:** Facilitate market linkages between farmers and non-farm sectors, such as agribusinesses, processors, retailers, and service providers. Encourage governments to invest in rural infrastructure, provide incentives for agricultural industries for local consumption.
31%		

Note: Percentage within parenthesis represent contribution of the indicator to Vulnerability Index (VI)

Table 31:
Priority actions and policy interventions for Nong Ha village.

V8: B. Nong Ha		
Indicators	**Actions/practices**	**Policy Interventions**
Crop diversity (crops/100 rai)* **(6.9%)**	(1) Intercropping (2) Crop rotation (3) Planting cover crops	**Seed policy and access:** Promote open access to diverse seeds, including traditional and locally adapted varieties streamlining seed certification processes, removing barriers to seed exchange, and supporting community-based seed-saving initiatives. **Land use policies:** Integrate crop diversity considerations into land use planning and zoning policies.
Change in annual rainfall (mm/y)* **(6.9%)**	**Development of alternative irrigation facilities:** (1) On-farm reservoirs (2) Rainwater harvesting **Shift to efficient irrigation systems:** (1) Solar Irrigation, Keyline water management, Drip irrigation, Subsurface Irrigation (2) Vertical Farming and Hydroponics	**Demonstration projects:** Establish demonstration projects where farmers can observe and learn about the benefits and effectiveness of efficient irrigation systems, alternative irrigation facilities and use of water efficient crops. **Technical assistance program:** Establish programs that offer technical assistance to farmers, helping them assess their irrigation needs, select suitable crops, select suitable technologies, and provide guidance on system design, installation, and maintenance. **Information and extension services:** Improve access to information and extension services for farmers, providing them with up-to-date knowledge and resources.
Soil organic matter in topsoil (% of cultivable land with moderate fertile soil) **(6.8%)**	(1) Enhance soil management practices (2) Addition of organic matter such as biochar, compost (3) Crop rotation helps break disease cycles, improve soil structure, and enhance nutrient availability (4) Conservation tillage to minimize soil erosion and disturbances	**Soil health monitoring and assessment programs:** Establish soil health monitoring and assessment programs to track soil quality and provide feedback to farmers. **Incentives for organic and regenerative agriculture:** Certification support, market access assistance and premium prices for organic or regenerative products.
Proportion of off-farm median income to total income (%) **(5.9%)**	(1) Increasing farm income (2) Value-added processing of agricultural products (3) Direct Marketing and Community Supported Agriculture (Farm-to-Restaurant) (4) Climate Smart Agriculture (Use of drought tolerant crops, shifting to high value crops)	**Market diversification, value addition, linkages, and value chain development:** Promote diversification and support farmers in adding value to their agricultural products through processing, packaging, branding, and marketing initiatives. Facilitate market linkages between farmers and non-farm sectors, such as agribusinesses, processors, retailers, and service providers. **Access to agriculture inputs:**

V8: B. Nong Ha		
Indicators	**Actions/practices**	**Policy Interventions**
	(5) Access to Improved Inputs (seeds, fertilizers, agricultural tools and equipment) (6) Creating alternative occupation (7) Agritourism (farm tours, farm stays, educational workshops, or hosting events like farm-to-table dinners or festivals)	Input subsidies, quality control and certification of agricultural inputs, farmer cooperatives and group purchasing. **Access to credit and financial services:** Improve access to credit and financial services for farmers seeking to establish or expand non-farm businesses. **Rural employment programs:** Create job opportunities for farmers in sectors such as rural services, public works projects and infrastructure development.
Crop water use efficiency (Kg/m3)^^ (5.9%)	(1) Shifting to water efficient crops (2) Cover cropping, Mulching	**Demonstration projects:** Establish demonstration projects where farmers can observe and learn about the benefits and effectiveness of efficient irrigation systems, alternative irrigation facilities and use of water efficient crops. **Technical assistance program:** Establish programs that offer technical assistance to farmers, helping them assess their irrigation needs, select suitable crops, select suitable technologies, and provide guidance on system design, installation, and maintenance. **Information and extension services:** Improve access to information and extension services for farmers, providing them with up-to-date knowledge and resources.
32%		

Note: Percentage within parenthesis represent contribution of the indicator to Vulnerability Index (VI)

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9. Annex

9.1 Maps

Figure 17:
Spatiotemporal distribution of absolute change in minimum temperature 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.

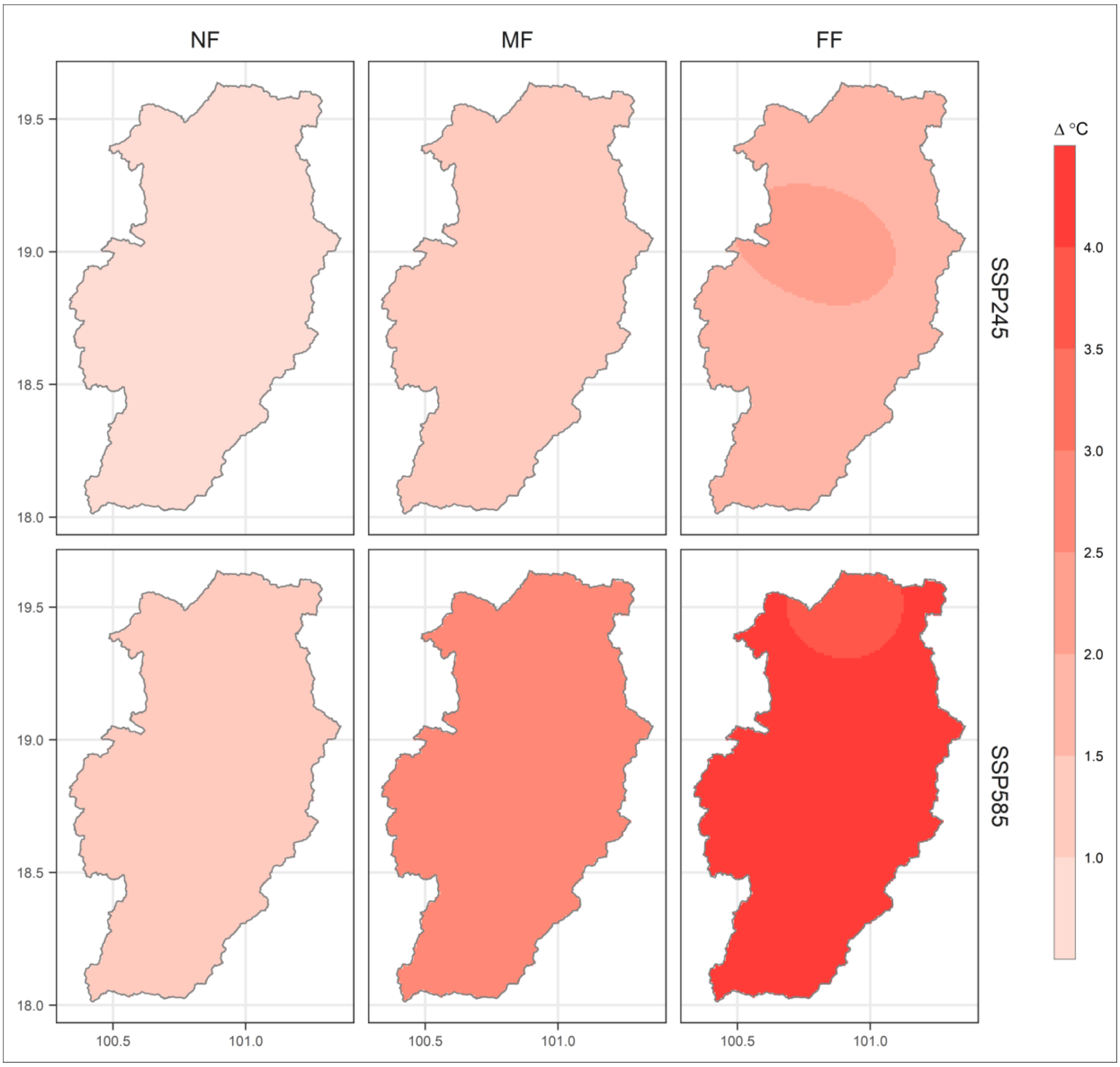
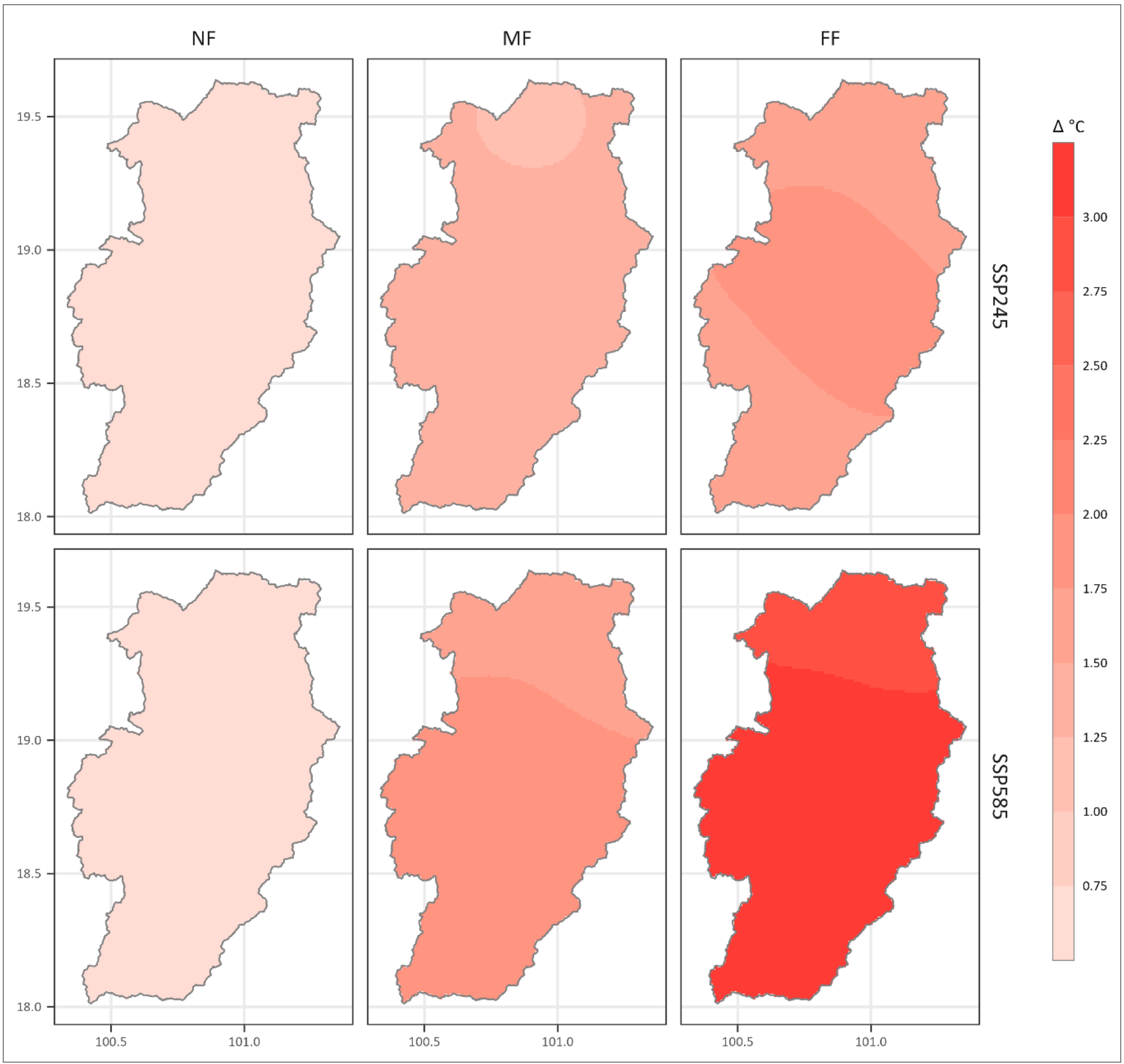
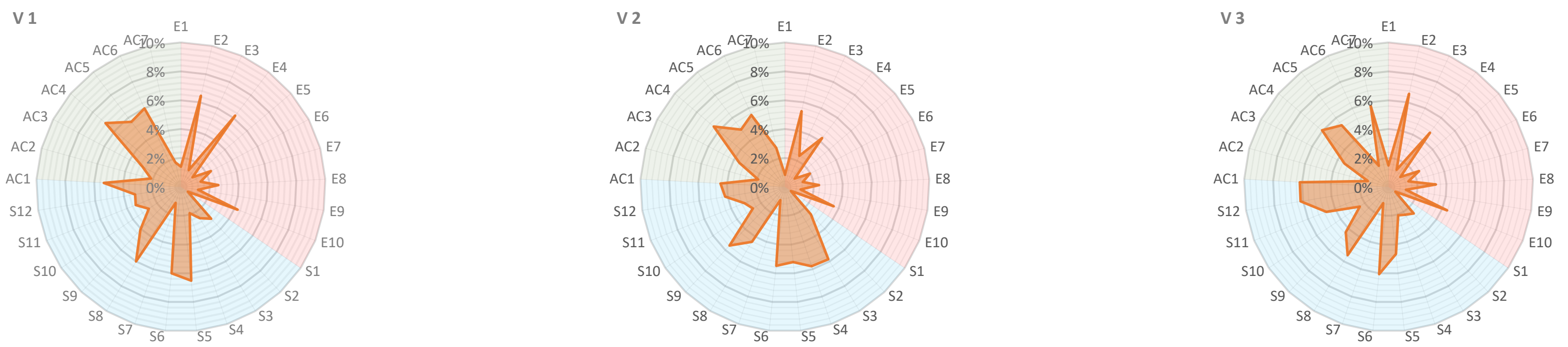


Figure 18:
Spatiotemporal distribution of absolute change in maximum temperature in Nan province during near (NF), mid (MF) and far (FF) future compared to the baseline period (1985–2014). Results are from the mean of six GCMs under SSP245 and SSP585 emission scenarios.



9.2 Driving Indicators

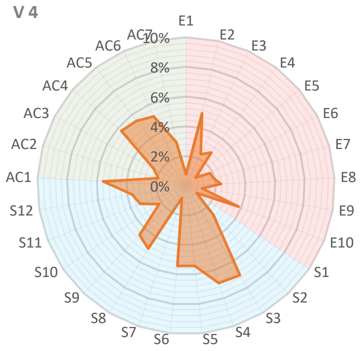
Figure 19:
Driving indicators during baseline period (1985–2014) (% in parenthesis: indicator contribution to VI).



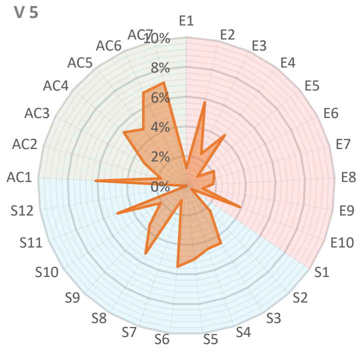
AC4: Proportion of off-farm median income to total income (%) (6.8%)
S5: Proportion of arable land to agricultural land (%) (6.5%)
E2: Drought severity for dry/secondary season (-Sum of SPEI <=-1.5)* (6.5%)
E4: Drought duration for dry/secondary season (Month)* (6.2%)
S8: HH living on farm income only (%) (6%)

AC4: Proportion of off-farm median income to total income (%) (6.5%)
S3: Soil organic matter in topsoil (% of cultivable land with moderate fertile soil) (5.8%)
S4: Soil acidity (% of cultivable land with medium to neutral soil) (5.8%)
S9: Deforestation rate (% of forest area destroyed/30years) (5.6%)
AC6: Livestock density (Animal Unit: AU/HH)^ (5.5%)

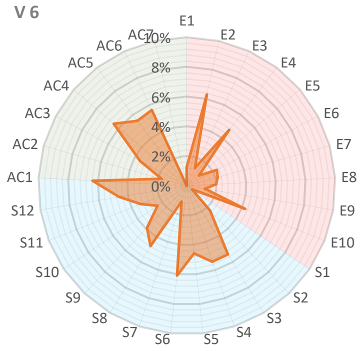
E2: Drought severity for dry/secondary season (-Sum of SPEI <=-1.5)* (6.6%)
S12: Crop diversity (crops/100 rai)* (6.2%)
AC1: Land holding size (rai/HH)^ (6.2%)
S6: Crop water use efficiency (Kg/m3)^^ (6.1%)
AC4: Proportion of off-farm median income to total income (%) (6%)



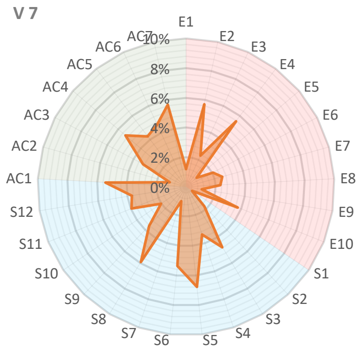
S3: Soil organic matter in topsoil (% of cultivable land with moderate fertile soil) (7%)
S4: Soil acidity (% of cultivable land with medium to neutral soil) (6.9%)
AC4: Proportion of off-farm median income to total income (%) (5.7%)
AC1: Land holding size (rai/HH)^ (5.6%)
AC5: Education level (% of respondents with education higher than primary level) (5.5%)



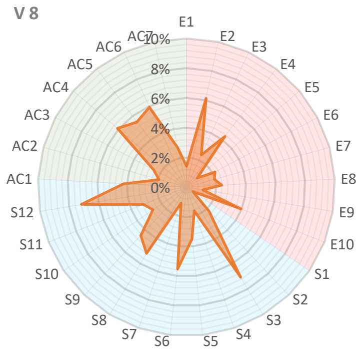
AC7: Transportation cost from home to selling place (Baht/rai)* (7.1%)
AC6: Livestock density (Animal Unit: AU/HH)^ (6.9%)
AC1: Land holding size (rai/HH)^ (6.1%)
E2: Drought severity for dry/secondary season (-Sum of SPEI <=-1.5)* (5.7%)
AC4: Proportion of off-farm median income to total income (%) (5.5%)



AC4: Proportion of off-farm median income to total income (%) (6.5%)
AC1: Land holding size (rai/HH)^ (6.4%)
E2: Drought severity for dry/secondary season (-Sum of SPEI <=-1.5)* (6.3%)
S6: Crop water use efficiency (Kg/m3)^^ (6.1%)
AC6: Livestock density (Animal Unit: AU/HH)^ (5.6%)

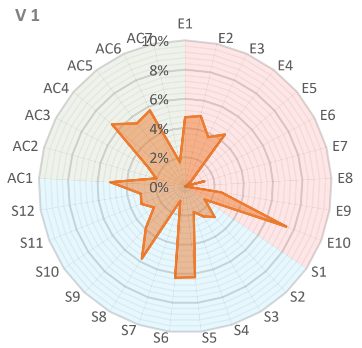


S5: Proportion of arable land to agricultural land (%) (6.8%)
S8: HH living on farm income only (%) (5.9%)
E2: Drought severity for dry/secondary season (-Sum of SPEI <=-1.5)* (5.7%)
AC7: Transportation cost from home to selling place (Baht/rai)* (5.7%)
E4: Drought duration for dry/secondary season (Month)* (5.6%)

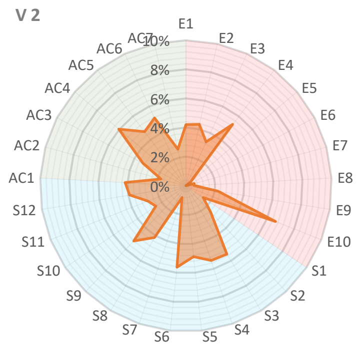


S12: Crop diversity (crops/100 rai)* (7.2%)
S3: Soil organic matter in topsoil (% of cultivable land with moderate fertile soil) (7.1%)
E2: Drought severity for dry/secondary season (-Sum of SPEI <=-1.5)* (6.1%)
AC4: Proportion of off-farm median income to total income (%) (6.1%)
AC6: Livestock density (Animal Unit: AU/HH)^ (5.9%)

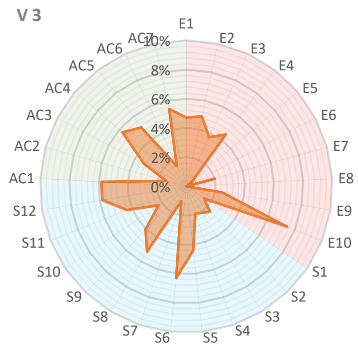
Figure 20:
Driving indicators for ssp245 scenario during near future period (2020–2046).



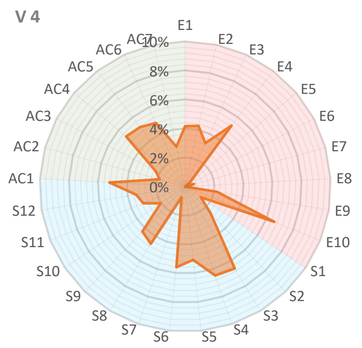
E10: Change in annual rainfall (mm/yr)* (7.4%)
AC4: Proportion of off-farm median income to total income (%) (6.5%)
S6: Crop water use efficiency (Kg/m3)^^ (6.3%)
S5: Proportion of arable land to agricultural land (%) (6.2%)
S8: HH living on farm income only (%) (5.8%)



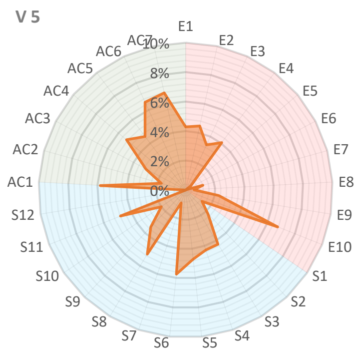
E10: Change in annual rainfall (mm/yr)* (6.6%)
AC4: Proportion of off-farm median income to total income (%) (6%)
S6: Crop water use efficiency (Kg/m3)^^ (5.6%)
S3: Soil organic matter in topsoil (% of cultivable land with moderate fertile soil) (5.5%)
S4: Soil acidity (% of cultivable land with medium to neutral soil) (5.4%)



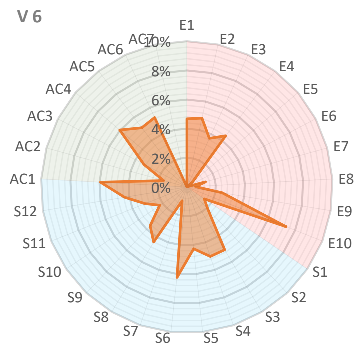
E10: Change in annual rainfall (mm/yr)* (7.4%)
S6: Crop water use efficiency (Kg/m3)^^ (6.3%)
S12: Crop diversity (crops/100 rai)* (5.8%)
AC1: Land holding size (rai/HH)^ (5.8%)
AC4: Proportion of off-farm median income to total income (%) (5.7%)



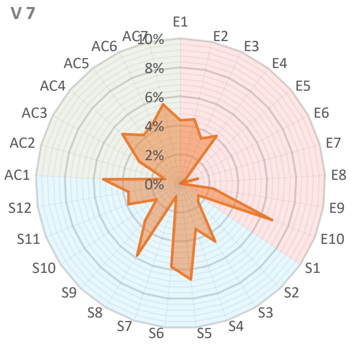
E10: Change in annual rainfall (mm/yr)* (6.6%)
S3: Soil organic matter in topsoil (% of cultivable land with moderate fertile soil) (6.6%)
S4: Soil acidity (% of cultivable land with medium to neutral soil) (6.5%)
S6: Crop water use efficiency (Kg/m3)^^ (5.6%)
AC4: Proportion of off-farm median income to total income (%) (5.3%)



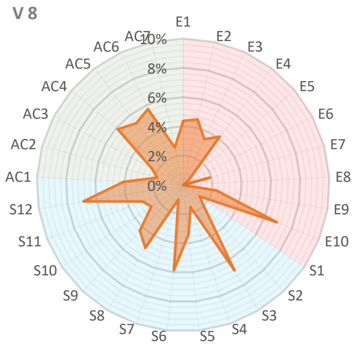
AC7: Transportation cost from home to selling place (Baht/rai)* (6.8%)
E10: Change in annual rainfall (mm/yr)* (6.7%)
AC6: Livestock density (Animal Unit: AU/HH)^ (6.6%)
AC1: Land holding size (rai/HH)^ (5.8%)
S6: Crop water use efficiency (Kg/m3)^^ (5.7%)



E10: Change in annual rainfall (mm/yr)* (7.3%)
S6: Crop water use efficiency (Kg/m3)^^ (6.2%)
AC4: Proportion of off-farm median income to total income (%) (6%)
AC1: Land holding size (rai/HH)^ (5.9%)
AC6: Livestock density (Animal Unit: AU/HH)^ (5.3%)

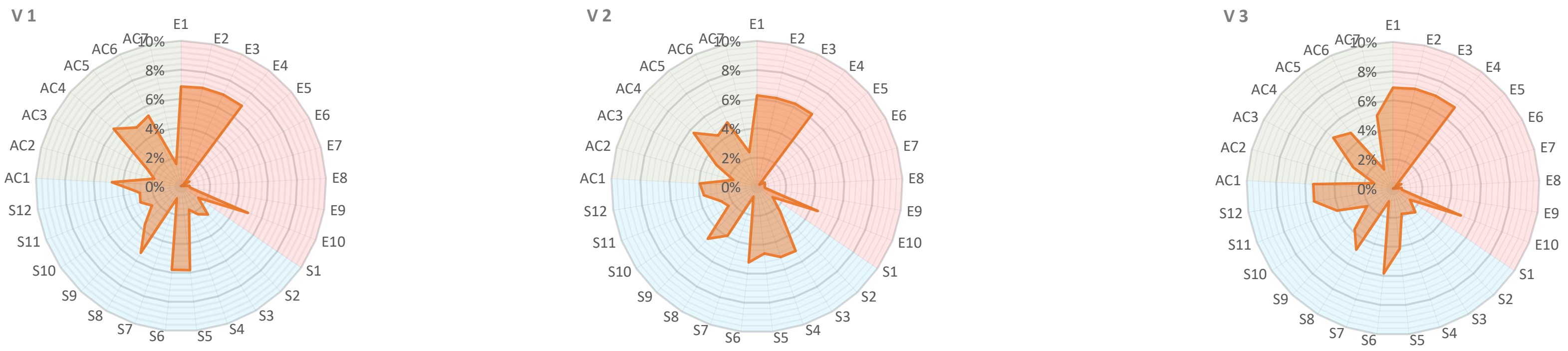


E10: Change in annual rainfall (mm/yr)* (6.8%)
S5: Proportion of arable land to agricultural land (%) (6.7%)
S8: HH living on farm income only (%) (5.8%)
S6: Crop water use efficiency (Kg/m3)^^ (5.8%)
AC7: Transportation cost from home to selling place (Baht/rai)* (5.6%)



S12: Crop diversity (crops/100 rai)* (6.9%)
E10: Change in annual rainfall (mm/yr)* (6.9%)
S3: Soil organic matter in topsoil (% of cultivable land with moderate fertile soil) (6.8%)
AC4: Proportion of off-farm median income to total income (%) (5.9%)
S6: Crop water use efficiency (Kg/m3)^^ (5.9%)

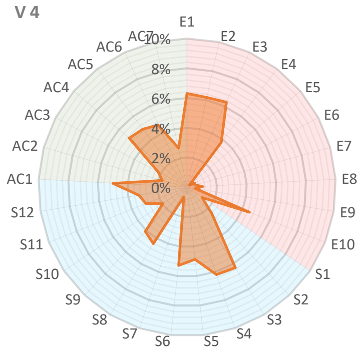
Figure 21:
Driving indicators for ssp245 scenario during mid future period (2047–2073).



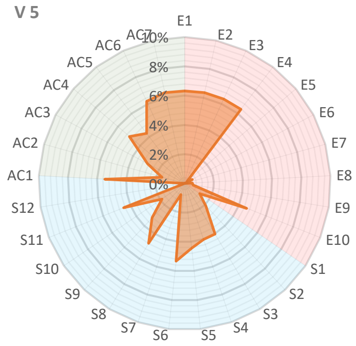
E2: Drought severity for dry/secondary season (-Sum of SPEI <=-1.5)* (6.9%)
E3: Drought duration for wet/primary season (Month)* (6.9%)
E4: Drought duration for dry/secondary season (Month)* (6.9%)
E1: Drought severity for wet/primary season (-Sum of SPEI <=-1.5)* (6.9%)
AC4: Proportion of off-farm median income to total income (%) (6.1%)

E1: Drought severity for wet/primary season (-Sum of SPEI <=-1.5)* (6.3%)
E3: Drought duration for wet/primary season (Month)* (6.3%)
E4: Drought duration for dry/secondary season (Month)* (6.3%)
E2: Drought severity for dry/secondary season (-Sum of SPEI <=-1.5)* (6.2%)
AC4: Proportion of off-farm median income to total income (%) (5.7%)

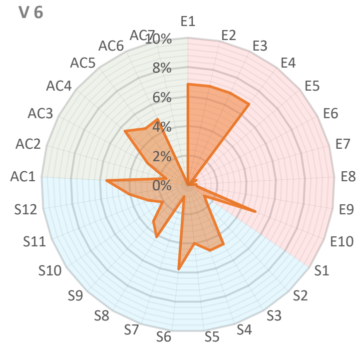
E3: Drought duration for wet/primary season (Month)* (7%)
E4: Drought duration for dry/secondary season (Month)* (7%)
E2: Drought severity for dry/secondary season (-Sum of SPEI <=-1.5)* (7%)
E1: Drought severity for wet/primary season (-Sum of SPEI <=-1.5)* (6.9%)
S6: Crop water use efficiency (Kg/m3)^^ (5.8%)



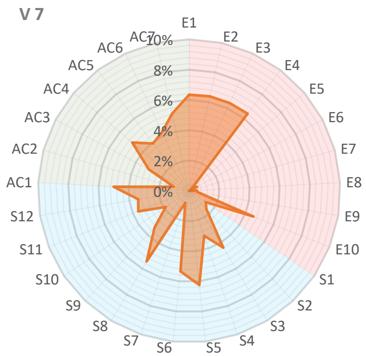
E3: Drought duration for wet/primary season (Month)* (6.3%)
E1: Drought severity for wet/primary season (-Sum of SPEI <=-1.5)* (6.3%)
S3: Soil organic matter in topsoil (% of cultivable land with moderate fertile soil) (6.3%)
S4: Soil acidity (% of cultivable land with medium to neutral soil) (6.2%)
E2: Drought severity for dry/secondary season (-Sum of SPEI <=-1.5)* (6.2%)



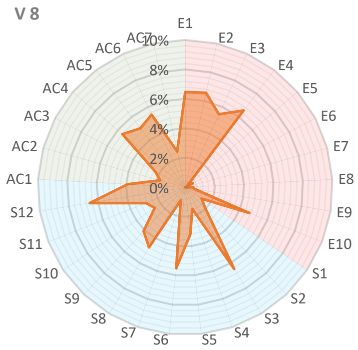
E3: Drought duration for wet/primary season (Month)* (6.4%)
E4: Drought duration for dry/secondary season (Month)* (6.4%)
AC7: Transportation cost from home to selling place (Baht/rai)* (6.4%)
E2: Drought severity for dry/secondary season (-Sum of SPEI <=-1.5)* (6.3%)
E1: Drought severity for wet/primary season (-Sum of SPEI <=-1.5)* (6.3%)



E3: Drought duration for wet/primary season (Month)* (6.9%)
E4: Drought duration for dry/secondary season (Month)* (6.9%)
E2: Drought severity for dry/secondary season (-Sum of SPEI <=-1.5)* (6.9%)
E1: Drought severity for wet/primary season (-Sum of SPEI <=-1.5)* (6.8%)
S6: Crop water use efficiency (Kg/m3)^^ (5.8%)

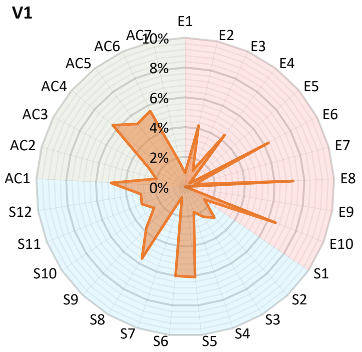


E3: Drought duration for wet/primary season (Month)* (6.4%)
E4: Drought duration for dry/secondary season (Month)* (6.4%)
E2: Drought severity for dry/secondary season (-Sum of SPEI <=-1.5)* (6.4%)
E1: Drought severity for wet/primary season (-Sum of SPEI <=-1.5)* (6.3%)
S5: Proportion of arable land to agricultural land (%) (6.2%)

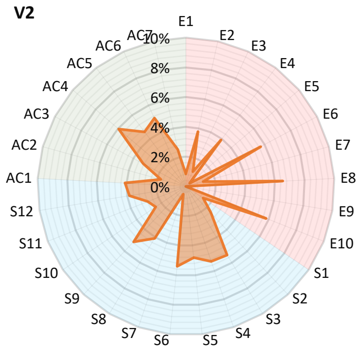


E4: Drought duration for dry/secondary season (Month)* (6.6%)
S12: Crop diversity (crops/100 rai)* (6.6%)
E2: Drought severity for dry/secondary season (-Sum of SPEI <=-1.5)* (6.6%)
S3: Soil organic matter in topsoil (% of cultivable land with moderate fertile soil) (6.5%)
E1: Drought severity for wet/primary season (-Sum of SPEI <=-1.5)* (6.5%)

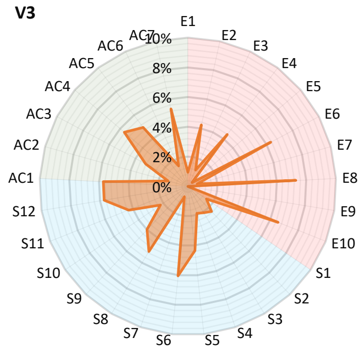
Figure 22:
Driving indicators for ssp245 scenario during far future period (2074–2100).



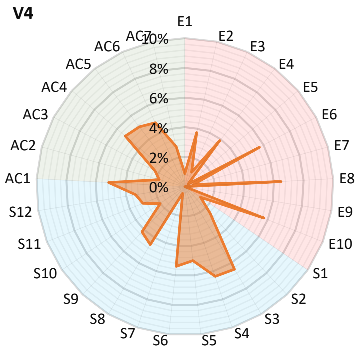
E8: Flood duration for dry/secondary season (Month)* (7.3%)
E10: Change in annual rainfall (mm/yr)* (6.5%)
AC4: Proportion of off-farm median income to total income (%) (6.4%)
E6: Flood severity for dry/secondary season (Sum of SPEI >1.5)* (6.3%)
S5: Proportion of arable land to agricultural land (%) (6.1%)



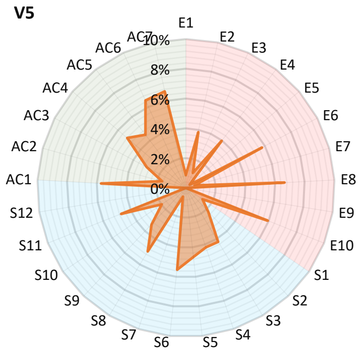
E8: Flood duration for dry/secondary season (Month)* (6.5%)
AC4: Proportion of off-farm median income to total income (%) (5.9%)
E10: Change in annual rainfall (mm/yr)* (5.8%)
E6: Flood severity for dry/secondary season (Sum of SPEI >1.5)* (5.7%)
S6: Crop water use efficiency (Kg/m3)^^ (5.4%)



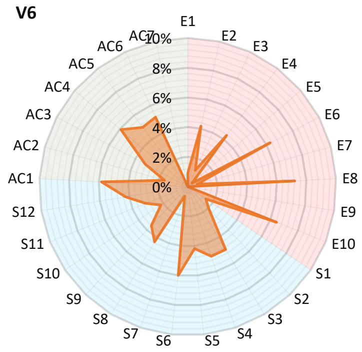
E8: Flood duration for dry/secondary season (Month)* (7.3%)
E10: Change in annual rainfall (mm/yr)* (6.5%)
E6: Flood severity for dry/secondary season (Sum of SPEI >1.5)* (6.3%)
S6: Crop water use efficiency (Kg/m3)^^ (6.1%)
S12: Crop diversity (crops/100 rai)* (5.7%)



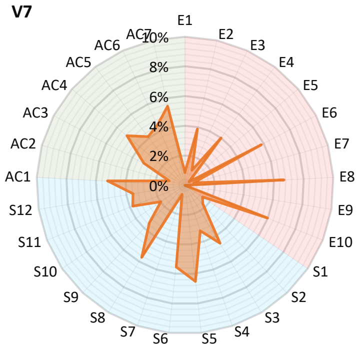
E8: Flood duration for dry/secondary season (Month)* (6.5%)
S3: Soil organic matter in topsoil (% of cultivable land with moderate fertile soil) (6.5%)
S4: Soil acidity (% of cultivable land with medium to neutral soil) (6.4%)
E10: Change in annual rainfall (mm/yr)* (5.7%)
E6: Flood severity for dry/secondary season (Sum of SPEI >1.5)* (5.7%)



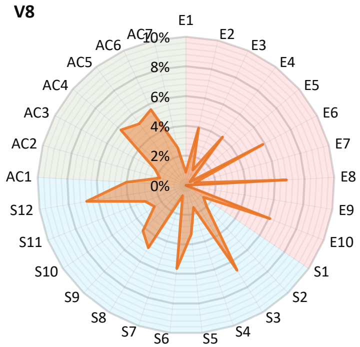
E8: Flood duration for dry/secondary season (Month)* (6.6%)
AC7: Transportation cost from home to selling place (Baht/rai)* (6.6%)
AC6: Livestock density (Animal Unit: AU/HH)^ (6.5%)
E10: Change in annual rainfall (mm/yr)* (5.9%)
E6: Flood severity for dry/secondary season (Sum of SPEI >1.5)* (5.8%)



E8: Flood duration for dry/secondary season (Month)* (7.2%)
E10: Change in annual rainfall (mm/yr)* (6.4%)
E6: Flood severity for dry/secondary season (Sum of SPEI >1.5)* (6.3%)
S6: Crop water use efficiency (Kg/m3)^^ (6%)
AC4: Proportion of off-farm median income to total income (%) (5.9%)

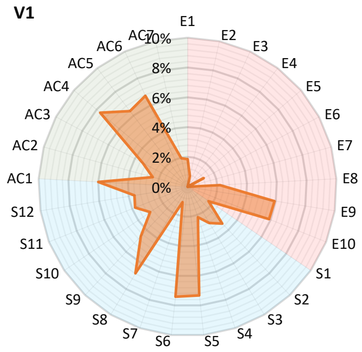


E8: Flood duration for dry/secondary season (Month)* (6.7%)
S5: Proportion of arable land to agricultural land (%) (6.5%)
E10: Change in annual rainfall (mm/yr)* (6%)
E6: Flood severity for dry/secondary season (Sum of SPEI >1.5)* (5.8%)
S8: HH living on farm income only (%) (5.7%)

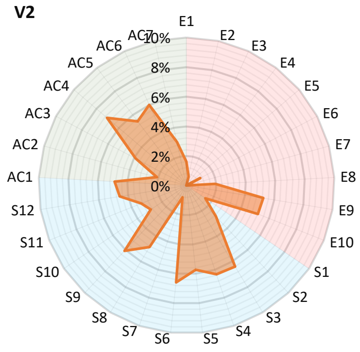


E8: Flood duration for dry/secondary season (Month)* (6.8%)
S12: Crop diversity (crops/100 rai)* (6.8%)
S3: Soil organic matter in topsoil (% of cultivable land with moderate fertile soil) (6.7%)
E10: Change in annual rainfall (mm/yr.)* (6.1%)
E6: Flood severity for dry/secondary season (Sum of SPEI >1.5)* (5.9%)

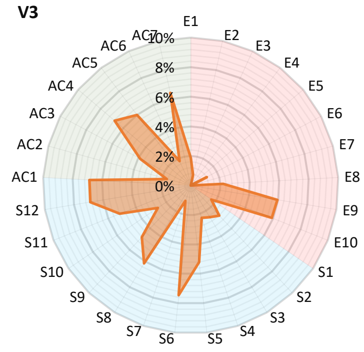
Figure 23:
Driving indicators for ssp585 scenario during near future period (2020–2046).



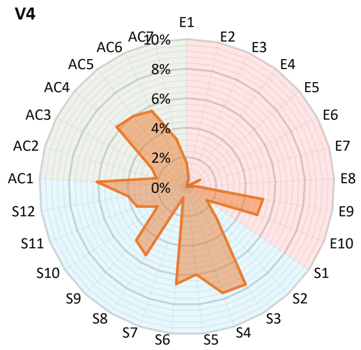
AC4: Proportion of off-farm median income to total income (%) (7.7%)
S6: Crop water use efficiency (Kg/m3)^^ (7.4%)
S5: Proportion of arable land to agricultural land (%) (7.3%)
S8: HH living on farm income only (%) (6.8%)
AC6: Livestock density (Animal Unit: AU/HH)^ (6.7%)



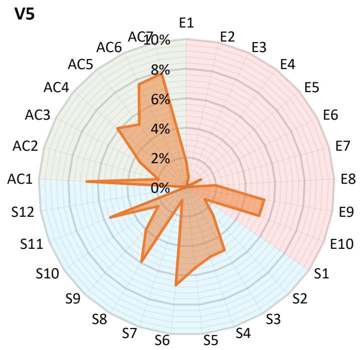
AC4: Proportion of off-farm median income to total income (%) (7.1%)
S6: Crop water use efficiency (Kg/m3)^^ (6.6%)
S3: Soil organic matter in topsoil (% of cultivable land with moderate fertile soil) (6.4%)
S4: Soil acidity (% of cultivable land with medium to neutral soil) (6.3%)
S9: Deforestation rate (% of forest area destroyed/30years) (6.1%)



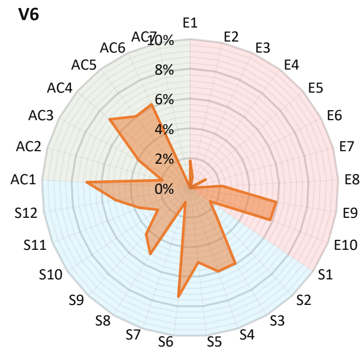
S6: Crop water use efficiency (Kg/m3)^^ (7.5%)
S12: Crop diversity (crops/100 rai)* (6.9%)
AC1: Land holding size (rai/HH)^ (6.9%)
AC4: Proportion of off-farm median income to total income (%) (6.8%)
AC7: Transportation cost from home to selling place (Baht/rai)* (6.4%)



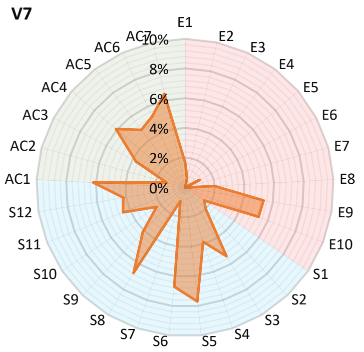
S3: Soil organic matter in topsoil (% of cultivable land with moderate fertile soil) (7.7%)
S4: Soil acidity (% of cultivable land with medium to neutral soil) (7.6%)
S6: Crop water use efficiency (Kg/m3)^^ (6.6%)
AC4: Proportion of off-farm median income to total income (%) (6.3%)
AC1: Land holding size (rai/HH)^ (6.1%)



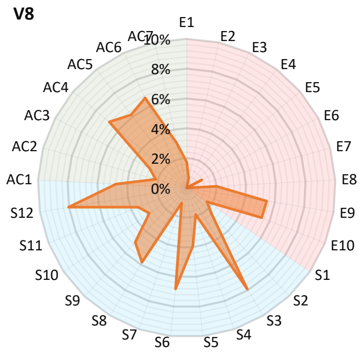
AC7: Transportation cost from home to selling place (Baht/rai)* (7.8%)
AC6: Livestock density (Animal Unit: AU/HH)^ (7.6%)
AC1: Land holding size (rai/HH)^ (6.8%)
S6: Crop water use efficiency (Kg/m3)^^ (6.7%)
AC4: Proportion of off-farm median income to total income (%) (6.1%)



S6: Crop water use efficiency (Kg/m3)^^ (7.4%)
AC4: Proportion of off-farm median income to total income (%) (7.1%)
AC1: Land holding size (rai/HH)^ (7%)
AC6: Livestock density (Animal Unit: AU/HH)^ (6.2%)
AC5: Education level (% of respondents with education higher than primary level) (6%)

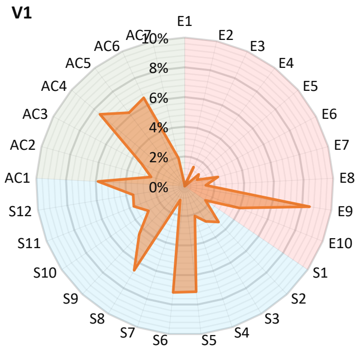


S5: Proportion of arable land to agricultural land (%) (7.7%)
S8: HH living on farm income only (%) (6.7%)
S6: Crop water use efficiency (Kg/m3)^^ (6.7%)
AC7: Transportation cost from home to selling place (Baht/rai)* (6.4%)
AC1: Land holding size (rai/HH)^ (6.2%)

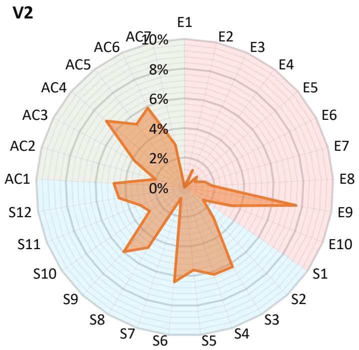


S12: Crop diversity (crops/100 rai)* (8%)
S3: Soil organic matter in topsoil (% of cultivable land with moderate fertile soil) (7.9%)
AC4: Proportion of off-farm median income to total income (%) (6.8%)
S6: Crop water use efficiency (Kg/m3)^^ (6.8%)
AC6: Livestock density (Animal Unit: AU/HH)^ (6.7%)

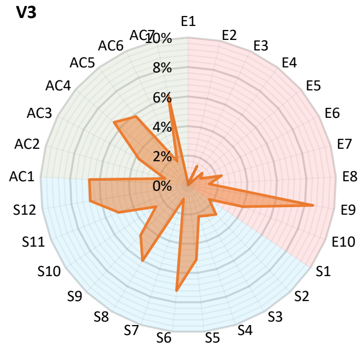
Figure 24:
Driving indicators for ssp585 scenario during mid future period (2047–2073).



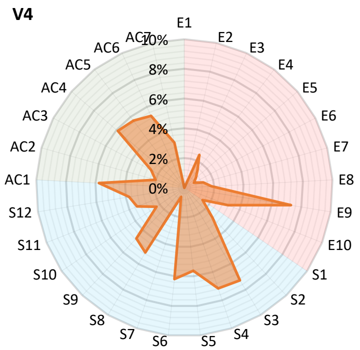
E9: Change in annual temperature (°C/yr)* (8.5%)
AC4: Proportion of off-farm median income to total income (%) (7.5%)
S6: Crop water use efficiency (Kg/m3)^^ (7.2%)
S5: Proportion of arable land to agricultural land (%) (7.1%)
S8: HH living on farm income only (%) (6.6%)



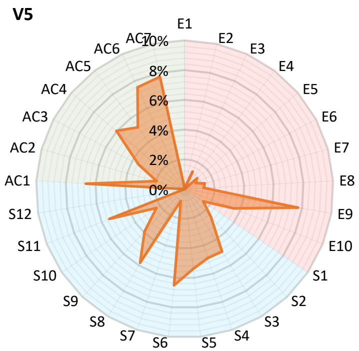
E9: Change in annual temperature (°C/yr)* (7.6%)
AC4: Proportion of off-farm median income to total income (%) (6.9%)
S6: Crop water use efficiency (Kg/m3)^^ (6.4%)
S3: Soil organic matter in topsoil (% of cultivable land with moderate fertile soil) (6.3%)
S4: Soil acidity (% of cultivable land with medium to neutral soil) (6.2%)



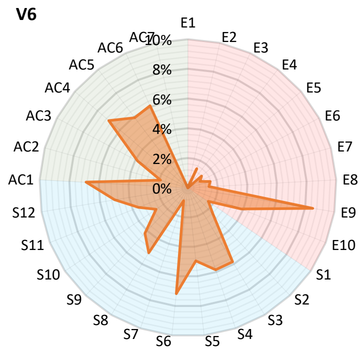
E9: Change in annual temperature (°C/yr)* (8.5%)
S6: Crop water use efficiency (Kg/m3)^^ (7.2%)
S12: Crop diversity (crops/100 rai)* (6.7%)
AC1: Land holding size (rai/HH)^ (6.7%)
AC4: Proportion of off-farm median income to total income (%) (6.6%)



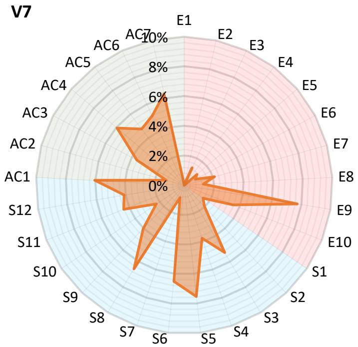
E9: Change in annual temperature (°C/yr)* (7.3%)
S3: Soil organic matter in topsoil (% of cultivable land with moderate fertile soil) (7.3%)
S4: Soil acidity (% of cultivable land with medium to neutral soil) (7.2%)
S6: Crop water use efficiency (Kg/m3)^^ (6.2%)
AC4: Proportion of off-farm median income to total income (%) (5.9%)



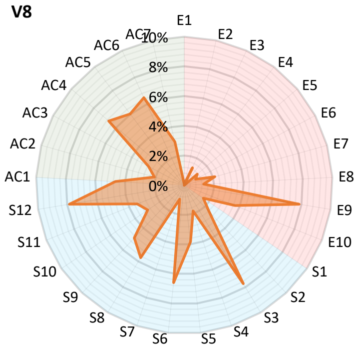
E9: Change in annual temperature (°C/yr)* (7.7%)
AC7: Transportation cost from home to selling place (Baht/rai)* (7.7%)
AC6: Livestock density (Animal Unit: AU/HH)^ (7.5%)
AC1: Land holding size (rai/HH)^ (6.7%)
S6: Crop water use efficiency (Kg/m3)^^ (6.5%)



E9: Change in annual temperature (°C/yr)* (8.5%)
S6: Crop water use efficiency (Kg/m3)^^ (7.2%)
AC4: Proportion of off-farm median income to total income (%) (7%)
AC1: Land holding size (rai/HH)^ (6.9%)
AC6: Livestock density (Animal Unit: AU/HH)^ (6.1%)



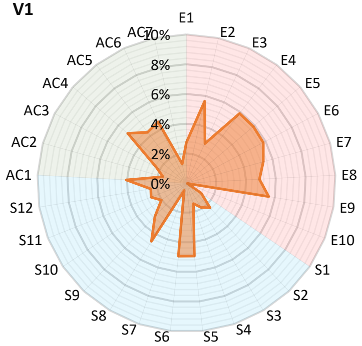
E9: Change in annual temperature (°C/yr)* (7.7%)
S5: Proportion of arable land to agricultural land (%) (7.5%)
S8: HH living on farm income only (%) (6.6%)
S6: Crop water use efficiency (Kg/m3)^^ (6.5%)
AC7: Transportation cost from home to selling place (Baht/rai)* (6.3%)



E9: Change in annual temperature (°C/yr.)* (7.9%)
S12: Crop diversity (crops/100 rai)* (7.9%)
S3: Soil organic matter in topsoil (% of cultivable land with moderate fertile soil) (7.7%)
AC4: Proportion of off-farm median income to total income (%) (6.7%)
S6: Crop water use efficiency (Kg/m3)^^ (6.6%)

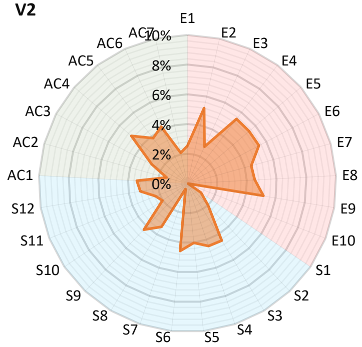
Figure 25:
Driving indicators for ssp585 scenario during far future period (2074–2100).

V1



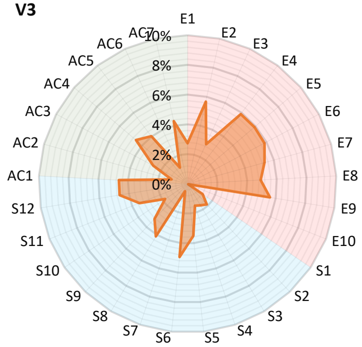
E4: Drought duration for dry/secondary season (Month)* (5.9%)
E5: Flood severity for wet/primary season (Sum of SPEI >1.5)* (5.9%)
E6: Flood severity for dry/secondary season (Sum of SPEI >1.5)* (5.8%)
E2: Drought severity for dry/secondary season (-Sum of SPEI <=-1.5)* (5.6%)
E9: Change in annual temperature (°C/yr)* (5.6%)

V2



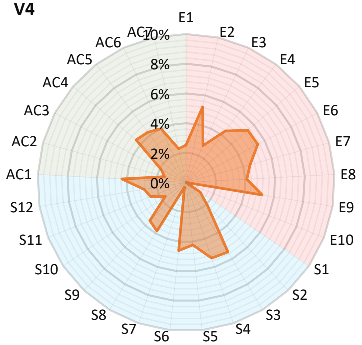
E4: Drought duration for dry/secondary season (Month)* (5.4%)
E6: Flood severity for dry/secondary season (Sum of SPEI >1.5)* (5.4%)
E5: Flood severity for wet/primary season (Sum of SPEI >1.5)* (5.4%)
E2: Drought severity for dry/secondary season (-Sum of SPEI <=-1.5)* (5.2%)
E9: Change in annual temperature (°C/yr)* (5.2%)

V3



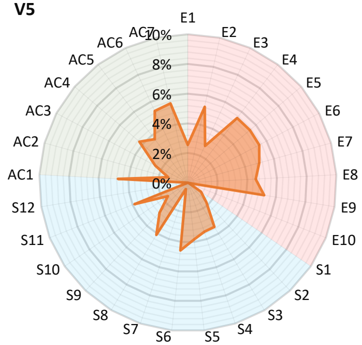
E4: Drought duration for dry/secondary season (Month)* (5.9%)
E5: Flood severity for wet/primary season (Sum of SPEI >1.5)* (5.9%)
E6: Flood severity for dry/secondary season (Sum of SPEI >1.5)* (5.8%)
E2: Drought severity for dry/secondary season (-Sum of SPEI <=-1.5)* (5.7%)
E9: Change in annual temperature (°C/yr)* (5.6%)

V4



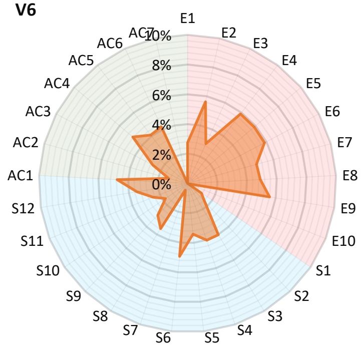
E6: Flood severity for dry/secondary season (Sum of SPEI >1.5)* (5.5%)
S3: Soil organic matter in topsoil (% of cultivable land with moderate fertile soil) (5.5%)
E5: Flood severity for wet/primary season (Sum of SPEI >1.5)* (5.5%)
S4: Soil acidity (% of cultivable land with medium to neutral soil) (5.4%)
E2: Drought severity for dry/secondary season (-Sum of SPEI <=-1.5)* (5.2%)

V5



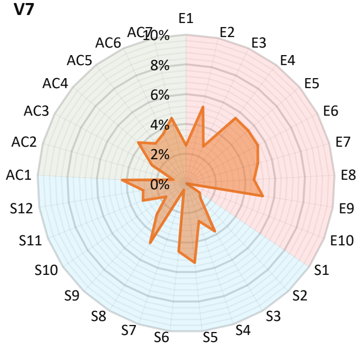
E4: Drought duration for dry/secondary season (Month)* (5.5%)
E5: Flood severity for wet/primary season (Sum of SPEI >1.5)* (5.5%)
AC7: Transportation cost from home to selling place (Baht/rai)* (5.5%)
E6: Flood severity for dry/secondary season (Sum of SPEI >1.5)* (5.4%)
AC6: Livestock density (Animal Unit: AU/HH)^ (5.3%)

V6



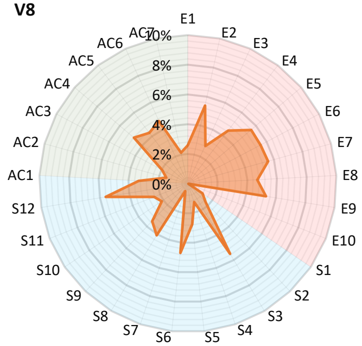
E4: Drought duration for dry/secondary season (Month)* (5.9%)
E5: Flood severity for wet/primary season (Sum of SPEI >1.5)* (5.9%)
E6: Flood severity for dry/secondary season (Sum of SPEI >1.5)* (5.9%)
E2: Drought severity for dry/secondary season (-Sum of SPEI <=-1.5)* (5.6%)
E9: Change in annual temperature (°C/yr)* (5.6%)

V7



E4: Drought duration for dry/secondary season (Month)* (5.5%)
E5: Flood severity for wet/primary season (Sum of SPEI >1.5)* (5.5%)
E6: Flood severity for dry/secondary season (Sum of SPEI >1.5)* (5.5%)
S5: Proportion of arable land to agricultural land (%) (5.4%)
E2: Drought severity for dry/secondary season (-Sum of SPEI <=-1.5)* (5.3%)

V8



E7: Flood duration for wet/primary season (Month)* (5.6%)
S12: Crop diversity (crops/100 rai)* (5.6%)
E5: Flood severity for wet/primary season (Sum of SPEI >1.5)* (5.6%)
E6: Flood severity for dry/secondary season (Sum of SPEI >1.5)* (5.5%)
S3: Soil organic matter in topsoil (% of cultivable land with moderate fertile soil) (5.5%)

9.3 Stakeholder consultation, including women and ethnic groups to determine factors contributing to climate change vulnerability of highland agriculture

Table 32:
Key stakeholder from government sector and their estimated interest and influence.

Stakeholders	Interest	Influence	Mapping
National Level			
MOAC	High	High	Manage Closely
OAE	High	High	Manage Closely
Provincial Level			
Nan Governor's Office	High	High	Manage Closely
Na Noi District Office	High	High	Manage Closely
Mobile Development Office 31, Royal Thai Armed Forces Headquarters	Low	High	Anticipate and Meet Needs
Nan Provincial Social Development and Human Security Office	Low	High	Anticipate and Meet Needs
Nan Provincial Office for Natural Resources and Environment	High	High	Manage Closely
Nan Provincial Public Health Office	Low	High	Anticipate and Meet Needs
Office of Commercial Affairs Nan	High	High	Manage Closely
Community Development Office Nan	High	High	Manage Closely
Nan Provincial Office for Local Administration	High	High	Manage Closely
Provincial Energy Office of Nan	Low	High	Anticipate and Meet Needs
Nan Provincial Agriculture Office	High	High	Manage Closely
Nan Provincial Livestock Office	High	High	Manage Closely
Nan Provincial Fisheries Office	High	High	Manage Closely
Nan Irrigation Project	High	High	Manage Closely
Nan Cooperatives Office	High	High	Manage Closely
Agricultural Land Reform Office	High	High	Manage Closely
Nan Land Development Station	High	High	Manage Closely
Nan Land Development Regional Office 7	High	High	Manage Closely
Nan Cooperatives Auditing Office	Low	High	Anticipate and Meet Needs
Nan Agricultural Research and Development Center	High	High	Manage Closely
Bank for Agriculture and Agricultural Cooperatives, Nan Office	High	Low	Keep Informed
Highland Development Project using the Royal Project System, Group 3, Nan Basin	High	High	Manage Closely
Freshwater Aquaculture Research and Development Center, Nan	High	High	Manage Closely
Nan Agricultural Occupation Promotion and Development Center	High	High	Manage Closely
Irrigation Office 2 (Lampang Province)	High	High	Manage Closely
Protected Area Regional Office 13 Phrae	High	High	Manage Closely

Stakeholders	Interest	Influence	Mapping
Agricultural Cooperatives Expansion Khun Sathan Royal Project, Ban Saensuk Co., Ltd., Na Noi District, Nan Province	High	High	Manage Closely
Nan Provincial Agriculture and Cooperatives Office	High	High	Manage Closely
Regional Office of Agricultural Economics 2	High	High	Manage Closely
Meteorological Station Nan	High	High	Manage Closely
Hydro Meteorological Station Tha Wang Pha	High	High	Manage Closely
Agricultural Meteorological Station Nan	High	High	Manage Closely
Bureau of Groundwater Resources Region 1 (Lampang)	High	High	Manage Closely

Table 33:
Key stakeholder from non-government sector and their estimated interest and influence.

Stakeholders	Interest	Influence	Mapping
Private sector			
Nan Chamber of Commerce	High	High	Manage Closely
Tops Supermarket	High	High	Manage Closely
TPP Foods Co., Ltd.	High	High	Manage Closely
SC and Agro Company Limited	High	High	Manage Closely
Lemon Farm	High	High	Manage Closely
Big C	High	High	Manage Closely
Academia			
Nan Community College	Low	Low	Monitor
Nan Rajabhat University	High	Low	Keep Informed
Rajamangala University of Technology Lanna Nan	High	Low	Keep Informed
School of Agriculture, Center of Learning Network for the Region, Chulalongkorn University, Nan Province	High	Low	Keep Informed
Nan Primary Educational Service Area Office 1	Low	Low	Monitor
Non-Governmental, Social, and Government Organizations			
Green Net (www.greennet.or.th) – Social=al Business Organization	High	Low	Keep Informed
Thai Health Promotion Foundation (http://en.thaihealth.or.th) – Government Public Organization	Low	Low	Monitor
Hug Muang Nan Foundation – Non-Governmental Organization	Low	Low	Monitor
Local Organizations/Communities			
Bua Yai Subdistrict Administrative Organization	High	High	Manage Closely

Stakeholders	Interest	Influence	Mapping
Village leaders and villagers/farmers in 8 villages in Bua Yai subdistrict	High	High	Manage Closely
Others			
Nan Sandbox	High	High	Manage Closely
Lemon Farm Organic Farming Group	High	High	Manage Closely
Nan Organic Agricultural Network	High	High	Manage Closely

Table 34:
Stakeholder mapping.

High level of influence	Anticipate and meet needs	Manage closely
Low level of influence	Monitor	Keep informed
Stakeholders	Low level of interest	High level of interest